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GreenTech made in Germany 3.0

Environmental Technology Atlas for Germany

The future made in Germany

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INTRODUCTION

In Germany and around the globe, environmental technology and resource efficiency have become powerful drivers of economic growth. Companies in this industry operate in a vibrant, dynamic market that is shaped by technological progress as well as by changing political and social conditions. At the same time, innovative products, processes and services that are efficient and ecofriendly are attracting unprecedented demand on international markets.

This third edition of *GreenTech made in Germany* adopts a slight shift of emphasis, placing the environmental technology industry more clearly in the context of the pivotal ecological, economic and political challenges of our day. It begins with the premise that the green tech industry and its various players are central to the transformation into a "green economy" that heeds and applies the principles of sustainability. At the same time, the atlas clearly shows that traditional industry sectors, too, have an integral part to play in this "greening" process: First, the fact that green tech has its roots in traditional engineering disciplines itself facilitates the development of environmental technologies. Second, these technologies in return drive modernization in traditional industries, especially by improving their energy and material efficiency – thereby giving companies a strategic advantage over international competitors.

GreenTech made in Germany 3.0 once again looks in detail at the six lead markets – environmentally friendly power generation and storage, energy efficiency, material efficiency, sustainable mobility, waste management and recycling and sustainable water management – that have proven to be a valuable structure for analyzing the green tech industry.

The rapid pace of growth in these lead markets nevertheless demands closer, more granular examination if trends and shifts in the marketplace are to be identified with sufficient accuracy. For this reason, two extra hierarchical levels – market segments and technology lines – have been added below the level of the lead markets. This structure maintains a systematic overview while also accommodating dynamic ongoing development. The breakdown allows us to dig deeper and provide more detail without losing sight of the equally important developments taking place on a wider scale.

To properly place the environmental technology and resource efficiency industry in the context of central ecological, economic and political challenges, *GreenTech made in Germany 3.0* also includes another new feature: a detailed account of four dimensions of transformation as we move toward a green economy. This addition enriches the GreenTech Atlas by specifying the kind of concrete solutions with which green tech can help us master the challenges of demographic development, scarce resources, climate change and other global megatrends.

Our description of the four dimensions of transformation is anchored in an extensive presentation and analysis of environmental technology and resource efficiency in Germany. The centerpiece of this portrait is a company database compiled specially for *GreenTech made in Germany 3.0* on behalf of the Federal Ministry for the Environment. It contains around 2,000 data sets on green tech companies – almost double the number of company profiles in the 2009 edition .

Executive summary

Environmental technology: Green and growing

Not even the financial and economic crisis of 2009 was able to put the brakes on rapid growth in the environmental technology and resource efficiency industry. Between 2007 and 2010, the global market for green tech expanded at an average rate of 11.8 percent per annum, reaching a volume of EUR 1,930 billion in 2010. This figure was well ahead of the forecast of EUR 1,670 billion published in the second edition of the GreenTech Atlas. The forceful expansion was driven by dynamic developments in environmental technology services plus the "green" economic programs launched internationally in response to the crisis.

In 2011, the global market volume for environmental technology and resource efficiency was put at just over EUR 2,000 billion. The lead market for energy efficiency accounted for the largest share of the market, up from EUR 538 billion in 2007 to EUR 720 billion in 2011. This increase was driven by rising energy prices and the scarcity of energy resources, coupled with growing demand. Economies around the world are realizing that they have to reduce energy consumption to the greatest extent possible. Accordingly, demand for products and processes that improve energy efficiency is on the rise.

The lead market for energy efficiency breaks down into four market segments: energy-efficient production processes, cross-application technologies for industry and commerce, energy-efficient buildings, and energy-efficient appliances. Together these segments constitute the key levers for reducing energy consumption. For all economies, improving energy efficiency will be a tremendously important issue in the years ahead. Further substantial growth is to be expected.

Worldwide, the six lead markets in the green tech industry will be worth a combined total of EUR 4,400 billion by 2025, a figure that corresponds to average annual growth of 5.6 percent between now and then. Even when the stimulus programs of 2008 and 2009 have run their course, the environmental technology and resource efficiency industry will still remain on course for expansion. According to current forecasts, energy efficiency will have a volume of EUR 1,236 billion in 2025, retaining its position as the largest single green tech market in the world.

Green global growth is giving positive impetus to environmental technology companies in Germany. The German green tech industry grew an average of 12 percent per annum from 2007 to 2010. In 2011, environmental technology and resource efficiency bearing the "made in Germany" label had a total market volume of EUR 300 billion. Thanks to their strong position on international markets, German green tech companies are benefiting from the upsurge in demand both at home and abroad. Energy efficiency represents an important part of the environmental technology market in Germany, as it does globally: the energy efficiency market in Germany is worth EUR 98 billion, almost one-third of the total German green tech market. This also reflects the strength of German green tech companies, whose energy efficiency solutions put them among the global market leaders. Clearly, German companies know how to make excellent use of their strengths in measurement and control systems, as well as in other cross-sector technologies such as electric motors and heat pumps.

The environmental technology and resource efficiency industry will be worth an estimated EUR 674 billion in 2025. By then, the lead market for environmentally friendly power generation and storage will probably account for the largest share – some EUR 220 billion – of the German green tech market. This particular lead market breaks down into three distinct segments that are crucial to a climate-compatible energy supply: renewable energy, the environmentally friendly use of fossil fuels, and energy storage. In Germany, the growing use of renewable energy is a key driver of developments in the lead market for environmentally friendly power generation and storage. These developments are leading not only to more capacity for power generation from renewable sources but also to greater demand for storage technologies. Energy fed into the grid from renewable sources fluctuates, making it more difficult to achieve the balance between production and demand that is essential for the stability of the grid. Storage technologies will play an increasingly important role in maintaining this equilibrium in the decades ahead. The lead market for environmentally friendly power generation and storage can expect to see strong growth.

Green tech industry strongly positioned in Germany and around the globe

German green tech providers' standing on the world's markets is excellent: Their global market share of 15 percent speaks for itself. In the future, German companies will continue to benefit from growing global demand for environmental technology and resource efficiency products and solutions. Current forecasts indicate that German-made green technology will still have a 15 percent share of the global market in 2025. Defending their turf in this way is a sign of just how resilient German

market players are. Even now, they are having to assert themselves on international markets against aggressive new competitors who also want a slice of this attractive, growing industry. Nor do all the new rivals come from industrialized countries: Many originate from emerging markets, first and foremost China, whose exports of photovoltaic and wind power technology are growing vigorously.

Environmental technology currently accounts for 11 percent of Germany's GDP. By 2025, the figure will probably be 15 percent. These numbers underscore the significance of environmental technology and resource efficiency in Germany. They also indicate the industry's growing contribution to German economic output.

The employment figures also reflect the ongoing growth of the green tech industry. In 2011, the six lead markets discussed in this GreenTech Atlas accounted for 1.4 million jobs. By 2025, they are expected to employ 2.4 million people.

The green tech industry in Germany

Environmental technology and resource efficiency is a typical cross-sector industry. Many companies that started out in traditional branches of industry such as electrical, mechanical and automotive engineering have gradually diversified their way into green technology. These deep roots in traditional industries have proved a key success factor for environmental technology in Germany. By the same token, traditional industries have environmental technology and resource efficiency to thank for valuable stimulus in the areas of innovation and market differentiation.

The majority of players in Germany's environmental technology and resource efficiency industry are small and medium-sized enterprises (SMEs) with an average workforce of around 300. Nine out of ten German green tech companies have annual revenues of less than EUR 50 million; the average is just under EUR 27 million. Revenue per employee averages out at EUR 90,000 – lower than that of traditional disciplines such as electrical engineering (at around EUR 220,000) and automotive engineering (EUR 470,000). SMEs play a prominent part in all lead markets in German environmental technology and resource efficiency. Many of these firms are extremely flexible and innovative. Moreover, since their solutions and processes stand out from the crowd, the rather fragmented structure of the industry does not necessarily put them at a competitive disadvantage on global markets.

More than 80 percent of green tech companies in Germany made a profit in 2010. Profitability averaged 6 percent across all companies in the industry. Energy efficiency led the field: 11 percent of companies in this market generated profits in excess of 20 percent.

German environmental technology and resource efficiency firms are upbeat about how business will develop in the years ahead. They expect to see average annual growth of 10.6 percent between now and 2015. Separate analysis of each lead market reveals that environmentally friendly power generation and storage companies have the greatest expectations in terms of revenue development (13.7 percent). In line with their positive take on revenue development, German companies in the environmental technology and resource efficiency industry also anticipate average annual growth in their workforce of 8.4 percent.

Global megatrends as drivers of growth

The confidence of Germany's green tech players is rooted in foreseeable growth in the global market for environmental technology and resource efficiency. This uptrend will to a very large degree be driven by five megatrends that will shape social, political and economic conditions around the world in the decades ahead. The megatrends in question are demographic development, urbanization, globalization, scarcity of resources, and climate change.

Demographic development

The Earth will probably be home to around 8.3 billion people in 2030 – around a fifth more than today. By 2050, according to United Nations forecasts the global population will have risen to over nine billion people. Demographic development will vary from region to region. In 2050, Europe will probably be inhabited by around 19 million fewer people than today. Conversely, the population of Africa will double in the same period. Asia's population will increase by a billion people between now and 2050.

Urbanization

United Nations statistics for 2010 showed that, for the first time in world history, more people lived in cities than in rural areas. By 2030, two-thirds of the world's population will probably live in urban areas. Urban growth is taking place mostly in Asia and Africa, where more and more megacities – cities with more than 10 million residents – are emerging. The rapid pace of urban growth is putting ever more pressure on the environment. Cities' need for energy, their traffic volume and the industry they spawn mean that they

are responsible for up to 80 percent of the world's carbon emissions.

Globalization
Various factors have sharply accelerated the pace of globalization in recent decades, causing both the world's capital markets and its real economy to become far more deeply integrated. Between 1990 and 2008, global gross domestic product (GDP) expanded at an average rate of 3.5 percent per year. Exports grew by an average of 8.7 percent per year, while foreign direct investment increased by 12.4 percent per year.

Scarcity of resources
The combination of population growth, urbanization and growing industrialization, especially in emerging countries, is driving up demand for energy and hence fossil fuels. The International Energy Agency (IEA) believes that primary energy consumption worldwide will climb by one-third between 2010 and 2035. Non-OECD countries will account for most of this forecast increase – some 93 percent.

Apart from a temporary dip during the economic and financial crisis of 2008/2009, the prices of mineral resources have risen constantly in recent years. This trend is set to continue. Growth in emerging countries and the increase in the global population to nine billion people by 2050 will cause demand for raw materials to continue to rise. Already, 60 billion tons of commodities are consumed worldwide every year – 50 percent more than three decades ago.

Climate change
In 2010, carbon emissions given off by the burning of fossil fuels set a new record of 30.6 gigatons. If emissions of greenhouse gases are not curbed, climate researchers reckon that the global temperature could increase by three to seven degrees Celsius relative to pre-industrial levels. Any increase of more than two degrees will pose a severe and in some cases unpredictable threat to the Earth's ecosystems. The sea level will rise and extreme weather events such as droughts, torrential rain and flooding will increase, for example. To limit the rise in the mean global temperature to two degrees Celsius, global greenhouse emissions must be reduced by 50 to 80 percent relative to their 1990 levels.

How environmental technology and resource efficiency can help us master the challenges posed by global megatrends

In light of demographic development, climate change and the scarcity of resources, there is no alternative but to make our economies sustainable in the long term. That means striking the right balance between enabling successful business, protecting the natural basis for human life, ensuring social cohesion and shouldering international responsibility. These main tenets of sustainable development show the direction we must take in mastering the transformation into a green economy.

The green economy is a form of economy characterized by innovation-driven, ecological and participatory growth. It rests on two pillars: a strong environmental technology industry on the one hand and, on the other, companies in traditional industries whose sustainability strategies are integrated into all levels of their management system. The environmental technology and resource efficiency industry is a key driver of development toward such a green economy.

Visible strategies and tangible product innovations already give us an idea of where this development might lead. Below, we describe four specific dimensions in which transformation is both necessary and already underway, illustrating the kind of solutions environmental technology and resource efficiency can provide for the urgent challenges humankind faces in the decades ahead as a result of demographic change, the scarcity of resources, climate change and the threat to biodiversity.

Each dimension of this transformation constitutes an important step along the road to sustainable economic and social development. The section entitled *The dawn of the green economy* stakes out the context for transformation in the other three dimensions.

The dawn of the green economy
The green economy is built on a combination of the environmental technology and resource efficiency industry and companies in traditional industries that rigorously implement sustainability strategies. Companies in every industry interact with different groups of stakeholders. **These stakeholders – especially governments, customers, investors and companies – play a pivotal role in the transformation to a green economy, providing a powerful stimulus.**

The expectations and demands of stakeholders are largely shaped by three global megatrends: climate change, the scarcity of resources, and population growth. The parts played by each group of stakeholders in the transformation to a green economy are illustrated by the following facts and trends: The **government** has been instrumental in writing Germany's environmental protection

success story. It was quick to stake out a regulatory framework and create economic incentives. These actions effectively gave the green light to investment and innovations that paved the way for the emergence of new markets for environmental technology and resource efficiency. For **customers**, sustainability is becoming an important aspect by which companies and their products are judged. Compliance with social and ecological standards is increasingly a key criterion in purchase decisions. This is as true for private consumers (business to consumer) as it is for intercompany (business to business) relationships.

In the **finance industry**, sustainability is established as an important yardstick in investment decisions by both private individuals and professional fund managers. This trend will grow even stronger in the years ahead. **Companies** are coming under increasing pressure from the government, customers and investors to align their business strategy with the dictates of a resource-efficient, low-carbon economy. If the challenges of climate change and scarce resources are to be mastered, companies must – irrespective of the industry in which they operate – formulate strategies that translate sustainable development principles into sustainable business operations.

Distributed power supply structure
The new energy policy ratified by Germany's Bundestag in summer 2011 envisages a fundamental change to Germany's power supply system. The package of laws links a clearly defined timeframe for phasing out the commercial use of nuclear power to a concept for improving energy efficiency and expanding the use of renewable energy. Renewable energy is to account for 80 percent of the national power supply by 2050. In the decades to come, distributed power generation systems will service an increasingly large proportion of Germany's demand for electricity. Environmental technology is playing a central role in shaping this historic transition.

Cutting-edge products and solutions create the conditions needed for the integration of distributed power producers into existing power grids in the years ahead. This in turn will enable renewable energy to meet the demand for electricity in the long term. More and more individual citizens are already seizing the opportunity to switch from being power consumers to power producers. They are doing this – jointly or in isolation – by using **photovoltaic, biomass and wind power plants** to meet their electricity needs. Since the energy-efficient production of power and heat is vital to the expansion of distributed power supply structures, **combined heat and power** ranks as one of the essential technological drivers in the new energy era. Moves to ramp up renewable energy necessitate the modernization of the grid infrastructure if the challenge of combining centralized and distributed power generation is to be mastered in the coming years. To keep the grid stable, load management is needed on the demand side, which is possible only if energy consumers are integrated intelligently via a **smart grid**. The term"smart grid" embraces all aspects of the intelligent coordination and control of the various components hooked up to the power grid. Another crucial aspect of the energy system of the future is the **expansion of centralized and distributed storage capacity** to help balance out fluctuations in power generation and demand.

Smart cities
By 2050, more than six billion people – around 70 percent of the world's population – will live in cities. Cities play an ambivalent role: On the one hand, they are our economic powerhouses, on the other, they are ecological danger zones. Cities in advanced economies face a very different set of challenges to cities in emerging and developing countries. In the latter, the most pressing need is to build a robust infrastructure where none exists at present. But the industrialized nations must overcome entirely different hurdles. In these countries, the primary challenge is to "retrofit" existing infrastructures in line with the need for sustainability and climate protection, thereby improving the quality of life and work.

Different regions of the world have widely differing starting points. However, intelligent environmental technology and resource efficiency offer solutions for urban areas in both the industrialized world and emerging and developing countries. The **smart cities concept**, in which information and communication technology (ICT) plays a key role as enabler, opens up the possibility of a sustainable future in urban agglomerations. **Networking within and between different urban subsystems** – traffic, the power supply, buildings, production facilities, healthcare, and so on – is a characteristic trait of smart cities. In the interest of brevity, this atlas zooms in on just two of these areas: traffic and buildings. **Focusing on smart mobility and smart buildings** highlights how immensely important environmental technology is as a cross-sector industry. Intelligent traffic solutions concentrate primarily on emission-free and low-emission strategies for personal mobility. For its part, the smart building concept is not confined merely to structural alterations that improve energy efficiency in new and renovated buildings: It also seeks to use intelligent control to enhance efficiency. Accordingly, a smart building is defined as a building that is fitted with cutting-edge automation systems and is part of a smart grid.

Environmental technology services – New challenges, new business models

Green services have proven a driver of growth in the global market for environmental technology and resource efficiency. From 2007 to 2010 they expanded rapidly, increasing their share of international green tech markets to 51 percent. In Germany, the market for environmental technology services grew from EUR 123 to EUR 155 billion between 2008 and 2010. One essential factor in the expansion of **environmental technology services** is their **innovative strength**. Exceptional dynamism typifies this particular dimension of transformation: Even as new business models have emerged, existing ones have been adapted to the specific needs of green tech companies.

Examples of green business model innovation are found in all different service segments. Mobile smartphone applications, for example, have heralded a new era in coordinating car-sharing opportunities, and that has helped to reduce traffic volumes. One relatively recent business model involves waste heat contracting and trading. Within the environmental technology and resource efficiency industry, there is also a clear **trend toward packaging products and services**. Matching services are built around the strengths of the core industrial product – something that German companies are excellently placed to do. The same goes for **project development**, which has an important part to play in the delivery of environmental technology services. Germany is home to respected consulting engineers that take care of **every link in the value chain**, from development to management, for renewable energy plants, water supply and wastewater disposal plants, and waste recycling and disposal plants.

Highlights of Germany's green tech industry

Environmental technology and resource efficiency already constitute a powerful driving force in the transition to a green economy in many areas of economic life. This is clear from the success of German green tech companies, many of which are pioneering the development of innovative products and business models. A further compelling argument in the face of global competition is the considerable market potential they enjoy. *GreenTech made in Germany 3.0* does not explore environmental technology and resource efficiency markets, products and processes on an abstract level only. It also profiles companies and institutions that are already successfully applying the principles of the green economy. Concrete examples illustrate the rich diversity and dynamism of the green tech industry. Fourteen portraits of companies and networks operating in different lead markets provide a series of snapshots of a vibrant, thriving industry. These examples were selected based on three factors that are key for the further development of Germany's green tech industry: innovation, networks and internationalization.

Megatrends – Global growth drivers for the environmental technology and resource efficiency markets

Although predicting what lies ahead is never easy, there are some clear signs of emerging development trajectories. We are talking about what are known as megatrends: long-term change processes that influence each other and that shape social, political and economic conditions around the world. They form the apex of what is referred to as a trend hierarchy. Megatrends can span several decades – and can have a far-reaching impact on global markets and global market players. This chapter describes the five megatrends that stake out the framework for the future development of the environmental technology industry.

Demographic development

The Earth will have a population of some 8.3 billion in 2030 – around a fifth more than today. **By 2050, according to United Nations forecasts, our blue planet will be home to 9 billion people.** Demographic development in the industrialized nations is, however, plotting a course different from that of emerging and developing countries. The population of the latter will swell from 5.7 billion to 7 billion people (an increase of 24 percent) over the next two decades. By contrast, population growth in today's advanced economies will be substantially more modest, at only 3.6 percent. **Population development will thus vary around the globe** (see table 1). In 2050, Europe will be inhabited by around 19 million fewer people than it is today. Conversely, the population of Africa is likely to double in the same period, with the result that nearly a quarter of the world's population (23.6 percent) will live on that continent by the middle of the century (2010: 14.8 percent). More than 5 billion people will call Asia their home in 2050. In absolute terms, that translates into growth of just under 1 billion relative to 2010 figures. In terms of Asia's share of the global population, however, it equates to a decline of roughly 5 percentage points.

The world's population is changing not only in quantitative terms, but also in terms of its age structure. The median age is rising as **life expectancy grows ever longer**. By 2030, half of the global population will be over 34 years of age, against today's median age of 29 years. Comparison of the age structures in advanced economies on the one hand and emerging and developing countries on the other again reveals stark differences. **In the industrialized countries, older people are accounting for an increasingly – and significantly – larger share of the total population.** Here, the median age is put at 44 years by 2030. The projected median age in emerging and developing countries (32 years) is considerably lower. [1]

Table 1: Forecast population growth through 2050

	World	%	Africa	%	Asia	%	Europe	%	North America	%
2010	6,895,889,000	100	1,022,234,000	14.8	4,164,252,000	60.4	738,199,000	10.7	344,529,000	5.0
2030	8,321,380,000	100	1,562,047,000	18.8	4,867,741,000	58.5	741,233,000	8.9	401,657,000	4.8
2050	9,306,128,000	100	2,191,599,000	23.6	5,142,220,000	55.3	719,257,000	7.7	446,862,000	4.8

Source: UN Desa (2011a)

Urbanization

United Nations statisticians announced in 2010 that a global tipping point had been reached: for the first time in history, the world had more city dwellers than rural inhabitants. Fifty years earlier, the urban population was one third of the total; yet by 2030, the ratio will have been reversed: by then, UN-Habitat forecasts that two thirds of the world's population will live in mostly urban areas.

Urban growth is taking place mostly in Asia and Africa, where more and more **megacities** [2] are emerging. Just a few decades ago, New York-Newark and Tokyo were the only conurbations in the world to have populations of over ten million. Today, there are more than 20 agglomerations of this magnitude, and 30 megacities will exist by 2025 (see table 2). As the population of large cities in developing countries increases, so too does the number of people whose only home is the slum districts. In developing countries, more than 800 million people currently live in "informal settlements", to use the common euphemism for urban slums.

Urbanization is progressing much faster in emerging and developing countries than in the cities of Europe. **And the rapid pace of urban growth is adding**

1 See UN Desa (2011b)
2 In this atlas, the term "megacities" refers to cities with more than ten million residents

to pressure on the environment too, as infrastructures that are often rudimentary at best are unable to cope with the flood of new arrivals. The resultant soil, groundwater and air pollution poses a threat to human health and burdens the environment to such an extent that ecosystems are no longer able to regenerate. **Cities'** need for energy, their traffic volume and the industry they spawn mean that they **are responsible for up to 80 percent of the world's CO_2 emissions around the globe**, making them a key factor in the advance of climate change. [3]

On the other hand, urbanization is not an exclusively negative phenomenon. While **cities** do indeed consume large volumes of resources, they often also serve as **economic powerhouses that deliver substantial economic output and drive innovation**. They also exploit economies of scale: In large conurbations, goods, services and infrastructure can be provided more efficiently, i.e. at a lower cost per capita, than in rural areas.

Globalization

In recent decades, the process of ever greater integration in the global economy has accelerated rapidly. Between 1990 and 2008, the world's gross domestic product (GDP) expanded at an average rate of 3.5 percent per year. Exports grew by an average of 8.7 percent per year, while foreign direct investment increased by 12.4 percent per year.

Various factors triggered this **quantum leap in global economic integration** and speeded up the process. The dismantling of customs barriers and non-tariff trade barriers did a lot to help liberalize world trade. A further catalyst to the convergence of international markets was the shift in the political status quo, which had far-reaching medium- to long-term consequences for the world economy. The collapse of the Soviet Union and other COMECON countries in Central and Eastern Europe in 1989 marked the end of Socialist-style central planning and the beginning of the transformation from planned to market economies. A good decade before the fall of the Berlin Wall, the "Four Modernizations" adopted by China's Communist Party had, in 1978, already signaled an end to decades of isolation for the Chinese economy, heralding the country's gradual opening toward foreign trade. This step was more than just a prerequisite for economic reforms in the People's Republic: It also ignited China's rise to the status of global economic superpower.

The liberalization of financial markets became another **driver of globalization**, paving the way to more and more transnational financial operations and facilitating a sharp **rise in foreign direct investment**. In recent years, increasing numbers of companies have taken advantage of the opportunity to engage in cross-border mergers and/or acquisitions and set up production facilities abroad. Both aspects are regarded as clear signs of the degree to which the fabric of the international economy has become tightly interwoven. Another indicator is the increase in global sourcing. Major corporations in particular are now forging value chains that span the globe.

Estimates differ on whether and at what pace globalization will continue to advance in the years and decades ahead. As oil prices rise, some experts expect globalization to shift into reverse in response to the spiraling cost of transportation, [4] believing that the trend toward offshoring will, in the long term, give way to the practice of onshoring. Others see global economic integration as an irreversible process that will accelerate further in the future.

However much opinions about the speed and direction of future developments may vary, one fact is undisputed: The developments witnessed in recent decades have **shifted both the balance of global economic power and the centers of economic growth**. The BRIC countries (Brazil, Russia, India and China) generated 18 percent of the world's GDP in

3 See UN-Habitat (2011b), p. vi
4 See Rubin, J. (2010)

Table 2: The 20 biggest cities in the world in 1950, 1975, 2000, 2010 and 2025

	1950		1975		2010		2025 (p)	
	City[1)]	Population [m]	City[1)]	Population [m]	City[1)]	Population [m]	City[1)]	Population [m]
1	New York-Newark	12.34	Tokyo	26.61	Tokyo	36.67	Tokyo	37.09
2	Tokyo	11.27	New York-Newark	15.88	Delhi	22.16	Delhi	28.57
3	London	8.36	Mexico City	10.69	São Paulo	20.26	Mumbai	25.81
4	Paris	6.52	Osaka-Kobe	9.84	Mumbai	20.04	São Paulo	21.65
5	Moscow	5.36	São Paulo	9.61	Mexico City	19.46	Dhaka	20.94
6	Buenos Aires	5.10	Los Angeles	8.93	New York-Newark	19.43	Mexico City	20.71
7	Chicago	5.00	Buenos Aires	8.74	Shanghai	16.58	New York-Newark	20.64
8	Calcutta	4.51	Paris	8.56	Calcutta	15.55	Calcutta	20.11
9	Shanghai	4.30	Calcutta	7.89	Dhaka	14.65	Shanghai	20.02
10	Osaka-Kobe	4.15	Moscow	7.62	Karachi	13.12	Karachi	18.73
11	Los Angeles	4.05	Rio de Janeiro	7.56	Buenos Aires	13.07	Lagos	15.81
12	Berlin	3.34	London	7.55	Los Angeles	12.76	Kinshasa	15.04
13	Philadelphia	3.13	Chicago	7.16	Beijing	12.39	Beijing	15.02
14	Rio de Janeiro	2.95	Mumbai	7.08	Rio de Janeiro	11.95	Manila	14.92
15	St. Petersburg	2.90	Seoul	6.81	Manila	11.63	Buenos Aires	13.71
16	Mexico City	2.88	Cairo	6.45	Osaka-Kobe	11.34	Los Angeles	13.68
17	Mumbai	2.86	Shanghai	5.63	Cairo	11.00	Cairo	13.53
18	Detroit	2.77	Manila	5.00	Lagos	10.58	Rio de Janeiro	12.65
19	Boston	2.55	Beijing	4.83	Moscow	10.55	Istanbul	12.11
20	Cairo	2.49	Jakarta	4.81	Istanbul	10.52	Osaka-Kobe	11.37

1) Agglomeration

Source: UN Desa (2011c)

Table 3: The BRIC and Next 11 countries' share of global GDP

	2010		2020		2030		CAGR[1)]
	USD trillion	%	USD trillion	%	USD trillion	%	%
World	61	100	92	100	138	100	4
BRIC	11	18	26	28	50	36	8
Next 11	5	8	9	10	15	11	6

1) CAGR – Compound Annual Growth Rate

Source: Standard Chartered (2010): The Super-Cycle Report, p.6

2010. Forecasts for the year 2030, however, put that figure at 36 percent (see table 3). The BRIC countries' share of global exports is expanding too, with China leading the charge. And the countries dubbed the "Next 11" [5] will likewise play an increasingly important part on international markets. Over the next two decades, their combined share of global GDP will probably climb from around 8 percent (in 2010) to nearly 11 percent.

Similarly, assessments of globalization and its impact on different economies vary too – especially against the backdrop of the financial and economic crisis in 2008/2009 and current developments on the financial markets. Globalization is unquestionably linked to greater vulnerability on the world's markets, whose integration means that the shocks unleashed by economic crises are felt far from their epicenters. Imbalances between rich and poor countries likewise continue to exist despite globalization, as do similar disparities within national borders.

Aggregate global economic data nevertheless proves that globalization has helped many countries to experience greater growth, prosperity and employment. This development is most obvious in the emerging countries in general and China in particular. In the People's Republic, per capita income increased sixfold in the period from 1990 through 2010.

In the decades ahead, population growth, globalization and rising income levels in emerging countries will act as so many catalysts to **global vehicular traffic**, the volume of which **will probably triple between now and 2050**. Forecasts published in the Transport Outlook 2011 [6] indicate that passenger transport – measured in terms of passenger kilometers traveled – will increase by a factor of three to four. At the same time, an increase by a factor of between 2.5 and 3.5 is expected for freight transport volumes, expressed as ton kilometers.

5 The „Next 11" countries are: Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, the Philippines, South Korea, Turkey and Vietnam

6 The Transport Outlook is published once a year by the International Transport Forum. 53 countries are members of this special-purpose intergovernmental organization at the OECD. See International Transport Forum (2011)

Scarcity of resources

To describe this megatrend, it is useful to begin by specifying what we mean by the term "resource". For the purposes of this atlas, "resources" are naturally occurring raw materials, which can be categorized using different systems. The following discussion of the scarcity of resources distinguishes between raw materials that are used to generate power (energy resources such as oil, coal and natural gas) and those that are used in industrial production. The latter category includes metals, industrial minerals and non-metallic minerals. We shall also take an in-depth look at the global water supply, as this resource is of existential importance to sustainable development.

A scarce resource is any resource of which the desired quality and quantity is not available at all times and at every place. If one accepts this traditional definition, energy and other raw materials have always been scarce. What adds a **new dimension to the resource issue** is the circumstance that "the supply and demand structure for individual resources – and even for whole sets of resources – is, in a relatively short period, shifting into disequilibrium, and that new equilibriums are emerging at a substantially higher price level, or even at a higher level of price increases." [7] This is precisely the phenomenon we have observed in recent years, both for fossil fuels such as oil and gas and for a number of mineral raw materials.

Energy resources

Demand for the raw materials used to generate power is intrinsically linked to the trend in the world's demand for energy. The latter has surged forcefully in recent years. Energy statistics recorded in 2010 reflect a new record: A year-on-year increase of 5.6 percent marked the **highest rate of growth in worldwide consumption of primary energy since 1973**. Some 12,000 million tons of oil equivalent [8] were consumed worldwide – 29 percent more than in 2000. [9] The trend is obvious: Running at full tilt, the growth engines in emerging economies are developing an ever more voracious appetite for energy. Energy consumption in OECD countries was up 3.5 percent in 2010 compared to 2009. In non-OECD countries, the increase was 7.5 percent. Since the turn of the millennium, the latter's energy consumption has risen by around two thirds. China, whose primary energy consumption more than doubled between 2000 and 2010 (plus 134 percent), is responsible for a large proportion of this increase. Indeed, China overtook the US as the world's largest consumer of energy in 2010, ramping its share of global energy consumption up to roughly one fifth. [10]

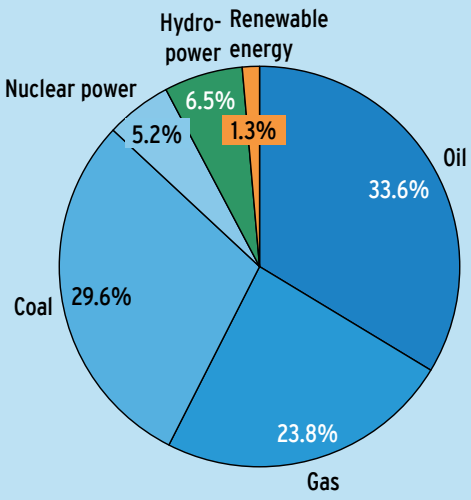
The combination of population growth, urbanization and growing industrialization in the emerging countries will drive demand for energy up further in the future. In three different scenarios, the International Energy Agency (IEA) has investigated the development of global energy demand between 2010 and 2035. [11] In its main scenario (the "New Policies Scenario"), primary energy consumption increases by a third in the reference period. [12]

The IEA predicts that **demand for energy will continue to grow in emerging countries** over the next few decades. Non-OECD countries will account for the overwhelming majority (93 percent) of the forecast increase in worldwide primary energy consumption by 2035. China's energy demand, for example, is projected to rise by 75 percent between 2008 and 2035. In the same period, India will probably double its energy consumption. [13]

Demand for electricity will also rise sharply. For the period from 2008 through 2035, the IEA's "New Policies Scenario" anticipates average annual growth in power consumption of 2.2 percent. Again, this increase will be driven to a very great extent by growing demand in non-OECD countries. Demand for electricity in China, for example, will triple in the specified period. [14] In its forecasts, the IEA assumes that power generation will experience a "far-reaching transition". As prices rise and governments act to

7 Grömling, M./Hass, H.-J. (2009), p. 35
8 Kilograms of oil equivalent (KGOE) are a unit of measurement for the energy contained in energy resources, or for energy consumption: 1 KGOE = 41,868 joules = 11.63 kWh
9 See BP Statistical Review of World Energy June 2011, p. 40
10 Ibid.
11 The main scenario is the "New Policies Scenario", which factors in the commitments of and obligations incumbent on the international community to reduce emissions of greenhouse gases and abolish subsidies for fossil fuels. The "Current Policies Scenario" – described as the reference scenario in previous years' projections – simply takes the status quo in 2010 and extrapolates it into the future. The "450 Scenario" is based on the assumption that all necessary actions will be taken to keep the concentration of greenhouse gases in the atmosphere below the level of 450 ppm, i.e. below the threshold that is necessary to achieve the 2 °C goal. See International Energy Agency (2010a)
12 International Energy Agency (2011a), p. 4
13 Ibid., p. 5f
14 Ibid., p. 9

Figure 1: Global primary energy mix, 2010



Source: BP Statistical Review of World Energy, June 2011, p.40

reduce emissions, fossil fuels' share of the electricity mix will decrease. Fossil fuels, primarily gas and coal, will still account for 55 percent of power generation at the end of the reference period. Even that, however, marks a considerable decline relative to 2008 (68 percent). [15]

Of the various fossil fuel resources, coal will continue to play the lead role in the electricity mix for decades to come. In the course of the reference period, its share of power generation will nevertheless shrink from 41 percent (in 2008) to 32 percent.

The **IEA predicts dynamic development in renewable energy in the next few decades.** Worldwide, renewable energy's share of power generation will climb from 3 percent in 2009 to 15 percent in 2035. [16]

Returning to the present, however, a glance at the global energy mix is enough to see that fossil fuels continue to dominate the supply of energy to humanity (see figure 1). The majority of greenhouse gas emissions – 41 percent – come from the energy sector and are given off during the generation of power and heat. [17] This underscores the **pivotal role played by the energy sector in the battle against global warming.** Significantly reducing carbon emissions during the power generation process is imperative if efforts to protect the climate are to succeed.

In its "New Policies Scenario", the IEA assumes that carbon emissions per unit of electricity produced will decrease by a third between 2008 and 2035. [18] However, this welcome news is one of precious few encouraging signs in what, all in all, is a gloomy outlook for climate policy. This is because the trends outlined in the IEA's main scenario would mean that the 2 °C goal will be missed. At 650 ppm [19] of CO_2 equivalent [20], the concentration of greenhouse gases in the atmosphere would be well above the required threshold of 450 ppm of CO_2 equivalent – with the result that the temperature would rise by 3.5 degrees Celsius. [21]

The IEA shows how this can be prevented from happening in its "450 Scenario". Core aspects include actions to reduce emissions in five regions (the US, the European Union, Japan, China and India), in order to

15 Ibid.
16 Ibid., p. 7
17 See International Energy Agency (2010b), p. 9
18 See International Energy Agency (2010a), p. 9
19 ppm – parts per million (in the air)
20 CO_2 equivalent: The effect of a certain quantity of a greenhouse gas on the greenhouse effect is expressed in terms of what is known as global warming potential (GWP). GWP describes the mean warming effect over a given period. The global warming potential of every greenhouse gas is translated into carbon dioxide (CO_2). See Henzelmann (2010), p. 221
21 Ibid., p. 12

reduce power generation's share of worldwide greenhouse gas emissions from 41 percent to 24 percent by 2035. This alone would constitute a crucial contribution to the decarbonization of the global economy. **Together with advances in energy efficiency, the transition to CO_2-free energy sources will play a major part in achieving the goal of a safe and climate-compatible power supply.** [22]

Water

In recent years, "blue gold" has emerged as a very telling metaphor for **water** – a clear indication that this element is a **scarce resource** in many regions of the world. Although around 70 percent of the Earth's surface is covered by water, only a fraction of this amount – 2.5 percent – is fresh water. And because most of the latter is bound up in ice and glaciers, humankind can directly use only about 1 percent of the world's water supply (a total of 1.4 billion cubic kilometers).

In the 20th century, global water consumption increased sixfold – far more quickly than population growth, which rose by a factor of 3.7 in the same period. There are a number of reasons for this inordinate rise in water consumption. More and more farmland, for example, is being irrigated artificially in order to satisfy growing demand for food. In 1966, 153 million hectares of farmland were watered around the world. By 2004, the number had already risen to 278.8 million hectares. Today, around 70 percent of the water consumed in the world flows into agriculture. Estimates nevertheless indicate that fully half of this volume either runs off or evaporates. The potential for improved efficiency, then, is considerable. [23]

Another driver of water consumption is the process of industrialization, which has been advancing at a frantic pace in emerging countries over the past few decades. Industrialization is accompanied by an increase in energy consumption. This in turn boosts demand for water, as the energy sector plays a large part in water usage. Growing prosperity in some emerging countries likewise affects water consumption. The consequences can be reduced to a simple formula: The higher the standard of living, the more water is consumed.

In the decades ahead, these trends will continue. At the same time, more and more people – 80 million newcomers every year – will populate planet Earth. And this too will not be without its consequences for global water consumption, which, according to forecasts in World Water Development Report 3, will increase by 64 billion cubic meters per year. The **impact of this demographic trend on the water supply** will be further exacerbated because population figures will rise principally in places where water is already in extremely short supply: in Sub-Saharan Africa, the Middle East and Southeast Asia.

Water shortages, impure drinking water and a lack of sanitary facilities are believed to be a cause of around 80 percent of all diseases in developing countries. There is an economic cost to the water crisis, too. For Africa, this cost is put at USD 28.4 billion per annum – the equivalent of 5 percent of the continent's total economic output. [24]

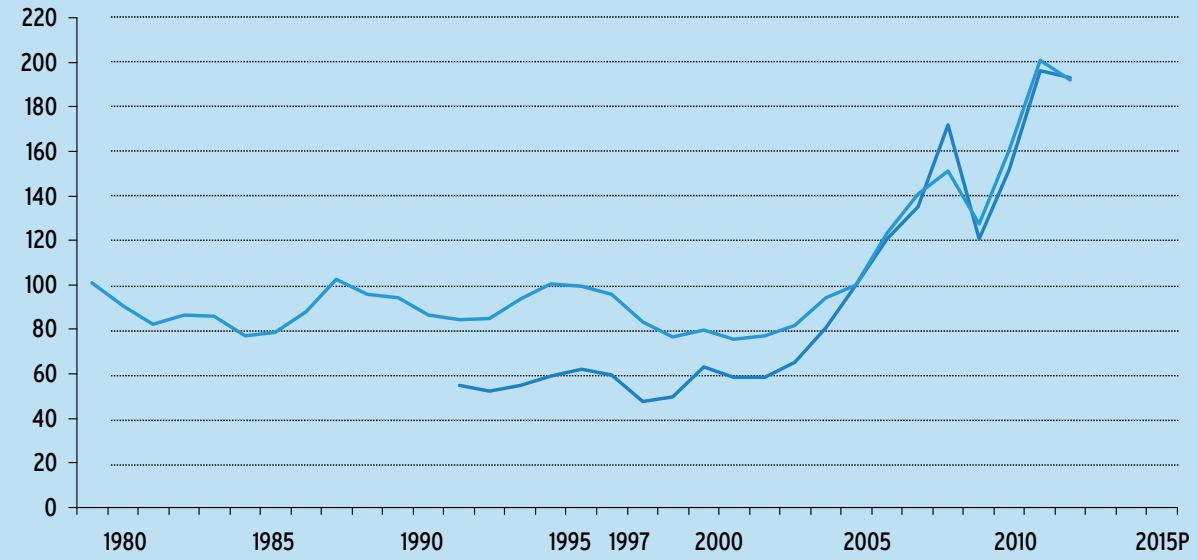
Climate change will make the shortage of water even worse in many regions. Global warming is changing the pattern of precipitation, surface water, soil moisture and the groundwater table. Estimates indicate that climate change is responsible for around 20 percent of the world's increasing shortage of water. Together with population growth and rising water consumption in emerging countries, an escalation in the water crisis is therefore not hard to foresee. By 2050 – according to UNESCO's moderate forecast – two million people in 48 countries will be affected by water scarcity [25] or water shortages. [26] Even though the General Assembly of the United Nations declared in July 2010 that clean drinking water and sanitary facilities are a universal human right, the practical outworking of this theory is still a dim and distant dream for many people. Today, one out of every ten people on Earth still has to get by without a reliable or safe supply of drinking water.

Industrial raw materials

Rising raw material prices are not new to the 21st century. Since the earliest days of international commodity trading, fluctuating prices on raw materials markets have always followed the ups and downs of the economy. The only question is on what level a new equilibrium will be reached. The index trajectory plotted in figure 2 shows that the **prices of mineral resources are heading up**. They initially peaked in summer 2008, before the economic and financial crisis in 2008/2009 triggered a dip in the

22 Ibid., p. 13
23 See OECD (2011)
24 See UNESCO (2009)
25 Where the availability of fresh water per capita is less than 1,666 m^3 a year
26 Where the availability of fresh water per capita is less than 1,000 m^3 a year

Figure 2: Raw materials prices from 1980 through 2015



Index, 2005 = 100

Commodity Price Index includes both Fuel and Non-Fuel Price Indices

Commodity Non-Fuel Price Index includes Food and Beverages and Industrial Inputs Price Indices

Source: IMF World Economic Outlook

price curve. In the recovery phase that followed this slump, however, prices for non-energy raw materials resumed their upward course.

It is unlikely that the prices of non-energy raw materials will return to the low levels of the 1990s. **Growth in emerging countries and the increase in the global population** to 9 billion people by 2050 **will cause demand for raw materials to continue to rise.** Yet deposits of raw materials are finite. The scarcity of resources, of course, does not necessarily mean that all reserves have been exhausted: In economic terms, raw material availability is a relative concept. Reserves of raw materials are defined as "deposits that are known and can be exploited under current economic and technological conditions". If demand shifts – and with it the price that can be realized – the criteria that determine whether it is economical to exploit deposits of raw materials shift as well.

At the present time, Europe consumes 43 kilograms of raw materials per capita per day. North America consumes 88 kilograms and Africa 10 kilograms. Every year, 60 million tons of raw materials are consumed worldwide – 50 percent more than three decades ago. [27] If this pattern continues, the burden on the Earth's ecosystem will become too great. Large volumes of CO_2 emissions and other pollutants are given off during the extraction, transportation and processing of raw materials. Extracting raw materials – especially in mining contexts – also involves massive interventions in nature. Moreover, rising prices make it profitable to exploit even deposits with relatively low concentrations, thus amplifying the negative impact on the environment.

The pressing arguments for the more sparing use of resources are not only of an ecological, but also of an economic nature. The current medium- to long-term uptrend in prices is placing a heavy burden on industrialized economies and the companies that operate in them. Germany, for instance, is heavily dependent on imports of raw materials and wholly dependent on imports of primary metal raw materials. In 2009, German imports of energy and mineral raw materials added up to EUR 83.9 billion, of which precious metals, non-ferrous metals and steel alloys accounted for roughly 22 percent. [28]

27 See Umweltbundesamt (2010a), p. 2
28 See Bundesanstalt für Geowissenschaften und Rohstoffe (eds.) (2010), p. 39f

Climate change

Since the dawn of the industrial age, the mean global temperature has increased by 0.8 degrees Celsius. Today, there is **broad scientific consensus that global warming in the latter half of the 20th century was "very probably"** [29] **attributable to the anthropogenic greenhouse effect**. The concentration of CO_2 in the Earth's atmosphere has risen from 280 ppm in the pre-industrial era to 387.2 ppm – probably the highest level for two million years. [30] Between 1971 and 2008, annual emissions of carbon dioxide more than doubled, increasing by 40 percent between 1990 and 2008. In 2010, CO_2 emissions given off by the burning of fossil fuels set a new record of 30.6 gigatons, pointing to an increase of around 24 percent between 2000 and 2009. [31]

If emissions of greenhouse gases are not curbed, climate researchers think that the global temperature could increase by three to seven degrees Celsius relative to pre-industrial levels. Based on current knowledge, the worst consequences of global warming ("dangerous disruptions to the climate system") can be avoided with a probability of two thirds if the **rise in the mean global temperature is limited to two degrees Celsius**. To stay below this threshold, cumulative carbon emissions must not exceed a limit of 750 billion tons between 2010 and 2050. And to achieve this goal, greenhouse gas emissions would have to be reduced by 50 percent to 80 percent relative to 1990 levels. If the existing trend in emission volumes continues, however, the "budget" of 750 billion tons of CO_2 will already have been used up in 25 years. [32]

In December 2010, the 16th UN Climate Change Conference in Cancún officially recognized the **two-degree limit as a concrete quantitative objective of international climate policy**. Then, at the 17th conference, hosted by the South African city of Durban in December 2011, the delegates ratified the "Durban Package" of important decisions for the future of international climate policy. At the Conference of the Parties (COP17), the decision was made to prepare a universal climate protection treaty to which all countries should sign up. The treaty is to be negotiated by 2015 and implemented starting in 2020. Based on this objective, the signatory countries have also agreed to a second commitment period of the Kyoto Protocol. Quantified reduction commitments, emission budgets and other content issues are to be clarified in time for the next UN Climate Change Conference, which is to be held in Qatar at the end of 2012. A series of implementation decisions were also made in Durban, including the launch of a Green Climate Fund, the creation of structures for a climate adjustment committee and the setup of an international network for technological cooperation. [33]

The **window of time for the battle against global warming** – the period in which it might still be possible to avoid the worst consequences of climate change – **will soon close**. The longer we wait before reversing the trend and reducing global CO_2 emissions, the greater the yearly reductions that will be needed if the targets set for 2050 are to be reached. [34] To put that even more bluntly: The 2 °C goal will no longer be realistic if we fail to cut global emissions of greenhouse gases in the next ten years.

The stakes are high. The **impact of global warming in excess of two degrees would pose a severe and, to some extent, incalculable threat to the Earth's ecosystems**. One consequence of climate change whose occurrence is "probable to very probable" is that the **sea level will rise**. Higher temperatures will heat up the oceans and mountain glaciers will melt, as will large bodies of ice in Greenland and the Antarctic. A rising sea level would pose a major threat to low-lying islands and coastal regions. Coastal cities such as Shanghai, New York, Buenos Aires and Rio de Janeiro would be endangered by flooding.

Climate change also poses a **threat to biodiversity**. Global warming is proceeding too fast to allow many species to adjust and keep up. One third of all the types of reef-building coral, for example, are already at risk due to rising water temperatures. In addition to climate change, the destruction and impairment of habitats and the overexploitation of ecosystems are likewise expediting the extinction of species. Every year, around 35,000 of the 1.72 million or so known species of flora and fauna die out. The natural extinction rate would be around ten species per year.

29 "Very probably" indicates a probability in excess of 90 percent. See IPPC (2008), p. 31
30 In 2009. See Global Carbon Project (2010)
31 See International Energy Agency (2011b), p. 46
32 See Wissenschaftlicher Beirat der Bundesregierung Globale Umweltfragen, Klimawandel (2009)
33 See Bundesumweltministerium (2011g)
34 See Wissenschaftlicher Beirat der Bundesregierung Globale Umweltfragen, Klimawandel (2009)

In order to rein in the loss of biodiversity, the United Nations has therefore declared **2011-2020** to be the **UN Decade on Biodiversity**.

If the climate continues to change, **extreme weather events** such as droughts, torrential rain and flooding will become more frequent. Above and beyond these foreseeable consequences of climate change, there is also the threat posed by what are known as "tipping points" in the Earth's climate system. [35] If critical thresholds are reached, tipping points can set processes in motion that would accelerate global warming and would largely be both irreversible and self-enhancing. Examples of such tipping points would be the melting of the Himalayan glaciers, the thawing of the Siberian permafrost and the associated release of methane, the instability of the Amazon rainforest, the bistability of the Indian monsoons and the instability of the ice sheets in both Greenland and the western Antarctic.

In light of the existential threat to the very resources and ecosystems on which human life depends, carrying on with carbon emissions as in the past is – from both an ecological and an economic perspective – quite simply not a legitimate option. Waiting and seeing what happens to the climate would be an expensive mistake for the global economy: The cost of failing to act would be far greater than the cost of financing countermeasures. As early as 2006, the Stern Review came to the conclusion that 1 percent of global GDP must be spent if the two-degree target is to be hit. Conversely, doing nothing could cause global economic output to shrink by as much as 20 percent by 2050.

To master the challenge of climate change, a dual strategy must be pursued. First, we must **adapt to the consequences of climate change**. And second, we must limit the ongoing rise in temperatures by **reducing emissions of greenhouse gases**. There is nothing contradictory about targeting adaptation and reduction at the same time. Adaptation is simply a response to global warming; it is not a tool to prevent or limit it. [36]

Progress in international climate policy has so far been slow. However, governments have in recent years increasingly understood the need to take action to protect the climate. One indicator of this gradual enlightenment has been the growing number of climate-related laws and ordinances. Between December 2008 and December 2010 alone, the 16 biggest economies on the planet – known as the MEF countries [37] – ratified nearly 300 actions relevant to climate policy. [38]

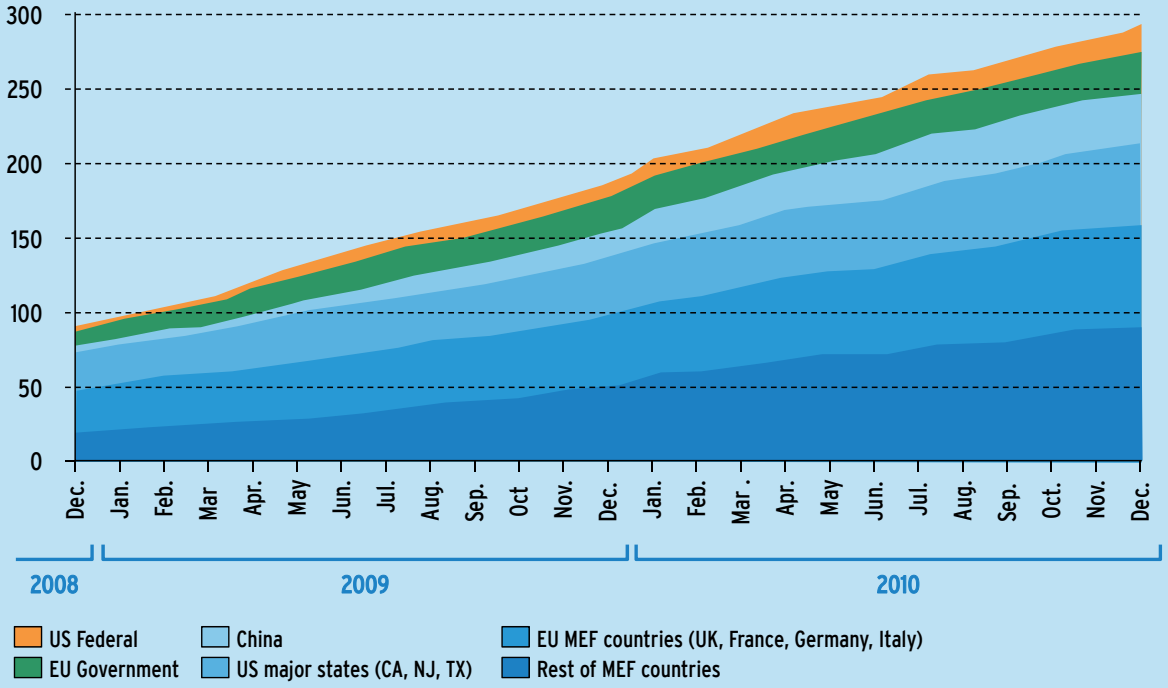
35 "The term 'tipping point' means that minor external disruptions could trigger a powerful reaction." – See Potsdam-Institut für Klimafolgenforschung (2011a)

36 "That which cannot be changed by reduction requires us to adapt. That to which we cannot adapt must be prevented." – Mastrandrea, M./Schneider, S., (2011), p. 39

37 The MEF countries (Major Economies Forum) include the G8 nations (Germany, France, the UK, Italy, Japan, Canada, Russia and the US) plus Australia, Brazil, China, India, Indonesia, Mexico, South Africa and South Korea

38 See DB Climate Change Advisors (2011), p. 9

Figure 3: Climate-related political initiatives, 2008 through 2010



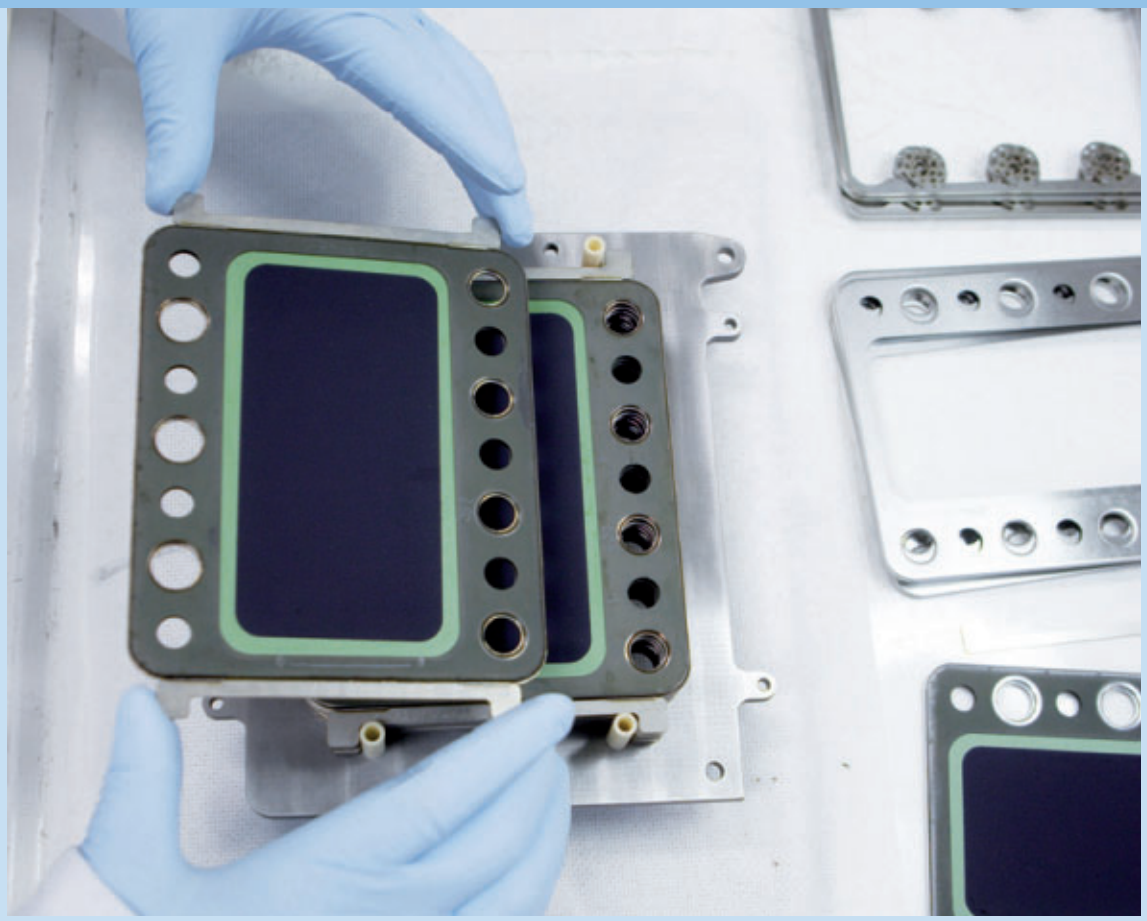
Source: DB Climate Change Advisors (2011), p. 9

Summary

Over the decades to come, the **megatrends** outlined in this section **will shape social, political and economic conditions around the globe. Climate change and the scarcity of resources in particular will be the key drivers of development in environmental technology.**

The latter has established itself as an international lead market in which German providers are excellently placed. A detailed overview of the green tech industry, its various markets and forecasts on how they will develop between now and 2025 are provided in the chapter below.

The German and international markets for environmental technology and resource efficiency – Traditional economic sectors are providing the basis for green tech growth



Plotting the map of a growth industry – What exactly are green markets?

Automotive engineering is about making cars. Mechanical engineering is about building machines. These industries have intuitive designations that give a clear impression of which companies belong to what lines of business and what they do to make money. With environmental technology and resource efficiency, the matter is a little more complex. Unable even to agree on its own nomenclature, this young industry goes by an assortment of names: environmental technology, green technology ("green tech" for short), clean technology, and so on. And indeed, the industry is as multi-faceted as attempts to describe it. Renewable energy may often be the first association that springs to mind when people talk about green tech. The two are by no means synonyms, however. True, generating, supplying and storing energy from renewable sources is an important aspect. Yet there is much more to the environmental technology industry than just this one segment.

Environmental technology and resource efficiency is a cross-sectoral industry that, in many areas, overlaps with other key industries such as mechanical, plant, electrical and automotive engineering. Business areas and technologies in these traditional branches of industry find themselves being broadened and, in some cases, redefined. In light of the resultant overlaps, it is not always possible to draw a clear line showing where environmental technology and resource efficiency ends and where other disciplines begin. All of this does not make it any easier to provide an unambiguous definition of the green tech industry itself.

In order to describe and define what we are talking about, this atlas **defines environmental technology and resource efficiency not in terms of products, but in terms of lead markets**. This was the approach used to present the environmental technology markets in *GreenTech made in Germany* and *GreenTech made in Germany 2.0*. It is therefore reasonable to regard it as an established method.

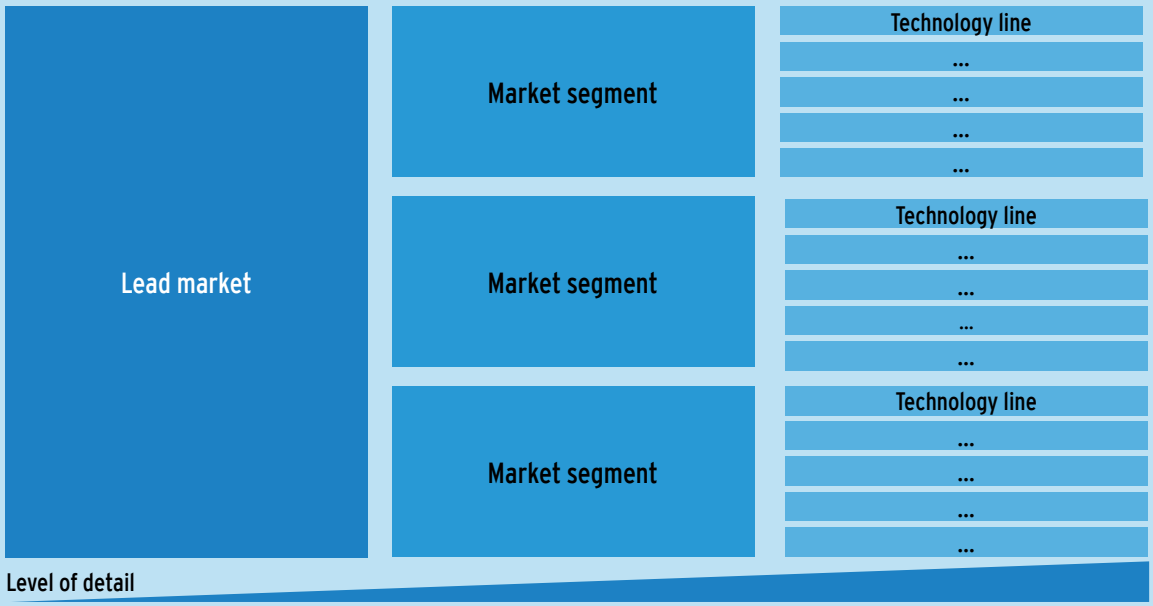
The lead markets referred to are key aspects of environmental technology and resource efficiency. Economic and ecological challenges are very closely intertwined in these core areas. The defined lead markets play a pivotal role in satisfying basic human needs and preserving ecosystems. Based on this conceptual premise, we have broken the **environmental technology and resource efficiency industry** down into **six lead markets**:

- Environmentally friendly power generation and storage
- Energy efficiency
- Material efficiency
- Sustainable mobility
- Waste management and recycling
- Sustainable water management

This segmentation into lead markets grew out of a large-scale survey of the corporate community conducted in advance of the first edition of the environmental technology atlas. Since then, this subdivision has proven its continued validity as a coherent framework for analysis of the green tech industry. Numerous surveys of market players have confirmed the point time and again.

While the framework for the analysis of the environmental technology and resource efficiency industry has thus remained unchanged since 2007, **the individual lead markets** that make up this notional construct have, in the meantime, **experienced decidedly dynamic development**. The breakdown into lead markets alone is therefore not enough to paint an accurate picture of all the trends and shifts that are observable in the green tech industry. Instead, a more granular segmentation is needed if we are to zoom in and obtain a clearer picture of German and international markets. Accordingly, this edition of the atlas introduces **two new hierarchic layers below the lead market level: market segments and technology lines**.

Figure 4: Breakdown of lead markets into market segments and technology lines



Source: Roland Berger

This overall structure (see figure 4) allows us to provide greater detail while not losing sight of developments that are emerging on a wider scale.

Technology lines form the **smallest unit in our breakdown of lead markets**. The term is, however, based on a broad understanding of the concept, as products, processes and services are all subsumed under this heading. As used in this atlas, the concept of a "technology line" in no way implies a narrow limitation to purely technological issues.

To put flesh on the bones of this explanation, figure 5 uses the example of the lead market for environmentally friendly power generation and storage to illustrate the breakdown into market segments and technology lines.

Figure 5: Market segments and technology lines in the lead market for environmentally friendly power generation and storage

Market segments		Technology lines
	Renewable energy	• Photovoltaics • Solar thermal energy • (Near-surface and deep) geothermal energy • (Offshore and onshore) wind power • Hydropower • Biomass (e.g. biogas plants, biomass treatment, biomass cogeneration plants) • Sewage gas burning
	Ecofriendly use of fossil fuels	• Gas and steam power plants • Cogeneration units (combined heat and power, district/local heating networks) • High-capacity power plants (high-temperature technology) • Low-carbon power generation
	Storage technologies	• Mechanical storage of energy (e.g. pumped storage, compressed-air storage, flywheels) • Electrochemical storage of energy (e.g. batteries, hydrogen storage) • Electronic storage of energy (e.g. capacitors, magnetic storage) • Thermal storage of energy (e.g. storage of geothermal energy)

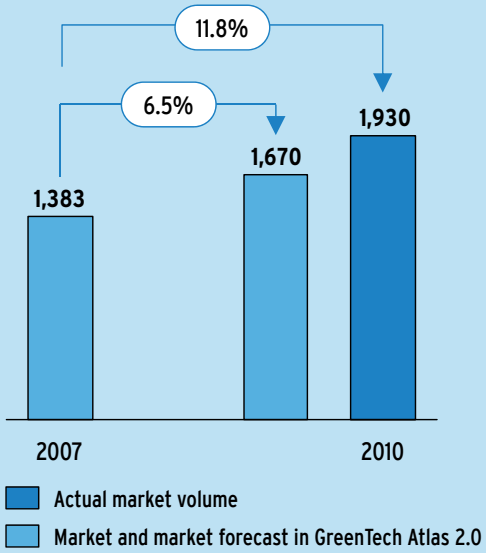
Source: Roland Berger

Plotting a growth trajectory – Developments in global and national green tech markets

When *GreenTech made in Germany 2.0* was published in 2009, a glowing future was predicted for environmental technology and resource efficiency. According to the forecasts presented in the second edition of the environmental technology atlas, this market would grow at an annual average rate of 6.5 percent from 2007 through 2010. Reality has outshone even these bold prophecies, however. **Between 2007 and 2010, the global market for environmental technology and resource efficiency expanded at an average rate of 11.8 percent per annum, reaching a volume of EUR 1,930 billion in 2010** (see figure 6). The second edition of this atlas had put the forecast figure at EUR 1,670 billion.

The EUR 260 billion discrepancy between forecast and fact is attributable primarily to two things. First, the **environmental technology services** sector **experienced huge growth** in the specified period. Second, **"green" stimulus programs** were launched in 2009 to get the economy back on its feet again in the wake of the 2008/2009 financial and economic crisis. These economic stimulus packages were the main reason why international demand for environmental technology gathered momentum faster than expected. The majority of the growth that had not been forecast – EUR 240 billion in all – can be chalked up to programs to revive the economy.

Figure 6: Growth in the global market for environmental technology and resource efficiency, 2007-2010 (in EUR billion, average annual change in percent)



Source: Roland Berger

Despite this powerful surge from 2007 through 2010, however, growth forecasts for the overall period from 2007 through 2025 will not be corrected upward. Average annual growth in this period is still put at 6.5 percent. The high level of investment witnessed from 2007 through 2010 will not be maintained, as much of it consisted simply of projects being brought forward.

Economic stimulus programs launched by some countries in response to the financial and economic crisis in 2008/2009 are now acting as **catalysts to global expansion of the environmental technology and resource efficiency industry**. Additionally, many countries operate specific mechanisms to promote the deeper market penetration of efficiency-enhancing technologies and renewable energy. Different countries focus on different areas. A few examples taken from key industrialized nations and emerging countries illustrate the sheer diversity of green infrastructure programs.

Brazil responded to the economic crisis in 2008/2009 by introducing an extensive infrastructure program dubbed PAC 1 (Programa de Aceleramento do Crescimento). This was followed by PAC 2, which involved capital spending projects from 2011 through 2014. The largest country in South America sees these "economic acceleration programs" first and foremost as a way to bridge the gap in its wastewater and water management industries. Under the aegis of PAC 2 (which has currently reached a volume of around USD 870 billion), nearly USD 48 billion is to be invested in "urban infrastructure and the supply of isolated regions with water and electricity". Between 2011 and 2014, USD 255.3 billion has been set aside to "expand the use of renewable energy and the production of oil and gas". [1]

India plans to invest some EUR 9 billion in its water supply and wastewater systems by 2012. [2] As part of the Solar Mission program, 20 gigawatts of capacity for the generation of solar power is to be created. At the same time, 17 million square meters of collectors is to be installed for use in solar hot water systems. [3]

China highlighted a number of ecological aspects back in its 11th five-year plan (2006-2010), focusing, for example, on improving energy efficiency and reducing carbon intensity. Energy and environmental issues also play a prominent part in the 12th five-year plan (2011-2015). Energy intensity is to be reduced by 16 percent between 2011 and 2015, CO_2 intensity by 17 percent. Taking 2010 as the base year, water consumption per unit of GDP is to be reduced by 30 percent.

1 See German Trade & Invest (2010a)
2 See German Trade & Invest (2011b)
3 See German Trade & Invest (2011a)

In response to the economic and financial crisis in 2008/2009, the **US** government passed the American Recovery and Reinvestment Act (ARRA). This package includes numerous environmental technology and resource efficiency investment projects. One example is the USD 14.5 billion set aside to improve energy efficiency in buildings. USD 23 billion is to be pumped into the energy sector. Of this sum, USD 6 billion will be used to expand the power grid for the integration of renewable energy. Carbon capture and storage (CCS) technologies will be subsidized to the tune of USD 3.4 billion. USD 11 billion has been set aside to modernize the power grid. Renewable energy will receive support worth a total of USD 30 billion. [4]

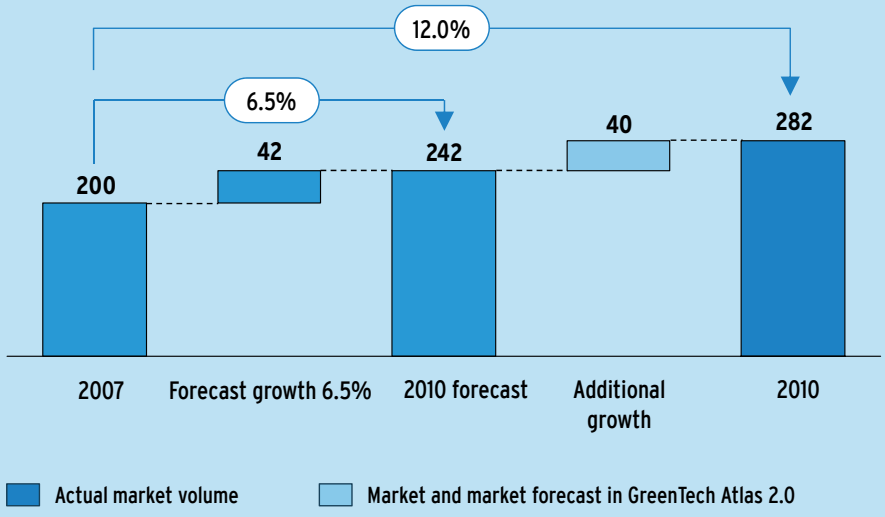
German providers of green technology can benefit handsomely as international markets for environmental technology and resource efficiency expand. Foreign demand for environmental technology in the wake of all these "green" stimulus packages has been a veritable windfall for German companies, thanks to their excellent positioning on the global market. Siemens alone is expecting extra orders worth around EUR 15 billion from government-backed green stimulus programs. A second stimulus package, approved in January 2009, likewise contains green elements such as the modernization of energy systems in public buildings and the promotion of electromobility.

Fueled by these economic stimulus programs, growing worldwide demand for environmental technology processes and products has provided **powerful impetus for the development of this industry in Germany**. As figure 7 shows, growth in Germany's green tech markets has outstripped the forecasts published in the second edition of the environmental technology atlas. Instead of growing by 6.5 percent per year in line with predictions, the **market for environmental technology and resource efficiency expanded by an average of 12 percent per annum from 2007 through 2010**.

This development alone makes a compelling case for the powerful position enjoyed by German providers. **Germany currently boasts a 15 percent share of the global market for environmental technology and resource efficiency** (see figure 8). Its green tech companies have, in other words, successfully asserted their excellent positioning in international markets. And in the long term, Germany is expected to continue defending its 15 percent share of the growing market for environmental technology and resource efficiency (see figure 9).

The analyses provided in this latest edition, the GreenTech Atlas 3.0, **reaffirm the importance of environmental technology and resource efficiency**

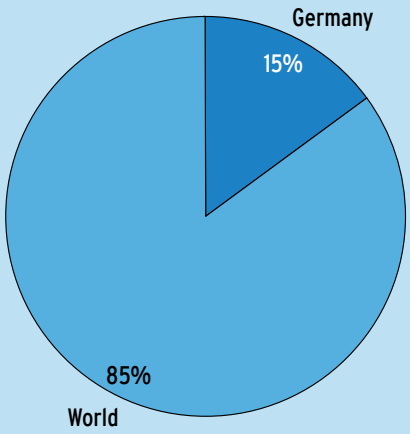
Figure 7: Market growth in Germany (in EUR billion, average annual change in percent)



Source: Roland Berger

4 See German Trade & Invest (2010b)

Figure 8: Germany's share of the global market for environmental technology and resource efficiency

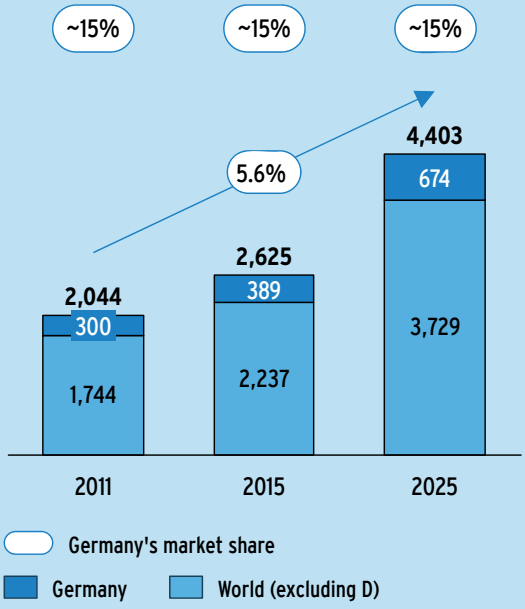


Source: Roland Berger

as a growth industry in Germany. This branch of industry currently accounts for nearly 11 percent of the country's GDP. And its contribution to economic output will rise to over 20 percent by 2025, thanks to global market growth that will stimulate demand for environmental technology and resource efficiency that bears the label "made in Germany".

This buoyant development is also reflected in the trend in employment. **In 2011, the six lead markets that make up the environmental technology and resource efficiency industry provided 1.4 million jobs.** [5] Around a million of these were in the environmental technology service sector. The remaining 400,000 can be found in production and plant

Figure 9: Growth forecast for the global environmental technology and resource efficiency market, 2011, 2015 and 2025 (in EUR billion, average annual change in percent)



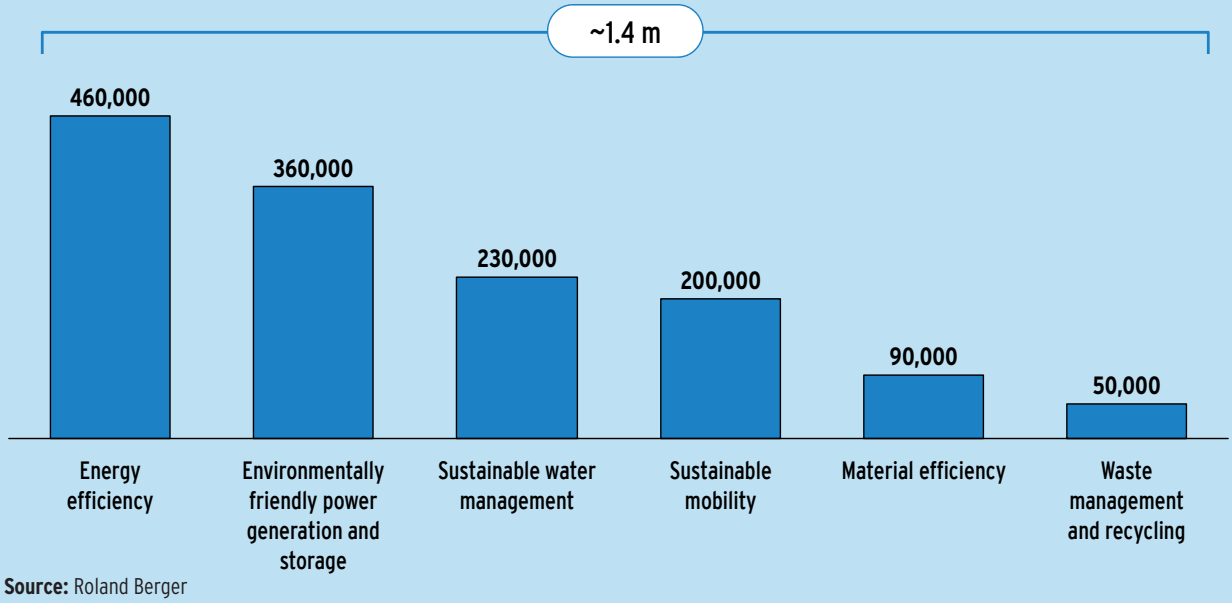
Source: Roland Berger

5 These six lead markets do not cover all jobs that are needed to provide environmental protection products and services. In 2008, nearly two million people worked in environmental protection in Germany. However, even this figure does not (or at least not adequately) reflect emerging disciplines such as sustainable tourism and environment-focused aspects of the insurance industry. See Bundesumweltministerium/Umweltbundesamt (2012)

engineering. Looking at the breakdown of green tech employment across the individual lead markets, energy efficiency and environmentally friendly power generation and storage stand out as the clear leaders (see figure 10).

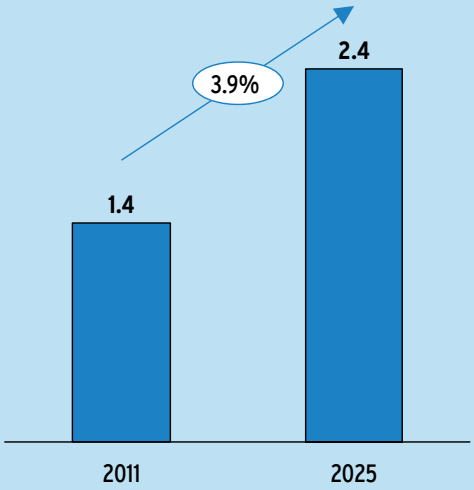
In 2025, there will probably be 2.4 million employees in the environmental technology and resource efficiency industry (see figure 11). Between now and then, the number of employees will grow at an average annual rate of 3.9 percent – lower than the 5.6 percent rate of growth predicted for the market itself in the same period. The discrepancy is explained by the assumption of a 2 percent gain in productivity.

Figure 10: Distribution of jobs across the individual lead markets in the environmental technology industry – Germany 2011



Source: Roland Berger

Figure 11: Growth in employment in the environmental technology and resource efficiency industry, 2011-2025 (millions, average annual change in percent)



Source: Roland Berger

Close-up analysis of selected trends in the individual lead markets

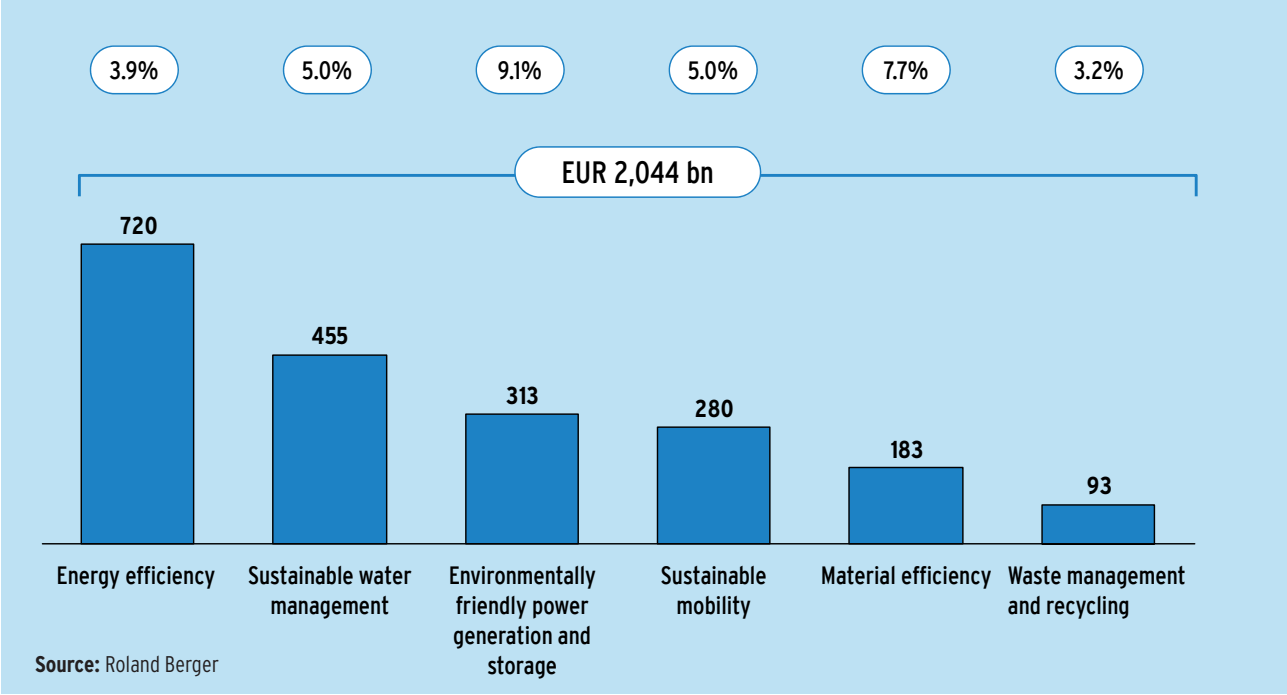
The six lead markets in the environmental technology and resource efficiency industry will have a combined volume of just over EUR 2,000 billion in 2011. This figure will more than double to above EUR 4,400 billion by 2025. Both globally and from a specifically German perspective, **energy efficiency is, by some distance, the lead market that currently boasts the largest volume** (see figure 12). Especially in a place like Germany, where production in industries such as mechanical engineering, chemicals and automotive engineering plays such a prominent part, demand for products and processes to improve energy efficiency is increasing at a tremendous pace. Investing in energy efficiency allows German customer companies to cut the cost of production and helps them stay competitive. On the supplier side, investing more in energy-efficient solutions stimulates the development of new, more efficient technologies, which in turn boosts demand.

As we saw above, **energy efficiency is the largest of the lead markets in Germany's national green tech industry** too, accounting for **EUR 98 billion** out of a total market volume of EUR 300 billion (see figure 13). While sustainable water management is the second-largest lead market internationally, environmentally friendly power generation and storage occupies second place in Germany. Early energy policy moves that charted a clear course toward promoting renewable energy have been the principal driver of development in this lead market. Since then, the German government's decision to pull out of nuclear energy by 2022 has further stimulated demand for renewable energy and storage technologies. This is reflected in the average annual growth rate of 8.4 percent expected between now and 2025.

Analysis of the position occupied by German environmental technology and resource efficiency products and services on the global market shows that the lead markets for environmentally friendly power generation and storage, waste management recycling and sustainable mobility stand out as special strengths (see figure 14). German providers currently have a share of 23 percent, 17 percent and 17 percent in these lead markets respectively.

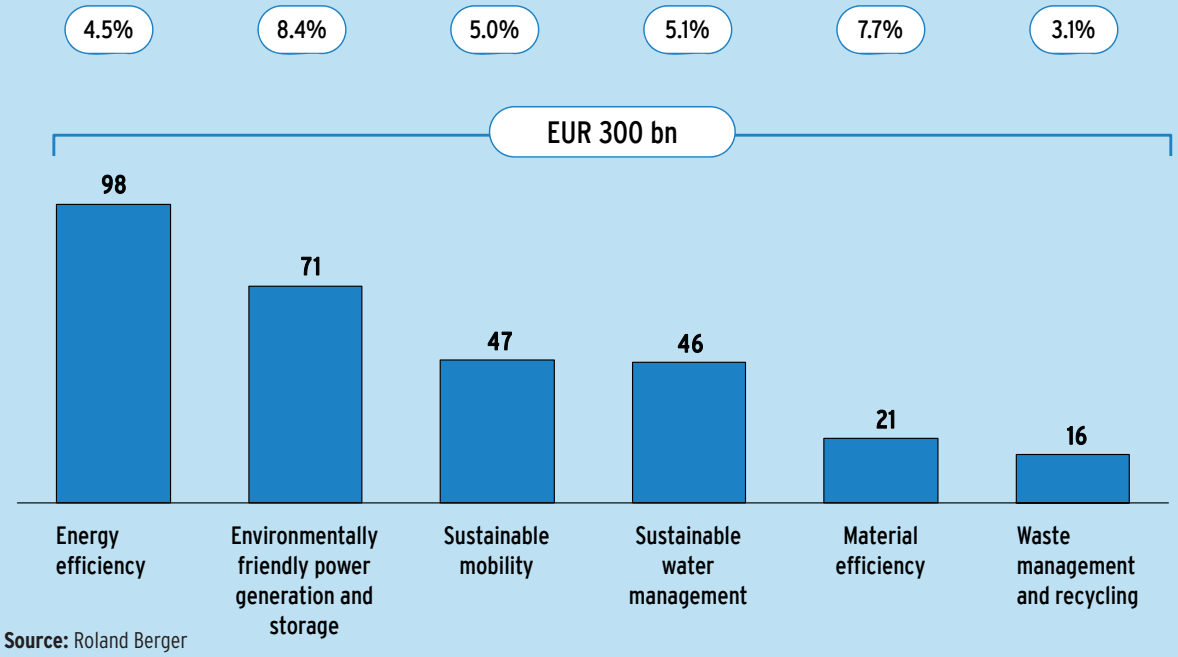
Forecasts for 2025 indicate that the lead market for environmentally friendly power generation and storage will take over from energy efficiency as the biggest lead market in terms of volume. The latter lead market will see its slice of the cake shrink from 33 percent to 27 percent, while environmentally friendly power generation and storage will increase by nine percentage points. The lead markets for sustainable mobility, waste management and recycling and sustainable water management will each see their share of the overall green tech industry decline slightly in Germany, while material efficiency will edge upward (see figure 15).

Figure 12: Global volume in the individual lead markets in 2011 (in EUR billion, average annual change 2011-2025 in percent)



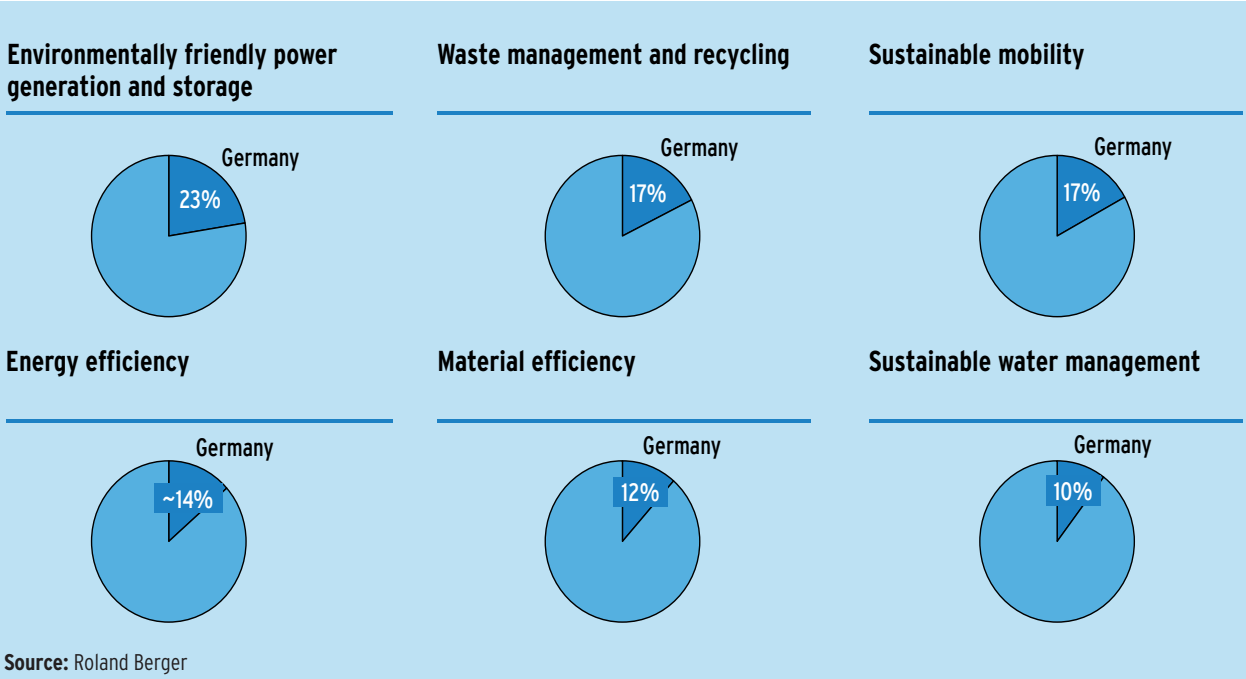
Source: Roland Berger

Figure 13: Volumes in the lead markets for environmental technology and resource efficiency in Germany in 2011 (in EUR billion, average annual change 2011-2025 in percent)



Source: Roland Berger

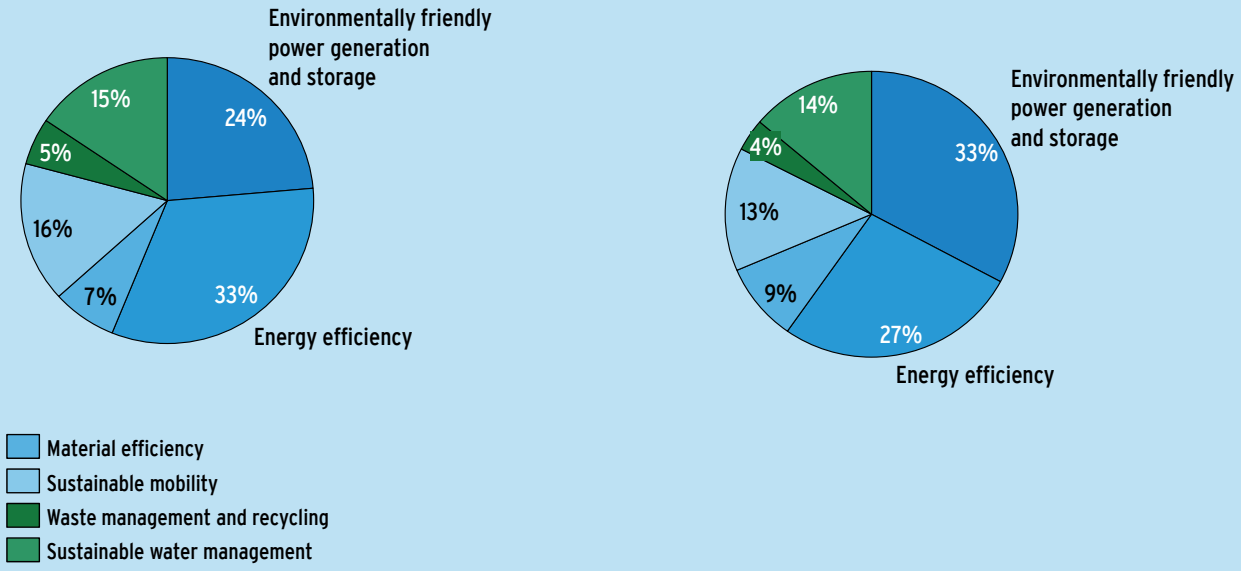
Figure 14: German companies' global share of the six lead markets for environmental technology and resource efficiency in 2011



Source: Roland Berger

Although the weighting of environmentally friendly power generation and storage will increase in Germany, the country will, in the medium to long term, be unable to maintain its share of the global volume in this lead market (see figure 16). In 2011, German providers controlled a 23 percent share of the global market for environmentally friendly power generation and storage. By 2025, this share is projected to shrink to 21 percent.

Figure 15: Projected changes in the relative size of lead markets



Source: Roland Berger

This development is due to the fact that other major industrialized and emerging countries have recognized the importance of renewable energy and their need to catch up in this sector – and that they are now ramping up their efforts to do so.

China's medium- to long-term development plan for renewable energy is to raise renewable energy as a share of the country's primary energy consumption to 15 percent by 2020. This goal is picked up in the 12th five-year plan (2011-2015). By 2015, non-fossil fuels are to account for 11.4 percent of primary energy consumption (up from 8.3 percent in 2010). The downside here is that "non-fossil fuels" also include nuclear power and large hydropower plants. Discounting these categories, solar power, wind power and biomass are to contribute around 2.6 percent to the mix. Government funding totaling RMB 5 trillion is slated to ramp up these "new energy sources". [6] In the course of the 12th five-year plan, production capacity for renewable energy is to be increased by 225 gigawatts.

In light of the above, German providers will likely find it increasingly difficult to defend their technology leadership. **Germany's photovoltaics industry** is already feeling the painful effects of **growing competition from Asia** in general and China in particular. In the future, German solar module producers above all will have a hard time making a profit on international markets with the business models they have operated up to now. More attractive financing terms, lower energy costs, lower personnel expenses and depreciation-related advantages give Asian module producers cost benefits in the order of 20 percent to 30 percent. Moreover, Chinese module manufacturers are targeting economies of scale to further increase their cost benefits and put pressure on the prices of modules and systems. The leading Chinese module producers had total production capacity of 8.6 gigawatts in 2011. Production capacity in Germany is estimated at 2.4 gigawatts. Faced with this kind of competition, it will not be easy for German photovoltaics manufacturers to keep up with international rivals, especially as the most common modules to date have little to set them apart in terms of their efficiency and brand profile. German manufacturers do, however, have the option of consolidating or improving their competitive position by asserting their technology leadership. Promising strategies involve the launch of highly efficient production processes, improvements to thin-layer modules and the further development of organic solar cells.

6 See German Trade & Invest (2011c)

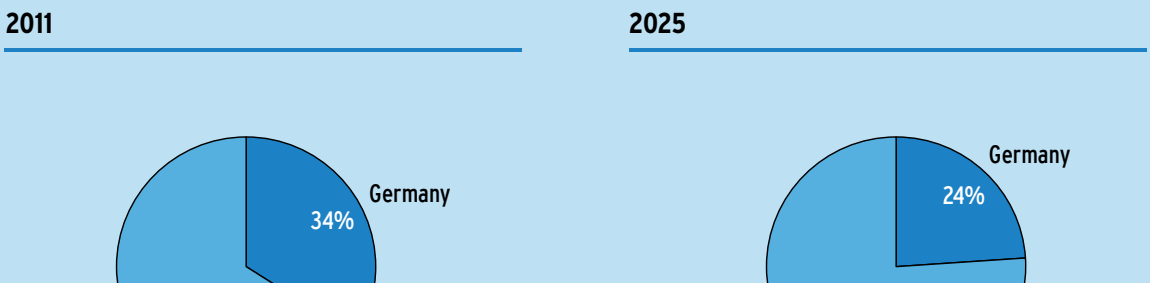
As other countries ramp up their production capacity, **Germany's share of the global photovoltaics market is projected to decline from 34 percent in 2011 to 24 percent in 2025** (see figure 17). These market figures include solar modules, inverters and the construction of solar power plants. As is clear from the figures for 2010, German companies' shares of these market segments vary considerably.

Germany has a share of around one fifth of solar module production, but controls roughly 70 percent of the inverter industry. In the solar power plant segment, German firms have cornered more than half of the global market.

Figure 16: German companies' share of the global lead market for environmentally friendly power generation and storage in 2011 and 2025

Source: Roland Berger

Figure 17: Germany's photovoltaics industry – Share of the global market in 2011 and 2025

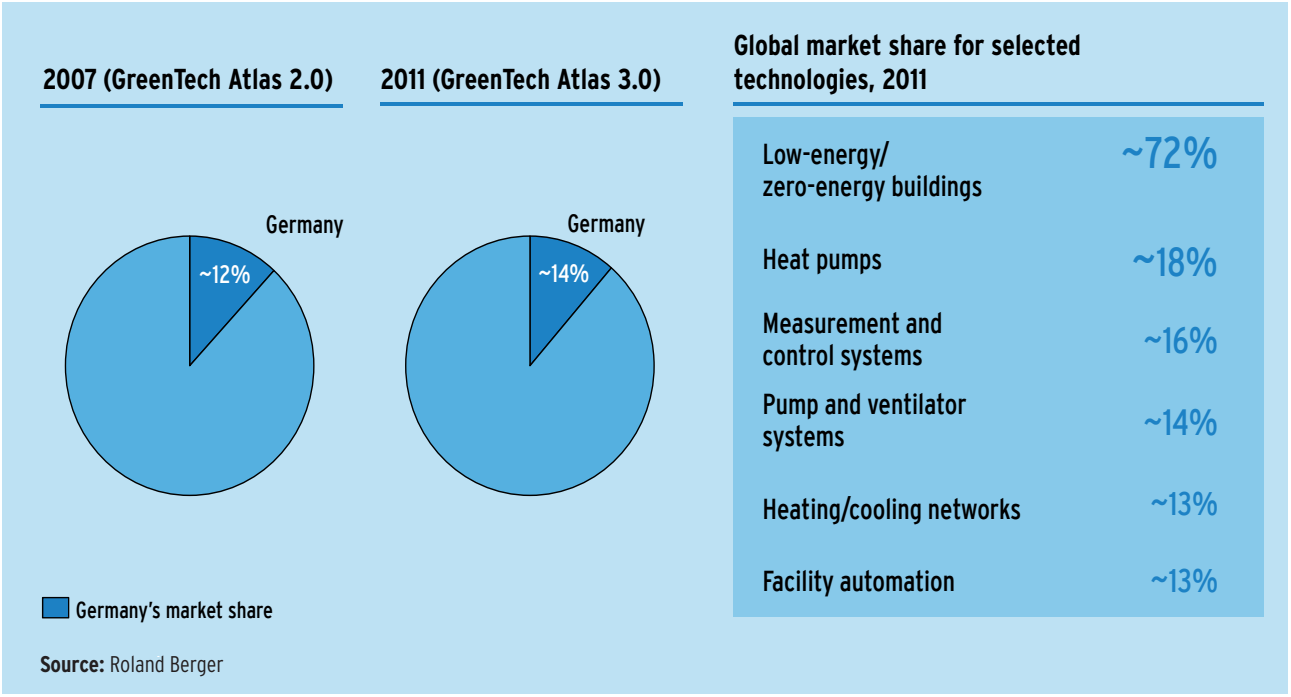


Source: Roland Berger

In the spotlight – The lead markets for energy efficiency and material efficiency

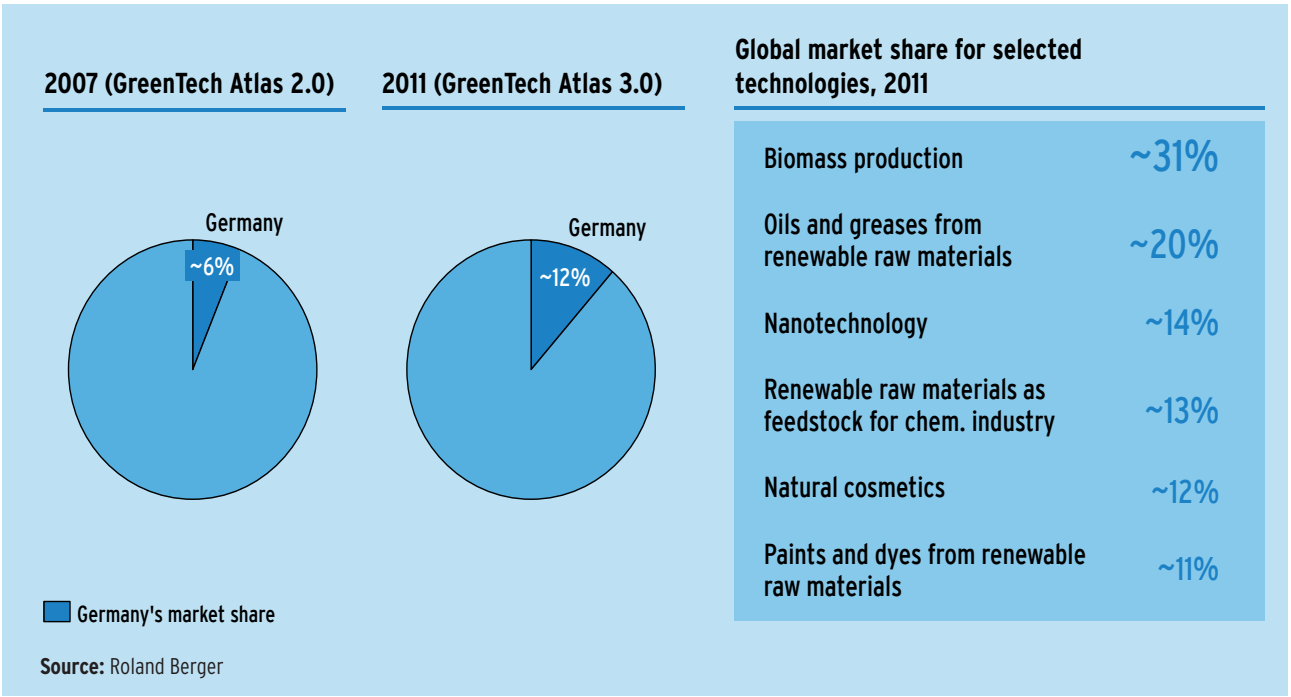
Analysis of the **period from 2007 through 2011 reveals that Germany was able to add to its share of the global market volume for both energy efficiency and material efficiency** (see figures 18 and 19). Both lead markets have seen their volume increase sharply over the past five years, albeit largely as a result of rising energy prices and the ever greater scarcity of resources coupled with growing demand.

Figure 18: German companies' share of the global lead market for energy efficiency in 2007 and 2011, and of selected technology lines in this lead market



Source: Roland Berger

Figure 19: German companies share of the global lead market for material efficiency in 2007 and 2011, and of selected technology lines in this lead market



Source: Roland Berger

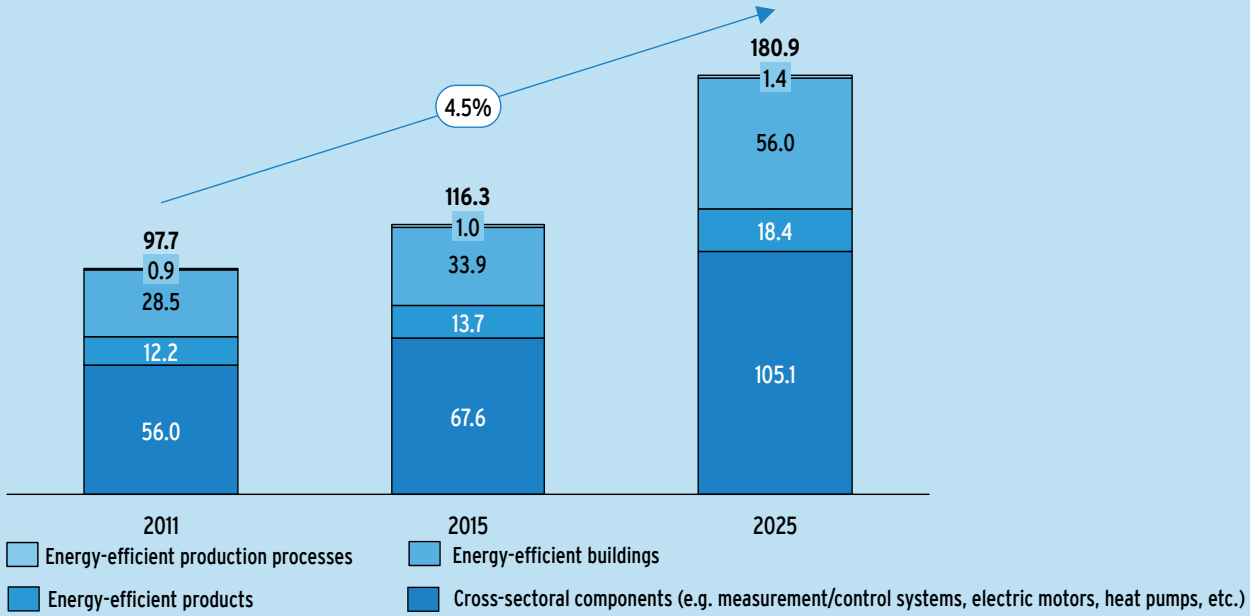
German providers lead the field in solutions to improve resource efficiency. The portfolio marketed by companies from Germany includes innovative products, processes and services to satisfy growing international demand.

In the **lead market for energy efficiency, German providers can make excellent use of their strengths in measurement and control systems as well as in other cross-sectoral technologies** (such as electric motors, heat pumps, etc.). These "horizontal" components account for a sizeable chunk of the lead market for energy efficiency. The volume of this market segment, in which measurement and control systems play a key role in improving energy efficiency, will jump from EUR 56 billion in 2011 to EUR 105.1 billion in 2025 (see figure 20). Energy efficiency in buildings is another important area, and one within which the importance of intelligent facility management systems is set to increase. German providers are similarly well placed to respond to growing demand for resource-efficient and climate-friendly heating systems. On the German market, the Renewable Energy Sources Act has provided stimulus for this segment. Sales of heat pumps in particular are likely to increase.

A detailed examination of the lead market for material efficiency primarily highlights the growing importance of biotechnology and nanotechnology (see figure 21). Germany is strong on industrial biotechnology. Also known as "white biotech", this segment is gaining in significance as finite fossil raw materials become increasingly scarce and their prices rise. German companies are excellently placed regarding the development of enzymes, new biomaterials and biotechnological production processes.

Nanotechnology ranks as a key technology in Germany. It harbors vast potential for innovation in an array of application areas. [7] In the context of environmental technology, nanotechnology is deployed above all to remove pollutants – in filtration processes or for catalytic purification, for instance. In fuel cells, nanotechnology takes the form of optimized electrons and catalysts. It is also being used to improve electrical energy storage in lithium-ion batteries, for example.

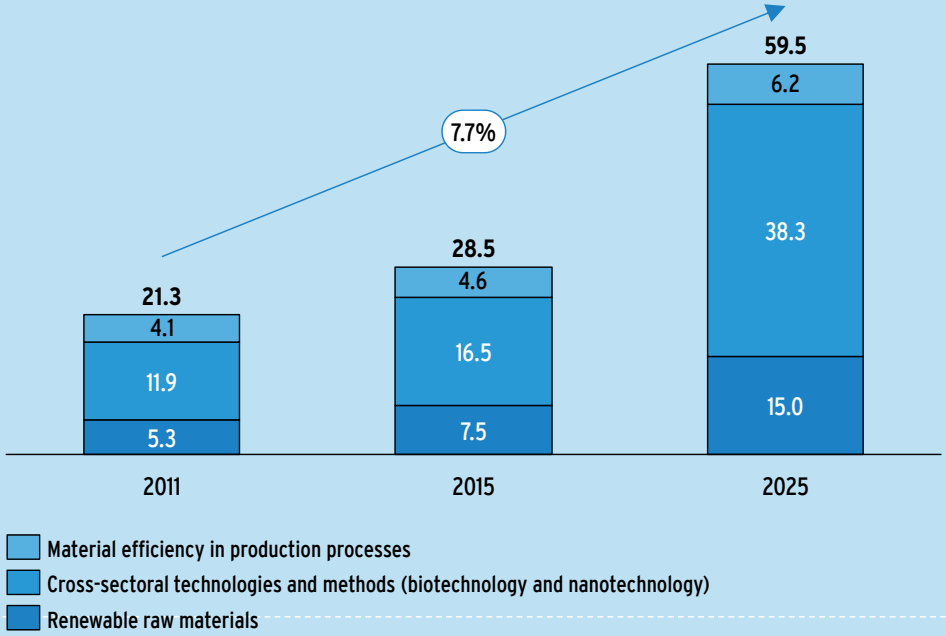
Figure 20: Market volumes in the lead market for energy efficiency in Germany, 2011, 2015 and 2025 (in EUR billion, average annual change in percent)



Source: Roland Berger

7 See the detailed account of the lead market for material efficiency

Figure 21: Market volumes in the lead market for material efficiency in Germany, 2011, 2015 and 2025 (in EUR billion, average annual change in percent)



Source: Roland Berger

Focus on leading technology lines

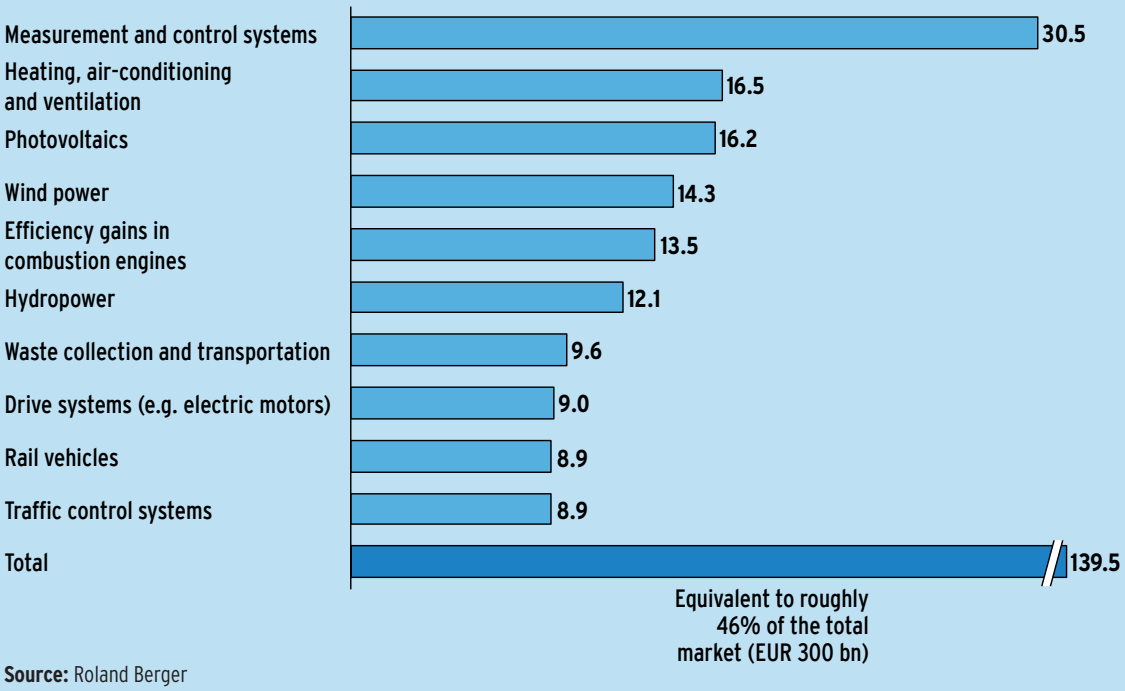
In Germany, it is not enough to analyze the market for environmental technology and resource efficiency only at the level of the defined lead markets. If we zoom in a little closer, this changes our perspective – and gives us a very revealing insight into specific lines of technology. Figure 22 lists the **ten biggest technology lines** in terms of market volume. **These lines add up to a total volume of EUR 139.6 billion, i.e. some 46 percent of the German green tech market.** Easily the leading technology, with a market volume approaching EUR 30.5 million, is the **measurement and control system** line. In Germany, this part of the industry is populated by superbly trained specialists. It also operates global distribution structures, boasts outstanding product quality and is strong on innovation. An added bonus is that German providers were quick to spot climate protection and the scarcity of resources as megatrends, and to align their strategies accordingly.

The fact that **photovoltaics and wind power** rank so highly among the technology lines in terms of market size underscores the leading positions that German firms currently occupy in these segments.

Looking ahead to the technology lines that will lead the German field in terms of market size in the future, **measurement and control systems will still be top of the table in 2025.** Compared to the 2011 rankings, there will be four newcomers among the top ten technology lines: high-capacity power plants, water distribution, low-energy/zero-energy buildings and solar thermal power plants. Raising steam parameters – as high as 700 °C in high-capacity power plants – can substantially improve the efficiency of existing plants. In the water distribution technology line, German providers are well placed to corner a share of the world's growing demand for valves, fittings, pumps and other products that are vital to the process of recovering, treating and distributing water.

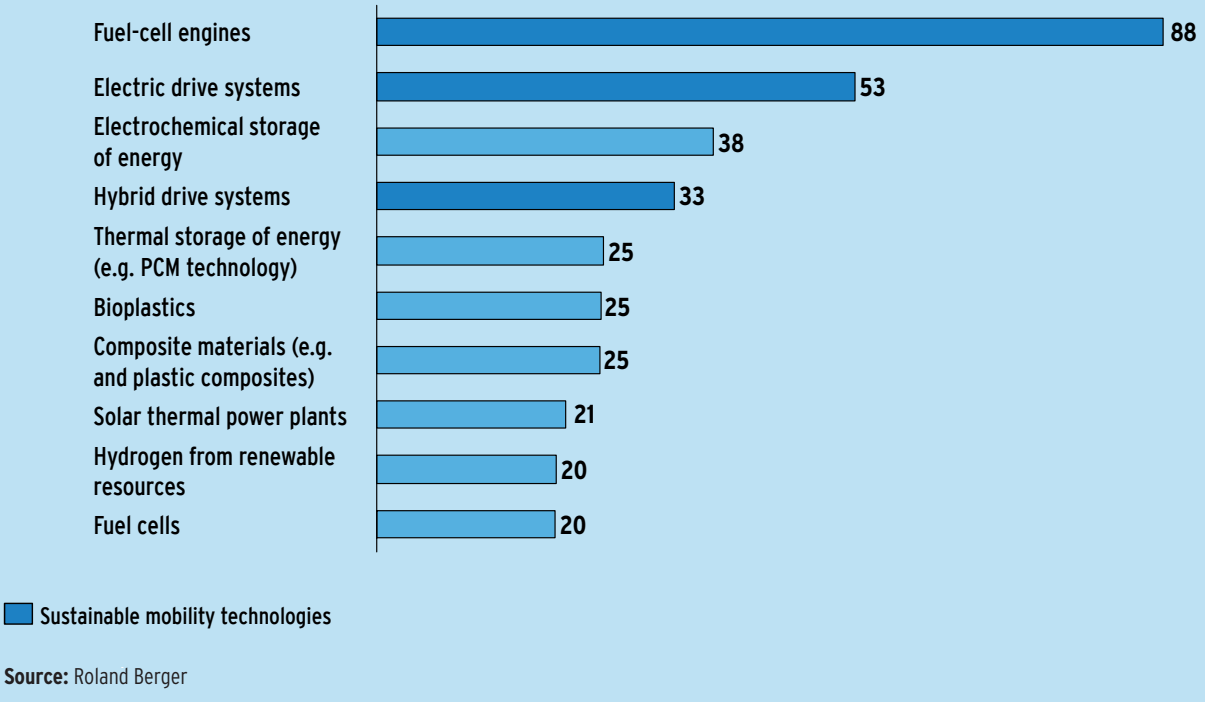
Companies' **knowledge of how to erect energy-efficient buildings and modernize the energy systems in existing buildings** is likely to increase considerably in the years ahead. In line with the stated aims of the German government's new energy policy, doubling the modernization rate from 1 percent to 2 percent per annum should make the real estate sector "virtually climate-neutral" by 2050. According to data from the German Federal Ministry of Transport, Building and Urban Development, some 30 million out of a total of 40 million buildings in Germany need their energy systems overhauled.

Figure 22: Top ten technology lines in Germany by market size in 2011 (in EUR billion)



Source: Roland Berger

Figure 23: Top ten technology lines in Germany by growth, 2011-2025 (average annual change in percent)



Source: Roland Berger

If the rankings for the leading technology lines were based on "average annual growth from 2011 through 2025" rather than on market size, the order shown in figure 23 would result. It thus becomes clear that the lead market for sustainable mobility in particular has a prominent position among the technology lines' growth champions. As vehicles powered by fossil fuels gradually shift into reverse, the outlook is bright for alternative technologies. In these rankings, fuel-cell engine systems come top of the range of expansive technologies, and that by some considerable distance. Admittedly, however, their exceptionally high average annual growth rate of 88 percent can be explained by the extremely low level from which this growth is beginning. At the present time, the market for this technology line is only marginal.

Second and fourth place too are occupied by technology lines from the lead market for sustainable mobility. This is a clear sign that moves to turn away from gasoline and diesel, two fossil fuels, are driving frantic growth in alternative fuels and drivetrains. Hybrid drive systems are playing an important role, bridging the technology gap until such time as electromobility can penetrate the market.

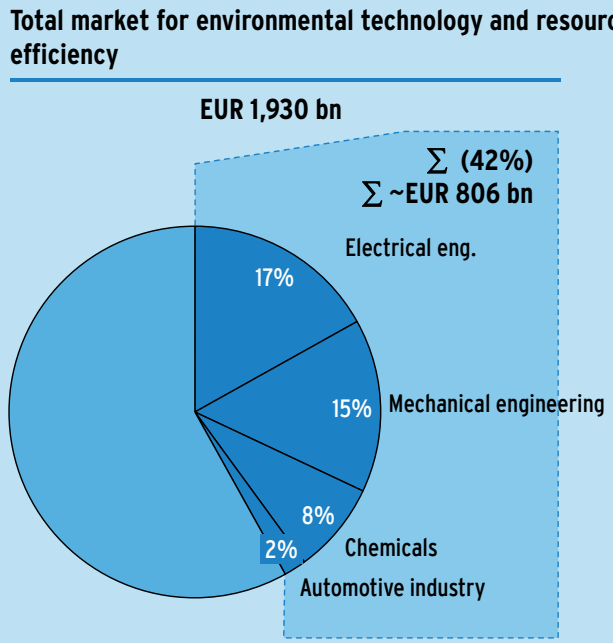
Powerful key industries – The platform on which to grow environmental technology "made in Germany"

The environmental technology and resource efficiency industry is a typical cross-sectoral industry that overlaps with many areas of key industries such as mechanical, plant, electrical and automotive engineering. A fair number of players in the green tech market initially moved into the environmental technology market from a background in these industries. Many companies have diversified their way into environmental technology but still operate one or more lines of business in their original industries. And precisely this **firm foothold in traditional industries has proved to be a key success factor for green technology in Germany**. The tender green shoot of environmental technology has been able to take root and grow in this fertile soil, benefiting in the process from the traditional strengths of German industry. The latter include innovative prowess, the ability to combine products and services to form complex solutions "from a single source", and a pronounced focus on exports. In return, environmental technology has generated valuable stimulus for innovation in traditional industries themselves. Especially in energy efficiency and material efficiency, the development of green technology has proven to be a powerful driver of modernization.

In the context of our current analysis, it is interesting to examine the extent to which **companies from other industries are playing an active part on the market for environmental technology and resource efficiency**. To do so, we have selected four branches of industry: electrical engineering, mechanical engineering, chemicals and the automotive sector. Electrical engineering occupies the largest share of the global green tech market (17 percent), followed by mechanical engineering (15 percent; see figure 24). The degree to which the individual industries are represented varies considerably from lead market to lead market. Electrical engineering, for example, accounts for a large share of the lead market for energy efficiency, whereas mechanical engineering has a strong presence in the lead market for environmentally friendly power generation and storage.

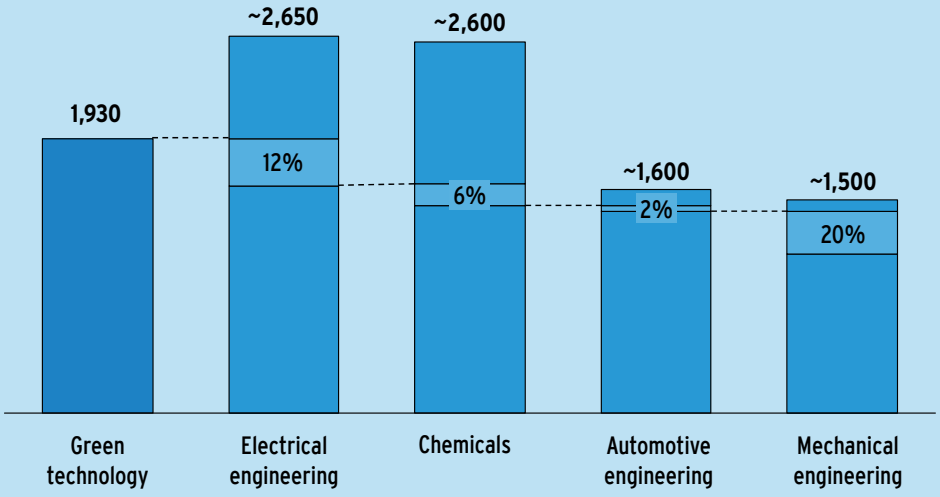
Now let us turn things around and examine the **market share that the environmental technology and resource efficiency industry holds in these other industries**. First and foremost, green technology plays a singularly prominent role in the mechanical engineering sector. Environmental technology and resource efficiency accounts for 20 percent of mechanical engineering – the largest relative share – in areas such as the construction of wind turbines (see figure 25). At the same time, 12 percent of the electrical engineering industry can be ascribed to environmental technology and resource efficiency (including measurement and control systems, for example). It thus becomes clear that environmental technology and resource efficiency already play an immensely important part in other key industries. Their significance will grow in the future too, as more and more companies in traditional industries see environmental technology as a way to set themselves apart from (international) competitors.

Figure 24: Traditional industries' share of the overall environmental technology and resource efficiency market (excerpt)



Source: Roland Berger

Figure 25: Green tech's share of the global market volume in selected industries (in EUR billion)



Source: Roland Berger

Innovative services – The growing importance of environmental technology services

If taken too literally, the term "environmental technology" can conjure up misleading images. After all, services are not usually the first thing one associates with the word "technology". **Yet services play an important part in the environmental technology and resource efficiency industry, accounting for over half of the total market** (see figure 26), with general industry services [8] accounting for the largest single share (43 percent).

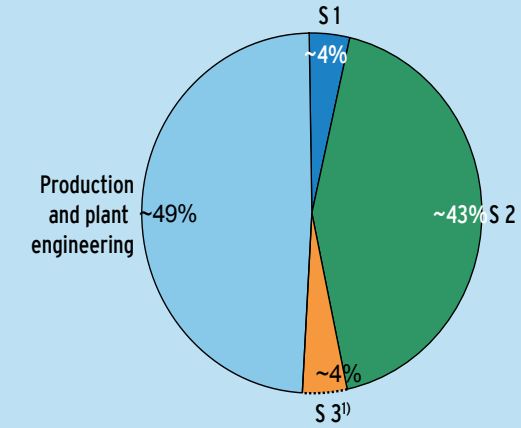
"Green services" fulfill an important purpose in developing the market for environmental technology and resource efficiency. [9] In many cases, fundamental services act as market drivers by opening the door for technologies to follow. This mechanism is then reinforced as services give rise to innovative business models, such as trading in green electricity, operating electricity filling stations and promoting ecotourism. General industry services likewise often drive innovation, while research organizations and development service providers actively support the process of innovation in the industry.

The global market for environmental technology services will continue to expand. Between 2011 and 2025, average annual growth is forecast to be nearly 6 percent (see figure 27).

In Germany, **services have visibly been gaining ground as a share of the overall market for environmental technology and resource efficiency since 2008** (see figure 28). Between 2008 and 2010, the market volume for environmental technology services rose from EUR 123 billion to EUR 155 billion. There are a number of reasons for such rapid growth. One is that, proportionally, Germany spends heavily on research and development, leading the field in both basic and applied research. Another is that German service partners are participating in international growth in environmental technology markets, for

Figure 26: Services as a share of the market for environmental technology and resource efficiency

Global service distribution, 2011



1) S 3 was not taken into account in the overall market analysis in the preceding sections

Source: Roland Berger

Notes

Fundamental services (S 1)
- Consulting firms in all lead markets
- Project development
- (Energy) contracting
- Innovative business models

General industry services (S 2)
- Research and development
- Technical planning, consulting and inspection
- Provisioning of materials and supplies
- Logistics and distribution
- Operation and maintenance
- Waste disposal and recycling

Corporate services (S 3)
- Finance and insurance
- Law practices
- Auditors/tax advisors
- Temporary employment/training and development

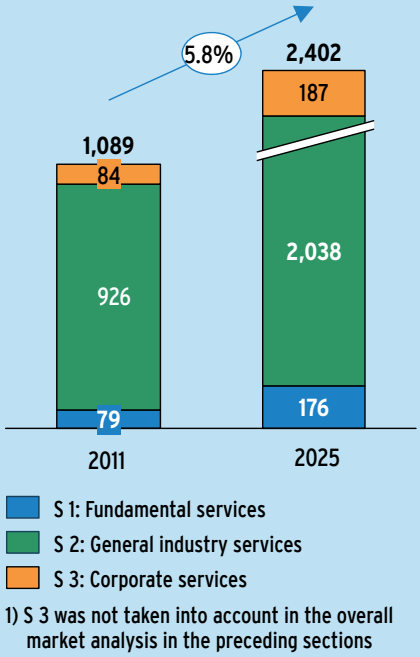
8 For a detailed and systematic breakdown of services, see the section on *Environmental technology services – New challenges, new business models*, p. 170ff.

9 See the detailed account provided in the study *Umwelttechnik-Dienstleistungen. Treiber für ökologische Modernisierung und Beschäftigung* ("Environmental services. Drivers of ecological modernization and employment"), published by the German Ministry for the Environment (Bundesumweltministerium, 2009d)

example by handling project development for orders from abroad. Still another is that companies based in Germany frequently play a pioneering role in the innovation of new and "green" business models.

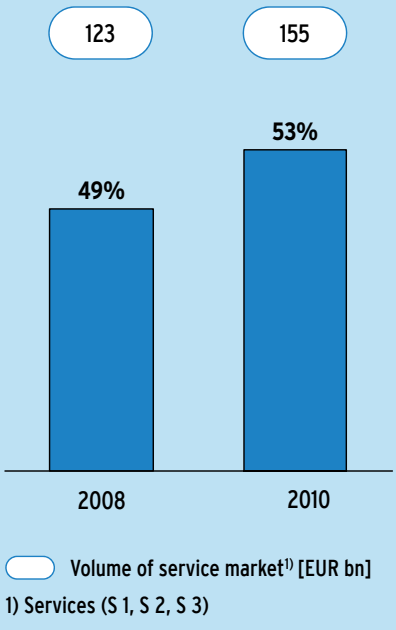
Analysis of services as a share of the individual lead markets for environmental technology and resource efficiency shows that **waste management and recycling** stands out as being **especially service-intensive** (see figure 29). In this lead market, service intensity is high above all in the collection and transportation of waste. The same goes for the renewable energy segment of the lead market for environmentally friendly power generation and storage. Numerous services are linked to the planning and operation of plants to generate power from renewable sources.

Figure 27: Growth in the global market for environmental technology services, 2011-2025 (in EUR billion, average annual change in percent)



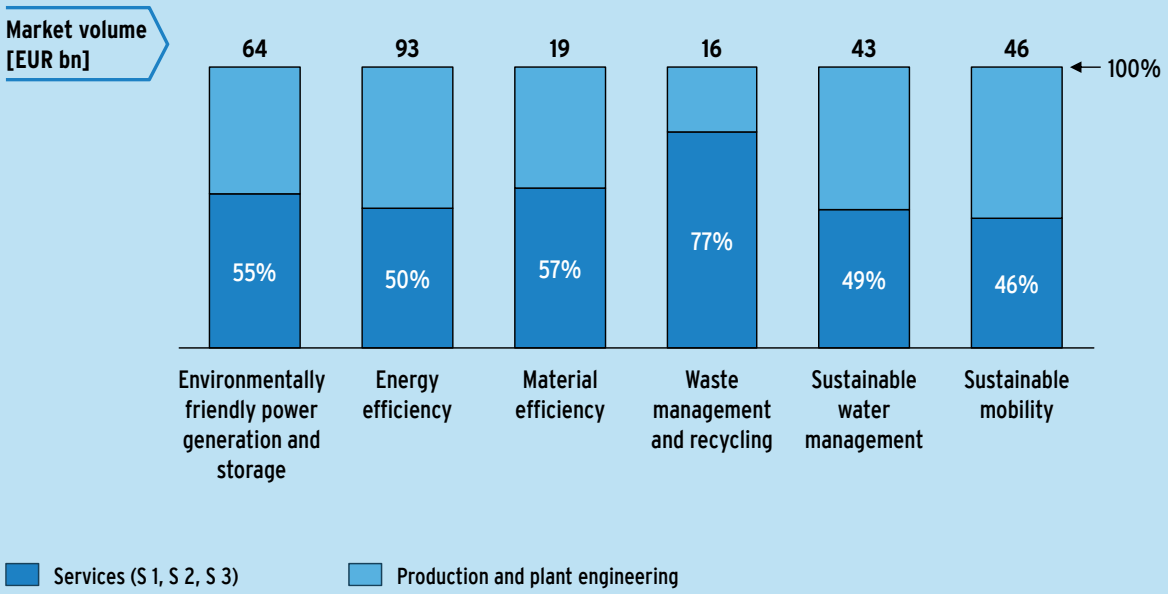
Source: Roland Berger

Figure 28: Services as a share of the market for environmental technology and resource efficiency in Germany since 2008



Source: Roland Berger

Figure 29: Service intensity in the lead markets in Germany in 2010



Source: Roland Berger

The six lead markets for environmental technology and resource efficiency

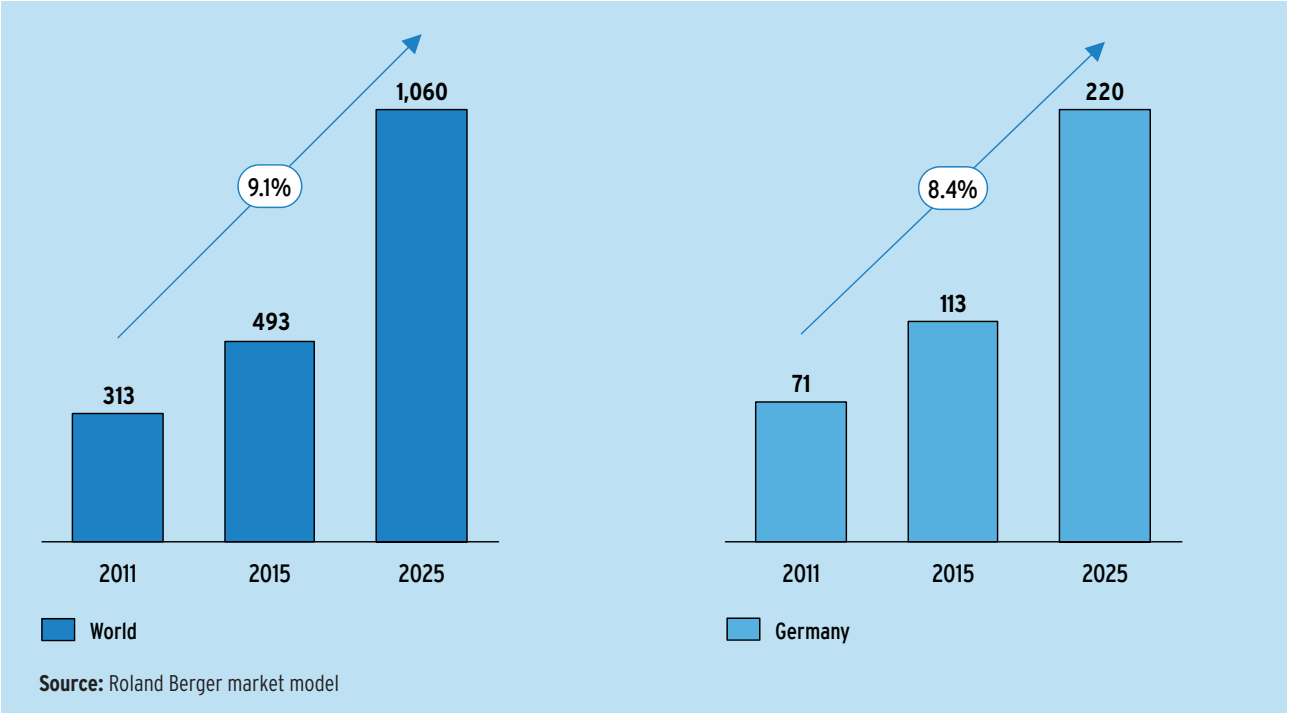
Environmentally friendly power generation and storage

The **energy sector is one of the main sources of environmentally damaging greenhouse gases.** Electricity and heat supply are responsible for around 40 percent of global CO_2 emissions. [1] Accounting for 46 percent of greenhouse gas emissions, the energy sector is also the biggest emitter of CO_2 in Germany; the transportation (16 percent), [2] industrial (13 percent) and household (11 percent) [3] sectors follow at considerable distance.

Given the major share that the energy sector accounts for in CO_2 emissions, one of the biggest challenges in the fight against global warming is to bring about a reduction of greenhouse gas emissions as the demand for energy rises around the globe. This can only be achieved if there is a massive increase in the share of CO_2-free or low-CO_2 sources used in power generation. At the same time we must learn to use fossil fuels in a more environmentally friendly manner given that coal, natural gas and oil will continue to play a major, though declining, role in the global energy mix in the coming decades. The importance of fossil fuels will diminish faster in Germany than it will globally. This is why we need technologies in the short and medium term that can minimize resource consumption and pollutant emissions during the generation of power from fossil fuels. Energy storage is another prerequisite for the decarbonization of the energy sector: storage capacity needs to grow considerably if the share of renewable energies such as photovoltaics and wind power is to increase. That is because the fluctuating feed-in of these renewable energy sources makes it more difficult to achieve the balance between power generation and demand for power required for network stability. Storage technologies will play a more and more important role in network balancing in the coming decades.

These **three areas that are crucial to environmentally friendly energy supply – the expansion of renewable energies, environmentally friendly use of fossil fuels, and energy storage – are the segments that make up the lead market for environmentally friendly power generation and storage**. This lead market is set to see strong growth in Germany and across the globe.

Figure 30: Market forecast for environmentally friendly power generation and storage, 2011, 2015 and 2025 (in EUR billion, average annual change 2011-2025 in percent)



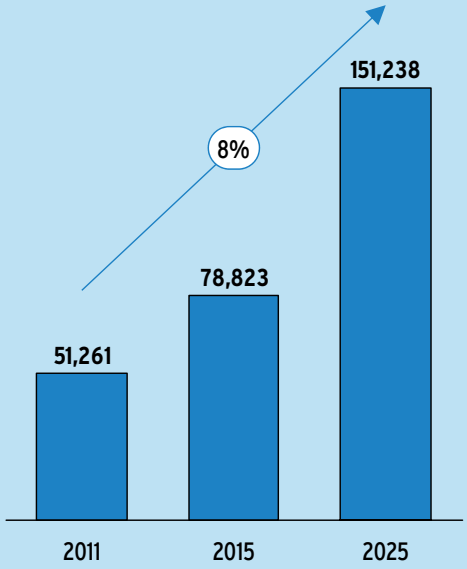
Source: Roland Berger market model

1 See International Energy Agency (2010b), p. 65
2 Actions to reduce greenhouse gas emissions in the transportation sector are examined in detail in the chapter on the lead market for sustainable mobility
3 See Umweltbundesamt (2012)

Renewable energies segment

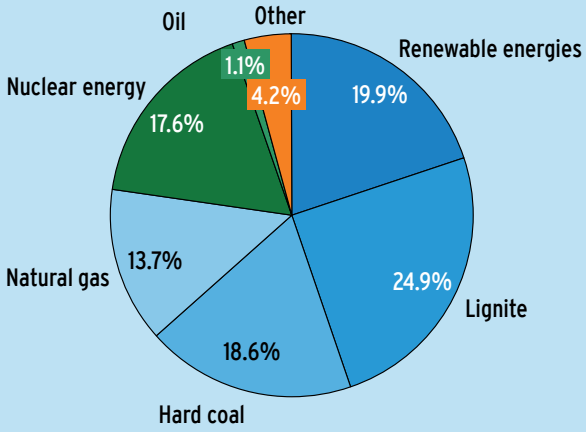
Renewable energy sources like hydropower, wind power, solar power, geothermal energy and biomass offer significant benefits over the fossil fuels coal, oil and natural gas: **renewable energies are environmentally friendly**. These properties make them indispensable for a future-proof energy policy given that they simultaneously address the challenges of **security of supply** and **environmental protection**. They reinforce our independence from imported fossil fuels like oil and natural gas, and generating electricity from renewable energy sources no greenhouse gas emissions. The use of renewable energy sources prevented the emission of 129 million tons of CO_2 equivalent in Germany alone in 2011. [4]

Figure 31: Market forecast for renewable energies, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

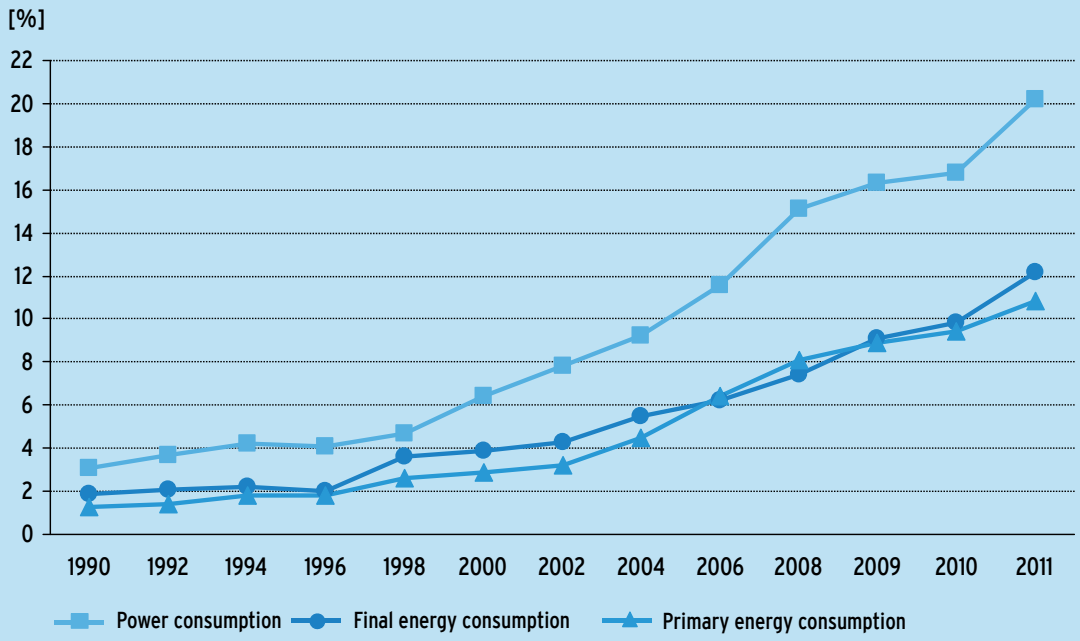
Figure 32: Gross power generation in Germany by fuel 2011



Source: AG Energiebilanzen e.V. (2012), p. 26

4 See Energiewende Aktuell – 2/2012

Figure 33: Renewable energy share in energy supply in Germany



Source: Bundesumweltministerium (2011d)

In the summer of 2011 both chambers of the German parliament passed a resolution on the **"accelerated energy transition"**, which set out the **key points of a fundamental transformation of energy provision in Germany** and sealed the country's **withdrawal from the nuclear energy program**. All of Germany's nuclear power plants will gradually be removed from the grid by the year 2022. Regenerative fuels are expected to largely replace the proportion of the energy mix currently made up by nuclear power (see Figure 32). The intention is also for greater energy efficiency to compensate for the loss of nuclear energy. Thus the **pressure is growing to speed up the expansion of renewable energies**. The Energy Concept 2050 plans for the share of regenerative electricity to reach at least 35 percent by 2020 and to rise steadily to 50 percent by 2030, 65 percent by 2040 and 80 percent by 2050. [5] The federal states' cumulative expansion targets for 2020 are even more ambitious than the 35 percent indicated above.

The lines in Figure 33 below chart a success story without parallel. **Renewable energies** have become a **key technology in Germany**. In 2011 they provided 12.2 percent of Germany's final energy consumption of electricity, heat and fuels. [6] Water, wind, solar, biomass and geothermal sources have increased their share in power generation from 3.1 percent to 17 percent in the space of two decades. [7] Renewables accounted for 20.1 percent of power generation in Germany in 2011. That year, 103.4 terawatt-hours of electricity were produced from regenerative sources in Germany. [8]

Germany has made much faster progress in expanding regenerative energies than other countries have. A major factor in the rise of renewables has been and remains the application of political instruments and government subsidies and grants. The expansion began with the passing of the Act on the Sale of Electricity to the Grid, which entered into force in 1991. For the first time, this law guaranteed that energy utilities would have to give preference to the purchase of electricity generated from regenerative sources and pay producers an amount stipulated by law. This principle was upheld in the Renewable Energy Sources Act that succeeded the Act on the Sale of Electricity to the Grid. The former came into force in 2000 and has since been amended several times.

The strategic promotion policy drove the expansion of renewables not only in power generation but also in the heating sector. The government already substantially bolstered the market incentive program for the

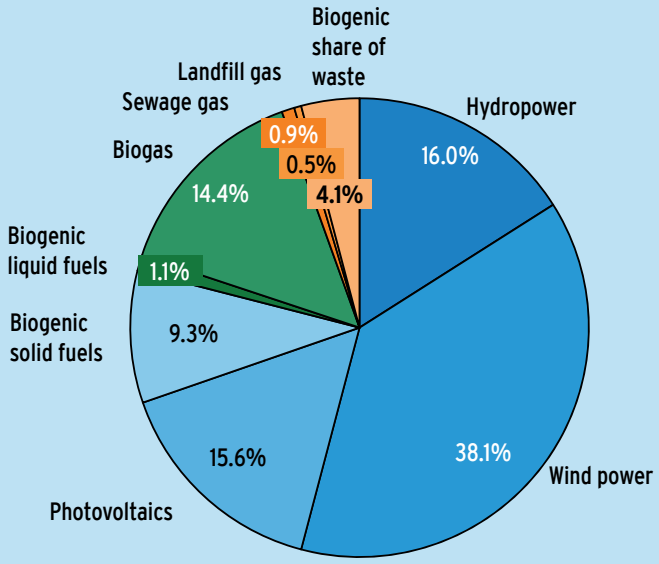
5 See Bundesministerium für Wirtschaft und Technologie/Bundesumweltministerium (2010), p. 5
6 See Energiewende Aktuell – Issue 2/2012
7 The percentages relate to total gross power consumption
8 See Energiewende Aktuell – Issue 2/2012

use of heat from renewable energies in 2000. Currently, 10.4 percent [9] of the heat supplied in Germany comes from renewables, and the aim is to raise the proportion to 14 percent by 2020.

The Renewable Energies Heat Act that came into force at the beginning of 2009 earmarks up to EUR 500 million per year in financial assistance for the generation of heat from renewable sources. The law makes it incumbent upon property developers to use regenerative energies to supply heating and warm water to their new residential and commercial real estate or to invest in improving energy efficiency. Furthermore, the government is using the market incentive program to cut energy consumption and CO_2 emissions in existing buildings: in February 2012, KfW (a government-owned development bank) and the Federal Ministry for the Environment agreed to join forces to support investment in the supply of heating from renewable energies: KfW's "Renewable Energies – Premium" program, itself a part of the Market Incentive Programme, provides support in the form of low-interest KfW loans and repayment bonuses for large plants, mostly commercial in nature: large-scale solar collectors, heat reservoirs, heating networks, biogas treatment plants, biomass plants and deep geothermal energy facilities.

The use of political instruments combined with subsidies and grants has helped turn renewable energies in Germany into a **high-tech industry**, one which emerged from the worst of the economic and financial crisis of 2008/2009 as an engine of growth. In 2010, statistics **recorded some 368,000 jobs in the field of renewable energies in Germany**, around 8 percent more than the previous year. This is more than double the number of people who had been employed in the area in 2004 (160,500 jobs).[10] The trend in investments also underlines the importance of renewable energies as an economic factor: more than EUR 26 billion was invested in plants and systems to make use of renewable energies in 2010, following on from EUR 19.9 billion the year before.[11] And it is apparent that public money directed at expanding renewable energies is being well spent: government support is stimulating investment and helping to keep existing jobs or create new ones. This produces more income from taxes than is distributed in the form of subsidies and grants. The Federal Ministry for the Environment, for example, expects the restrictions that apply and the support that is available under the policy of renewable heating to trigger almost EUR 44 billion in investment in the period through 2020. [12]

Figure 34: Structure of power generation from renewable sources in Germany, 2011: percentage share of individual fuels



Source: Energiewende Aktuell – 2/2012

9 See Energiewende Aktuell – Issue 2/2012
10 See Bundesumweltministerium (2011d), p. 10
11 See ibid.
12 See Umwelt spezial, p. 26

As a result of this successful development, renewable energies are a **key element in the growth industry that is environmental technology**: wind turbines and solar modules embody our emergence into the post-fossil fuel era and play a huge part in shaping the model of the low-carbon economy.

Joining forces to make a stronger impact together is essential for renewable energies. The different properties of these regenerative energies form the ideal complement to each other in the mix of wind power, bioenergy, solar power, hydropower and geothermal energy. While the amount of electricity that can be generated from wind and solar power fluctuates depending on the weather or the time of day, geothermal energy, biomass and water are always available. Renewable energies can be used to produce electricity, heat, fuels and gases (biogas, hydrogen, methane) for use in an enormous range of areas, including industrial applications. The following pages pick out a number of technologies from the spectrum of renewable energies and present them in detail. Figure 34 shows how much the individual fuels contribute to green power production.

Photovoltaics

Rooftops glinting with a bluish tinge have long been a familiar sight, especially in rural areas, and the number of photovoltaic systems being installed on residential buildings and barns is growing all the time. Functioning as miniature power plants, solar cells convert sunlight into electricity. The **photovoltaic market in Germany skyrocketed in 2011**: around 7,500 megawatts of photovoltaic capacity were added that year, resulting in the total installed capacity increasing to 24,800 megawatts – a rise of 43 percent year on year (17,320 megawatts in 2010). The total number of about 1,090,000 photovoltaic systems in Germany generated around 18,500 gigawatt-hours of electricity, equating to 4 percent of Germany's power consumption. [13]

The major rise in the share of photovoltaics in the power generation mix is not least a consequence of the significant improvement in solar cell effectiveness; we have technological innovation to thank for their **increased efficiency**. The conversion efficiency – the ratio of radiated solar energy to usable solar energy – of monocrystalline silicon solar cells grew from around 10 percent in the 1990s to about 17 percent today. Thin film cells [14] achieve conversion efficiencies of between 7.5 percent and 9.5 percent, with 10 percent clearly within reach.

This **efficiency boost** as well as sustained **price pressure from international competitors**, especially those in China, and **economies of scale** from the higher sales volumes have combined to lower the price of photovoltaic systems. The rule of thumb is that each time the global production of energy from this source doubles, the price of photovoltaic systems falls 22 percent.[15] In the fourth quarter of 2011, end customers therefore paid almost 60 percent less for a rooftop photovoltaic system than they had done in 2006.[16] The **downward trend in costs** is set to continue in the years to come.

In a world premiere, Schott Solar demonstrated the potential of photovoltaic cells: the German company produced a monocrystalline screen-printed solar cell in industry-standard 156 x 156 millimeter format with a conversion efficiency of 20.2 percent. What this shows is that the efficiency potential of photovoltaic systems has nowhere near peaked, and it marks a major success in the development of industry-focused manufacturing processes for high-performance solar cells on the part of Schott Solar. [17]

Scientists, on the other hand, are working not only on optimizing existing technologies. They are also pursuing completely different approaches in the **advancement of photovoltaic technology**. Though not yet ready for the market, **Grätzel's DSC cell (dye-sensitized solar cell)** represents a promising approach. It imitates the principle of photosynthesis in plants. The conversion efficiency of the dye-sensitized cells may still be substantially less than that of conventional silicon cells, but DSC offers other advantages, such as its suitability for in-building integration and its low production costs. [18]

No less interesting are the **advances in organic photovoltaics (OPV)**. Organic cells made of synthetic material could lead to substantially lower material and production costs: an organic solar cell could cost as little as one-quarter of the cost of a conventional silicon solar cell. Scientists are currently working intensively on OPV development in ventures like the Indo-German Largecells research project. This international team of scientists includes physicists and

13 See Bundesverband Solarwirtschaft (2012), p. 1
14 In the production of thin film cells, thin layers of photoactive semiconductors are applied to a substrate. See definition in the glossary of Solartechnikberater (2011)
15 See Greenpeace/European Photovoltaic Industry Association (2010), p. 1
16 See Bundesverband Solarwirtschaft (2012), p. 5
17 See Schott AG (2011)
18 See unattributed (2011a)

chemists from the University of Bayreuth. They are working with colleagues from India, the Netherlands and Israel to resolve the shortcomings of organic solar cells. Conversion efficiency is one aspect they want to improve in particular; the useful life of around 18 months is another factor that may restrict the application of OPV. [19]

In spite of their low conversion efficiencies compared with silicon solar cells, Grätzel cells and organic photovoltaics could in some areas represent an attractive alternative to current PV technology, especially in applications where conventional solar cells cannot be used, for instance in construction materials, electronic devices such as cell phones, or textiles.

Another of the photovoltaic innovations for which experts hold out great hopes is tandem cells, given the very high efficiency rates they achieve. Tandem cells are made of different semiconductor materials, giving them the ability to better exploit the solar spectrum. A tandem cell – also known as a multijunction or multispectral cell – made out of amorphous and micro-crystalline silicon can absorb many different wavelengths of sunlight. As a result, used in combination with convex lenses, which focus the incident light at concentrations of up to 500 times, tandem cells can achieve conversion efficiencies in excess of 40 percent.[20]

Solar thermal energy

Solar thermal energy is the conversion of solar power into heat. This heat can be used to **heat buildings** or **generate electricity in solar thermal power plants**. When the technology is used for solar thermal heating, collectors are placed on the roof to accumulate the solar irradiation. An absorber then turns the sunlight into heat, which passes through a heat exchanger and finally heats the water. If the system is sufficiently large, it can also be used to back up a building's central heating system in spring and autumn. There are around 1.66 million solar installations with a collector surface of around 15.3 million square meters in operation in Germany. Their total installed capacity comes to 10.7 gigawatts (therm.). [21]

Whereas the solar cells in photovoltaic systems use sunlight to produce electricity, solar thermal systems **turn sunlight into heat**. Solar thermal power plants use this heat to generate steam, which in turn drives a turbine that produces power (concentrated solar power technology – CSP).

Solar thermal power plants employ trough-shaped mirrors (parabolic trough collectors) that act like enormous magnifying glasses to focus sunlight and direct it to a receiver. Heat-proof thermal oil circulates inside the receiver and is heated to temperatures of up to 400 degrees Celsius. This working fluid transports the energy to a turbine house where steam is generated via a heat exchanger. The steam in turn drives a turbine, which generates electricity.

Solar thermal power plants can **store energy in the form of heat**. This is a big plus that enables them to produce electricity even when sunlight is scarce, such as at night or on very cloudy days. Because the collectors can only efficiently focus direct sunlight, the most suitable locations for large-scale solar thermal power plants are hot regions with plenty of sunshine and almost clear skies situated south of the 40th parallel. California and southern Spain already have their first commercial solar thermal power plants hooked up to the grid.

German companies play a **leading role** in concentrated solar power technology (CSP) worldwide in their capacity as component suppliers, system integrators and project developers. Solarlite GmbH from Mecklenburg-Western Pomerania, for example, has broken new technological ground in Thailand by building the first CSP power plant in Asia. Furthermore, its parabolic trough power plant in Kanchanaburi, with a capacity of five megawatts, is the first solar thermal power plant in the world to use water as the heat-transfer fluid in the receivers and to do without oil as a working medium in real-life operation.

Solar thermal installations are the key technology for realizing the Desertec projects. The name Desertec was coined to reflect the objective of achieving a sustainable supply of energy from the desert. In a bid to drive these plans forward in the EU-MENA region [22] (Europe, North Africa and the Middle East), a number of companies from industry and the financial sector joined together in 2009 to form the Desertec Industrial Initiative. [23] The goal of the industry consortium is to realize the production of power on a large scale in solar thermal plants in the desert regions of MENA

19 See unattributed (2011a)
20 See unattributed (2011b); Photovoltaiklexikon (2010)
21 See Bundesverband Solarwirtschaft (2012), p. 1
22 MENA – Middle East and North Africa
23 Companies involved in the Desertec Industrial Initiative, besides the Desertec Foundation, are ABB, ABENGOA Solar, CeVital, Deutsche Bank, Enel, E.ON, Flagsol, HSH Nordbank, M+W Zander, Munich Re, Nareva, RED Electrica, RWE, Saint-Gobain Solar, SCHOTT Solar, Siemens, Terna and UniCredit (as of 8/2011)

states. The ambitious plan aims to cover the majority of the rising demand for energy in MENA states by 2050. Some 15 percent of the power produced in the desert is transported to Europe through high-voltage DC networks. An estimated EUR 400 billion is being invested in Desertec.

Wind power

By the end of 2011 there were 22,297 wind turbines operating in Germany with an installed capacity of 29,060 megawatts. Of this total, 2,086 megawatts had been added in 2011. [24] **Accounting for 38.1 percent of the power produced in Germany today, wind power is now a key player in the regenerative energy mix.** And it will continue to be a pillar of Germany's energy strategy into the future: the government wants 25 percent of the country's power to be supplied from wind farms by 2025. [25] Offshore wind farms and the repowering of onshore wind turbines will drive the expansion of wind power.

Offshore wind farms

The government's energy strategy envisages 25 gigawatts of installed wind power capacity in the North and Baltic Seas by 2030. [26] The exploitation of wind power at sea scores high with a better power yield: **offshore installations produce about 40 percent more electricity** than onshore locations with good wind conditions. That's because you very rarely get dead calm conditions at sea, and wind speeds are higher than on land.

Yet the higher wind yield comes at a price: building a wind turbine at sea is much more expensive than constructing one on land. Building an offshore wind farm involves transporting the heavy components (rotor blades, tripods, tower segments, nacelles, etc.) out from the mainland to the planned location at sea. The dimensions of the parts – rotor blades can be up to 126 meters in diameter – place considerable demands on maritime logistics. RWE, for example, founded a subsidiary, RWE Offshore Logistics, which has built a base station in Bremerhaven and two installation vessels.

The **restrictions on offshore wind farm construction** are tougher in Germany than in neighboring European countries specifically for conservation reasons. The prescribed distance from the coast is greater, meaning that wind turbines have to be built in deeper waters. This places greater demands on the technology used for the installations and their foundations; the harsh weather conditions and heavy seas make the process of putting it together all the more difficult. Servicing the more distant offshore wind farms is also more complicated than maintaining those closer to the shore.

Germany made its first foray into offshore power in 2009. The country's offshore pilot project, **alpha ventus**, has been feeding power into the grid ever since. The wind farm has twelve turbines and is situated in 30 meters of water some 45 kilometers north of the North Sea island of Borkum. Its 60 megawatts of installed capacity supply the electricity needs of 50,000 households. The consortium that operates the wind farm, DOTI, was formed by the energy companies EWE, E.ON and Vattenfall. [27]

Since then a number of purely commercial offshore wind farms have joined the grid. **Baltic 1** is Germany's first wind farm in the Baltic Sea. Covering an area of seven square kilometers, the rotor blades of 21 wind turbines slice through the air 16 kilometers off the Darss peninsula. The wind farm has an output of 48.3 megawatts and is operated by EnBW. The energy conglomerate plans to build another offshore wind farm off the coast of Rügen: Baltic 2 will have 80 wind turbines, four times as many as Baltic 1, and will produce six times as much power. According to EnBW, their investment in both Baltic Sea projects totals EUR 1.2 billion. [28]

Some 100 kilometers northwest of Borkum, a second offshore wind farm in the German sector of the North Sea went into operation at the end of 2010, known as BARD Offshore 1. The BARD Group's project field currently encompasses 19 wind turbines (as of August 2011); the plan is to expand it gradually to 80 turbines producing a total power output of 400 megawatts. The electricity produced by **BARD Offshore 1** is transported to the mainland through 120 kilometers of DC cable and fed into the high-performance grid. [29]

The waters off Germany are set to see a great many more rotor blades revolving in the future. Twenty-four offshore wind farms have already been granted approval in the North Sea and five in the Baltic Sea (as of August 2011). The total output of all approved wind turbines comes to around 23,800 megawatts.

24 See Bundesverband WindEnergie e.V. (2012)
25 See Bundesumweltministerium (2011b)
26 See Bundesministerium für Wirtschaft und Technologie/Bundesumweltministerium (2010), p. 8
27 See Bundesumweltministerium (2011b)
28 See EnBW (2011)
29 See BARD Group (2010)

Repowering

Even wind turbines require modernization – experts estimate that more than 9,000 turbines in Germany will be over 12 years old in 2012. Technological developments in the area of wind power generation have taken a number of quantum leaps during their lifespan: in the early 1980s the nominal capacity of wind turbines amounted to 50 kilowatts, rising to 300 kilowatts a decade later. Today the biggest turbines in offshore wind farms achieve a nominal capacity of six megawatts. [30]

Repowering means replacing first generation wind turbines with higher-output systems at the cutting edge of technology. The principle is to have **"half the number of installations producing twice the output and three times the energy yield"**. [31]

Modern wind turbines increase the efficiency of wind farms with their **improved energy yield**. The better the wind is exploited, the cheaper the power is to produce. The considerable advances made in recent years in the key components involved in producing wind power – the rotor blades and engine – are what make this possible. Numerous manufacturers are now using a **direct drive** system for the engine, in which the rotor hub and ring generator are directly connected in a single unit. The new generation of wind turbines also offer greater **grid stability** than their predecessors: the **optimized electronic controls** are better at regulating voltage, frequency and output, making it easier to integrate the wind power into the grid. Not only that, modern wind turbines are also quieter and rotate at lower speeds: whereas the rotor blades operated at 40 to 80 revolutions per minute in the 1990s, their speed today is just 10 to 20 rpm. These new, low speeds minimize the amount of shadow flicker. [32]

These plus points offered by modern turbines mean that repowering can make a big difference to raising public acceptance of wind power: more power from fewer turbines gives providers a chance to consolidate wind farms into fewer locations and prevent the feared blighting of the landscape. According to estimates by the Bundesverband WindEnergie e.V., repowering in the coming years will create a market totaling 1,000 megawatts a year. The association anticipates an investment volume of EUR 60 billion in the period up to 2020. [33]

Geothermal energy

Temperatures in the earth's core – a ball of molten iron and nickel – reach 5,000 degrees Celsius. Heat moves out from the earth's core through the earth's mantle and crust and up toward the surface. Known as **geothermal energy**, this energy is stored in the outer layers of the earth's 30-kilometer-thick crust in various forms, including thermal water and hot rock. While these water layers are relatively close to the earth's surface in volcanic areas such as Iceland and New Zealand, aquifers bearing water heated to more than 100 degrees Celsius are found at depths of 1,000 to 3,500 meters in Germany.

ENERGY FROM 3,300 METERS BELOW GROUND

The era of geothermal power generation began for the town of Unterhaching near Munich in February 2009, when the first geothermal power plant in southern Germany went live. With a mean electrical output of 3.6 megawatts electrical, it generated 10.9 million kilowatt-hours of electricity in 2010. But its main purpose is to provide heat; the power plant currently meets around one-quarter of the town's heating needs through 36 kilometers of district heating network with a delivery rate of 46.5 megawatts thermal. Expansion plans are already in place: geothermal energy is set to service 60 percent of Unterhaching's heating requirements in the long term. The town's geothermal plant gets its thermal water, at temperatures of around 122 degrees Celsius, pumped up through the supply well from a depth of about 3,300 meters below the ground. Around 150 liters are pumped up every second. Having reached the surface, the water flows through the overground facility containing the heat exchangers before flowing back down through the injection well when it has cooled. The two wells are about 3.5 kilometers apart; the distance is bridged by a thermal waterway made of glass fiber reinforced plastic.

Source: Geothermie Unterhaching (2011)

30 See Bundesverband WindEnergie e.V. (2010a), p. 3
31 See ibid, p. 8
32 See ibid.
33 See ibid, p. 3

Geothermal energy can be used to heat buildings and generate power. There are two different types: **near-surface geothermal energy** (found at depths of up to 400 meters) and **deep geothermal energy**. Heating with geothermal energy works on the basis of heat pumps, which get heat from the depths of the earth either through borehole heat exchangers or ground heat collectors. The heat pumps bring the heat up to the temperature needed for use in heating systems.

In **geothermal power generation**, hot water is pumped to the surface through a supply well. A heat exchanger transfers the energy into a secondary circuit. This contains a liquid with a low boiling point, for example an ammonia-water mixture, which serves as a working medium and drives a steam turbine (the Kalina process). Cogeneration technology is employed to make the heat produced in this process usable in heating systems. The cooled thermal water is then directed back underground through an injection well to replenish the earth's water reserves.

Another method used to convert geothermal energy into electric energy is **OCR technology (the organic rankine cycle)**. Instead of water, the secondary circuit employs an organic working medium (such as silicone, refrigerants, etc.) that evaporates at low temperatures. OCR technology is also used in biomass power plants and solar thermal installations and is ideal when the temperature of the heat source is not high enough to generate steam to operate a turbine.

Germany has 22 geothermal power plants producing heat and electricity (as of the end of 2010).[34] Geothermal energy's share in the power generation mix in Germany is currently marginal, with an installed capacity of eight megawatts; it supplies five billion kilowatt-hours of heat (2009)[35]. In spite of its minor contribution to the country's power and heat supply, geothermal energy plays an important part in the renewables mix. Geothermal energy is not weather dependent and is always available as a result **– geothermal energy is** therefore **capable of supplying base load power.**

Biomass utilization

Biomass in the energy sector is defined as "organic, non-fossil matter that can be used as a fuel in the power, heat and transportation sector"[36]. This matter can originate from plants, in the form of corn or grain, from animals (slurry) or from biowaste and sewage sludge. **Different types of fuels** can be obtained from biomass. Wood pellets or wood chips are typical examples in the sphere of solid bioenergy. Biofuels[37] transmit energy in liquid form, and biomethane is one of the gaseous bioenergy sources.[38] Combustion is the method used to **convert biomass into bioenergy** that can generate heat and electricity or power vehicles. When burned, biomass releases only as much CO_2 as sustainably produced vegetation takes in during its growth phase. In other words, combustion is considered climate neutral. Having said that, any consideration of the carbon footprint must bear in mind that gases harmful to the climate are emitted during the cultivation, transportation and processing of biomass.

The forestry and agriculture segments are significant suppliers of biomass. Non-food crops are cultivated in almost one-fifth of fields in Germany – some 2.1 million hectares – and most of them are used for the purposes of generating energy (as of 2010).[39] Quite apart from using wood and energy crops, energy can also be produced using **biomass from residues and waste**, such as organic waste, sewage sludge, sewage gas, landfill gas and slurry. Indeed, bioenergy from residues like these promises to play an ever greater role in the future and holds enormous potential. And these sources do not compete with farming for land use, unlike energy crops.

A HARMONIOUS BLEND

The world's first hydrogen hybrid power plant went into operation in Prenzlau, some 100 kilometers north of Berlin, in October 2011. Piloting a new form of power generation, the hybrid power plant built by Enertrag AG brings together hydrogen, wind power and biogas. The mixture scores highly in terms of storage capacity: the hybrid power plant – total investment EUR 21 million – is capable of supplying base load power because the use of hydrogen as a storage medium means that the wind energy is never lost. And the biogas plant can work in all weathers. As a result, the hybrid power plant can continue to supply electricity, heat and fuel even on a calm day.

Source: Enertrag (2011)

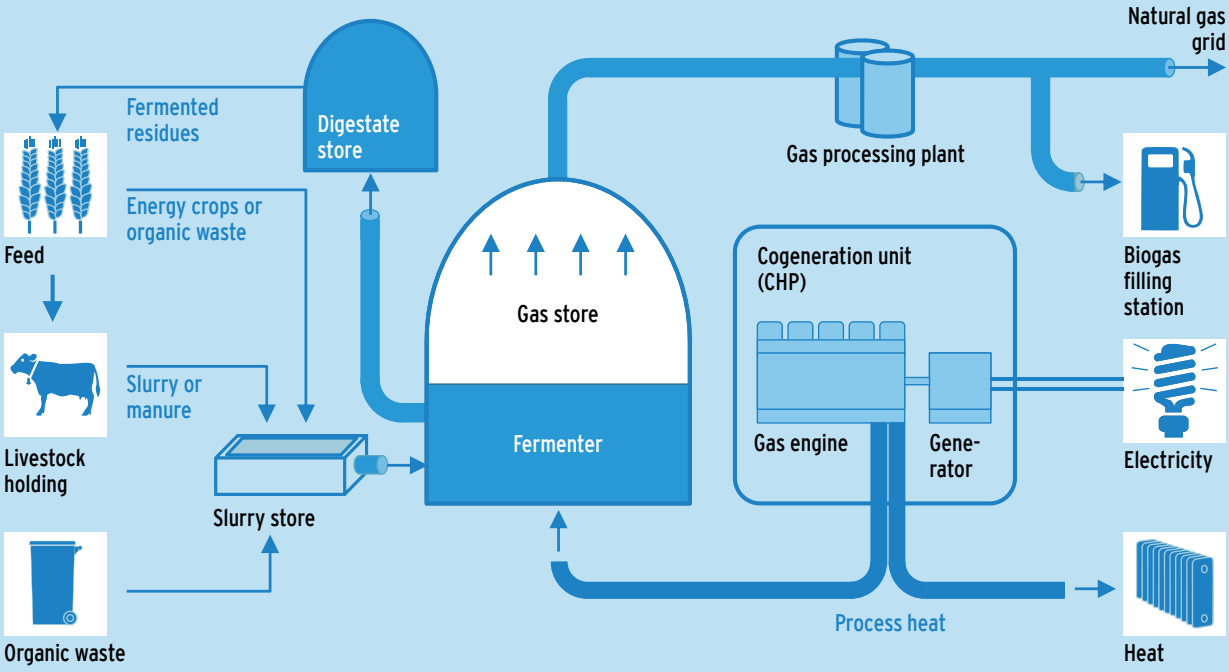
34 As of December 2010; see Bundesverband Geothermie e.V. (2011)
35 See Agentur für Erneuerbare Energien (2011b)
36 Bundesverband BioEnergie e.V. (2011)
37 Biofuels are discussed in detail in the chapter on the lead market for sustainable mobility
38 See Deutsches BiomasseForschungsZentrum (2011)
39 See Fachagentur für nachwachsende Rohstoffe e.V. (2011a)

Biogas plants are an especially important segment in Germany when it comes to energy extracted from biomass: at the end of 2007 there were 3,700 biogas plants in operation in Germany with an electrical output of 1,270 megawatts; by 2010 more than 5,900 biogas plants were producing electricity with a total output of around 2,300 megawatts. Biogas plants currently account for 14.4 percent of the power supplied from regenerative sources, placing them fourth behind wind power, photovoltaics and hydropower. [40, 41]

The first step in the production of biogas involves the delivery and preparation of the substrate to be used. This could be slurry or solid biowaste. The substrate goes into a fermenter (see Figure 35): inside this gas-tight, water-tight and light-proof container, microorganisms set in motion a process of fermentation that eventually produces gas. The resulting digestate is initially stored before being turned into high-grade fertilizer. The better the fermentation, the more biogas is produced and the higher the resulting energy yield is. Some of the gas is turned into thermal or electric energy by a generator. If the biogas is destined to be used as fuel, or to be fed into the natural gas grid, it requires additional treatment.

Biomass was used to produce 33.5 billion kilowatt-hours of electricity in Germany **in 2010**, 10 percent more than the previous year. This gives biomass around a 6 percent share in the power mix. [42] When it came to the production of heat from renewable energies, biomass accounted for 92 percent in 2010. It provided around 127 billion kilowatt-hours of heat in 2010 (10 percent up on 2009). The biggest rises were seen in the production of heat from biomass and the use of wood in private households. [43]

Figure 35: Diagram of a biogas plant



Source: Based on the description at www.bioenergie-portal.de

40 See ibid.
41 See Energiewende Aktuell – 2/2012
42 See ibid.
43 See ibid, p. 9

Hydropower

There is a **long tradition** of people making use of **hydropower**: mill wheels, hammer mills and sawmills were driven by the power of water long before the start of industrialization. Today, hydropower – a mature technology – accounts for 2.3 percent of primary energy consumption across the globe. In some countries, hydropower ranks particularly highly in the power supply mix: hydropower accounts for some 95 percent of domestic power generation in Norway, 84 percent in Brazil and more than 60 percent in Canada. [44]

Hydropower produces 3.2 percent of all of the electricity generated in Germany. Among the regenerative sources of energy, its 16 percent make it the second most heavily used technology in renewable power generation, behind wind power (38 percent) and ahead of photovoltaics (15.6 percent) [45]. There are some 7,400 hydropower plants in operation in Germany, which together generated around 19.5 terawatt-hours of power in 2011. The majority of hydropower plants are located in central and southern Germany alongside major bodies of water. More than 7,000 of Germany's hydropower plants are in the category of **small hydropower plants** with an output of less than 1 megawatt. They produce around 10 percent of the country's hydroelectricity.

The generation of electricity by hydropower is based on the principle that the kinetic and potential energy from a current of water flowing over a turbine wheel can be converted into mechanical rotation energy, which in turn drives a generator. **Run-of-river power plants** use the current of a river or a canal, whereas **storage hydropower plants** make use of the high gradient and the storage capacity of dams and mountain lakes to generate electricity. Quite apart from their quantitative contribution to power generation, hydropower plants play an important role in maintaining grid stability in that they are capable of supplying base load power and pumped storage plants can provide reserve power for peak load operation. [46]

There are plans to improve the exploitation of hydropower potential in Germany in the future through the replacement and modernization of existing plants. A study commissioned by the Federal Ministry for the Environment concludes that the amount of electricity that can be generated with hydropower can be increased by 3.5 terawatt-hours in the long term. By paying providers for hydroelectricity fed into the grid from newly built or modernized plants with an output of up to five megawatts, the Renewable Energy Sources Act is incentivizing the efficient use of hydropower at the cutting edge of technology. One of the key criteria for attracting this government support is, however, that the plants need to consider environmental aspects: any increase in power must be accompanied by an improvement in the water ecology.

The environmentally friendly use of fossil fuels segment

In spite of rapid advances in the expansion of renewable energies, **coal, natural gas and oil** will continue to play an important though declining role in the global energy mix in the coming years. According to forecasts by the International Energy Agency (IEA), these fossil fuels will account for 75 percent of the world's primary energy consumption in 2035. [47] **Technologies that minimize the resources consumed and the pollutants emitted by power generated from fossil fuels** are therefore

44 International Energy Agency (2011c), p. 19
45 See Energiewende Aktuell – 2/2012
46 See the detailed description in the storage technologies market segment
47 See International Energy Agency (2011a), p. 4

absolutely essential in the medium and long term. It is not only fossil fuels that these technologies are relevant for: in the energy system of the future they can also be operated with biomass, biogas and hydrogen or methane from renewable sources.

The **environmentally friendly use of fossil fuels segment** therefore **plays a crucial role in the fight against global warming**. Within this market segment, **efficiency improvements in large-scale power plants** and **combined heat and power generation** are particularly instrumental in mitigating the environmental impact of fossil fuels. Furthermore, this market segment also includes **carbon capture and storage (CCS)** – a technology still in its infancy. When CCS is used to capture the CO_2 emissions from biomass, the net amount of CO_2 in the atmosphere is reduced.

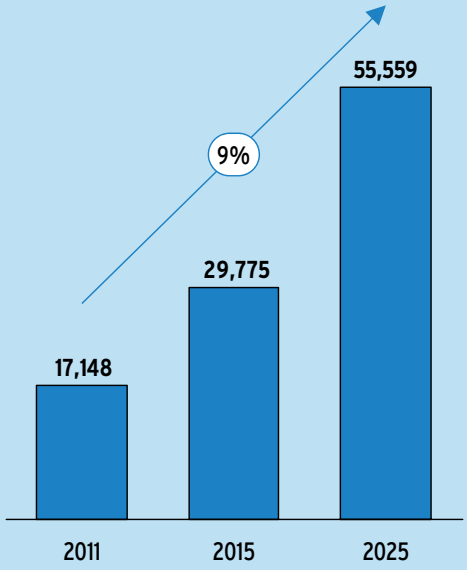
Efficiency improvements in large-scale power plants

Coal-fired power plants

The generation of power from coal is an important area in which climate protection actions are essential in view of the fact that an average of around 1,000 g/kWh [48] of CO_2 is released in the combustion of this energy source. Coal-fired power plants emitted a total of 12.6 billion tons of CO_2 in 2008. [49] The IEA expects **coal to remain the main fuel employed in power generation until 2035**, though its share will shrink from 41 percent (2008) to 32 percent. [50] Many emerging nations will meet their growing demand for energy primarily with electricity generated from coal for the time being. If we are to mitigate the catastrophic effects that this development will have on climate protection, or at least limit the damage, there is an urgent need for technologies that reduce CO_2 emissions from coal-fired power plants. The importance of coal is declining faster in Germany, given that the government's energy strategy stipulates at least 35 percent generation of power from renewable sources in 2020 and at least 50 percent in 2030.

The average conversion efficiency of coal-fired power plants is around 30 percent globally, with Germany achieving efficiency rates of 40 to 50 percent. [51] Emerging nations have especially great potential for improvement on this count. Average efficiency in China, for example, is 23 percent.

Figure 36: Market forecast for environmentally friendly use of fossil fuels, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

48 See co2-emissionen-vergleichen.de (2011)
49 See International Energy Agency (2010b), p. 47
50 See International Energy Agency (2010a), p. 9
51 See Bockhorst, M. (2011a)

WAIGAOQIAO III – PEAK CONVERSION EFFICIENCIES

China meets about 70 percent of its primary energy demand with coal, and the fossil fuel is set to continue to play a leading role in the energy mix of the People's Republic. Around half of the country's carbon dioxide emissions and almost three-quarters of its sulfur dioxide emissions belch out of the chimneys of coal-fired power plants. If it wants to cut emissions, China needs to push the application of clean technologies in the production of electricity from coal. The Waigaoqiao III coal-fired power plant in Shanghai is a good example.

The two 1,000-megawatt block units from Siemens achieve a conversion efficiency of 46 percent – the average efficiency of coal-fired power plants around the world is around 30 percent. The peak conversion efficiencies achieved at Waigaoqiao III are the result of optimized energy utilization based on ultra-supercritical technology: coal heats water into 600-degree steam, which is forced into the turbines at extremely high pressure (as much as 270 bar). According to Siemens Energy, the technology cuts coal consumption at the Waigaoqiao complex by about 1.1 tons per year and reduces CO_2 emissions by some 2.8 million tons.

Source: Siemens (2010b), p. 22

In a bid to **make coal-fired power plants more environmentally friendly**, Siemens and E.ON put a pilot facility into operation at Staudinger Power Station near Hanau, where up to 90 percent of the CO_2 in the flue gas can be separated using the Siemens CO_2 scrubbing process without any serious impact on the plant's efficiency.[52] The CO_2 is separated using an absorber containing metal sieves and a cleaning solution consisting of amino acid salts. The method binds the CO_2 and removes it from the flue gas. The salt is dissolved out at a later stage in the process by means of a chemical reaction, whereupon it can be reused in full.[53]

There are basically two ways of making coal-fired power plants more efficient and therefore more environmentally friendly in the future. The first is by raising the pressure and the temperature in steam turbines, and the second is by optimizing the lignite-drying process. But **integrated gasification combined cycle power plants (IGCC)** hold the promise of greater saving effects. These gas and steam turbine power plants with integrated coal gasification are still in the development stages. Research findings demonstrate that not only can this technology achieve conversion efficiencies in excess of 55 percent, the level of CO_2 emissions falls to 800 g/kWh at the same time.[54] The complexity of the plants makes the required investment very high, however. Scientists are therefore working intensively on developing brand new technologies that can beat the electricity production costs of less than EUR 40 per megawatt-hour that have already been achieved. RWE Power AG plans to build a CO_2-free IGCC power plant in Germany in 2014.

Combined cycle power plants

Gas-fired power plants are **more environmentally friendly** than coal-fired power plants because the combustion of coal results in more than double the amount of CO_2 emissions.[55] Moreover, power plants fueled by natural gas have **higher conversion efficiencies**; rates can be increased still higher when gas and steam turbine technology is combined.

In combined cycle power plants, the main drive system used for power generation is gas turbines. The conversion efficiency of these plants is increased by generating steam with the heat given off by the gas turbines. This then drives a steam turbine, which produces additional electricity. Boasting conversion efficiencies as high as 60 percent, these combined cycle power plants are among the most efficient of all large-scale power plants.[56] By way of comparison, a coal-fired power plant of the latest generation (see text box) can manage a conversion efficiency of 46 percent.

52 See Siemens AG (2011a)
53 See Siemens AG (2011b)
54 See BINE Informationsdienst (2006)
55 See Bund für Umwelt und Naturschutz Deutschland e.V. (BUND) (2011)
56 See BINE Informationsdienst (2010).

Expansion of combined heat and power generation

A large proportion of electricity in Germany is generated in condensing power plants, where thermal energy is converted into electric energy via a steam turbine. The hot steam coming out of the turbine is cooled down and condensed. If the facility is purely a thermal power plant, the waste heat from this process is not used: it is disposed of into rivers or cooling towers instead. The efficiency rating achieved in converting the thermal energy to electricity in that process therefore does not get above 40 to 60 percent. The **principle of combined heat and power generation (CHP)** is much less wasteful of primary energy. In this process, the steam coming out of the turbines is used to supply thermal heat; the waste heat is fed into the local or district heating network.

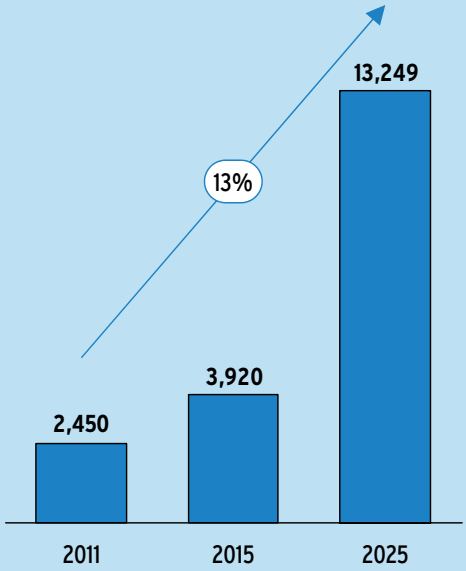
Combined heat and power generation is not limited to fossil fuels like natural gas, fuel oil or coal. The process can even be applied in facilities that operate on biomass, geothermal energy or solar power. There are **CHP plants** in **all different size categories**; their spectrum ranges from plants with an output of several hundred megawatts to those producing just a few kilowatts. [57] The proportion of electric energy produced by CHP plants is set to rise to 25 percent of the power mix in the period 2011 through 2020 according to the objective of the CHP Act [58], enacted to promote the construction and modernization of highly efficient CHP plants. [59]

Carbon capture and storage (CCS)

CO_2 produced during the combustion of fossil fuels is separated from the waste gases, captured and transported by pipeline or ship to a suitable long-term storage location, where it is injected through a borehole. The method is believed to reduce the amount of CO_2 released into the atmosphere. Saline aquifers (porous rock formations filled with saltwater), depleted oil and gas reservoirs and unmineable coal seams are potential storage sites. Demonstration projects have been under way to test CCS technology in Norway since 1996, in Canada since 2000 and in Algeria since 2004. [60]

In September 2008, energy company Vattenfall dedicated the Schwarze Pumpe industrial estate near Cottbus as the first **CCS pilot installation in Germany**. Scheduled to operate for at least five years, the facility is intended to "build bridges between the lab and the field" [61] and pave the way for technical implementation on a large scale. A technology known

Figure 37: Market forecast for storage technologies, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

57 The small CHP plants are known as cogeneration units. Since they are used predominantly in distributed energy supply, they are described in more detail in the chapter *Distributed power supply structure*
58 Law on the maintenance, modernization and expansion of combined heat and power generation
59 See Umweltbundesamt (2011a)
60 See CO_2 GeoNet Europäisches Exzellenznetzwerk (2009), p. 5
61 Vattenfall Europe AG (2011b)

as the oxyfuel method is applied to burn lignite in virtually pure oxygen. Sulfur oxides, fine particulates and other pollutants are then filtered out of the waste gas; the water is condensed out of the waste gas and the CO_2 separated.

Experts from the IEA and other institutions believe that reducing CO_2 on a global scale will be difficult to achieve without CCS, given that a large proportion of the world's rising demand for primary energy will be met by coal in the coming decades. The **European Commission** adopted a **directive on the geological storage of carbon dioxide** in 2009; it describes CCS as a "bridge technology that contributes to the slowing of climate change". [62] According to EU estimates, 160 million tons of CO_2 could be stored in the period through 2030; the resulting mitigation of CO_2 emissions would amount to around 15 percent of the reduction necessary to meet the EU's climate targets.

There is, however, a question mark over whether these forecasts are realistic within the given timeframe: Germany and other EU countries have a **problem with public acceptance of CCS technology**. Another obstacle to market penetration is the profitability factor: installing or retrofitting CCS technology makes a plant 40-75 percent more expensive than a conventional power plant. Moreover, considerable investments are still needed to get CCS technology ready for market. It only makes sense to spend this money if the price of CO_2 emissions rises. According to experts, the application of CCS technology starts to be economically attractive when the price hits EUR 35 to 50 per ton of CO_2. [63] In December 2011, the Carbon Index ("Carbix"), the reference price for emissions certificates on the European Energy Exchange in Leipzig, was EUR 7.75 per ton of CO_2. Emissions rights can currently be bought for just under EUR 13 per ton of CO_2. [64] And trading in CO_2 emissions is not an instrument employed in the USA or the People's Republic of China, which together account for more than 40 percent of global CO_2 emissions. [65]

Storage technologies market segment

Storage technologies will play a pivotal role in Germany's **"energy transition"**. Any rise in the share of green electricity produced will have a major impact on power supply: the production of power from sunlight and wind, the two sources set to account for the majority of regenerative electricity, fluctuates according to the weather and the time of day. And fluctuating feed-in creates a potential gap between electricity supply and demand or excessive electricity supply. Smoothing out these discrepancies and thus ensuring a stable power supply necessitates the upgrading of the electricity grid and the improvement of load management (think smart grid and smart meter), the expansion of highly flexible gas-fired power plants and an increase in storage capacity in Germany and neighboring countries. Germany's total storage capacity currently amounts to seven gigawatts. There is therefore reason to expect very high growth in the storage technologies market segment (average annual growth of 13 percent between 2011 and 2025).

Storage facilities must be able to provide buffer capacity for electric energy during a power surplus and feed it back into the grid when demand is high. The storage capacities concerned are considerable, and they need to be realized in a way that is not only technically feasible but also economically sustainable. **Besides the profitability aspect, keeping energy losses low is one of the key criteria for storage technologies:** the overall efficiency of energy conversion is between 20 and 95 percent, depending on the technology (see Figure 38). Increasing the conversion efficiency is a crucial aspect in the research and development work that is currently ongoing into storage technologies.

The various storage technologies can be categorized by the form in which the electric energy is stored (see Figure 39; the technologies highlighted in blue are presented below). There are three different forms of energy storage: **mechanical, electrochemical and electrical.**

62 Directive 2009/31/EC of the European Parliament and of the Council dated April 23, 2009
63 See Deutsche Bank Research (2011), p. 3
64 As of December 27, 2011
65 See International Energy Agency (2010b), p. 46

Figure 38: Energy conversion efficiencies (in percent)

	Storage	Discharging	Total
Pumped storage hydropower plants	84-88	86-91	72-80
Compressed air energy storage (adiabatic)	77-81	81-86	62-70
Lead batteries	80-88	81-90	65-79
Li-ion batteries			90-95
Redox-flow batteries	84-90	83-89	70-80
Hydrogen, electrolysis, fuel cell	59-66	35-65	21-43

Source: German Trade & Invest (2010c), p. 18

Figure 39: Classification of storage technologies

Classification of storage technologies

Mechanical	Electrochemical	Electrical
Pumped storage hydropower plants	Lead/NiCd/NiMH/Li-ion batteries	Double-layer capacitors
Compressed air energy storage	High-temperature NaS/NaNiCl batteries	Superconducting magnetic energy storage (SMES)
Lift storage power plants	Flow & gas batteries Redox and hybrid flow	
Flywheel mass storage	Hydrogen/regular fuel cell	

Source: German Trade & Invest (2010c), p. 9

Mechanical storage

Pumped storage hydropower plants
Water is not only used for electricity production; it can also be employed **to store energy**, to balance fluctuations in the power grid, and as a last resort in the event of a power station shutdown: pumped storage hydropower plants have the ability to "black start"– to start up within 15 seconds without relying on any external power sources.

Pumped storage hydropower plants basically consist of two water reservoirs with a considerable drop between them. When a power surplus is generated – for instance in strong winds, in times of high photovoltaic power infeed or when demand is low during the night – water is pumped from the lower reservoir to the higher water tank. When power is needed, the water plunges down from the upper reservoir onto the turbines down below, which in turn drive a generator. **Conversion efficiencies** average out at **between 70 and 80 percent** (see Figure 38).

Pumped storage hydropower plants have been built since the end of the 1920s; the first power plant of this type went online in Schluchsee in the southern Black Forest in 1931. Germany has 33 pumped storage hydropower plants in operation with a total pumped storage capacity of 6.6 gigawatts. That is about 95 percent of the capacity provided by large-scale grid-connected electric energy storage plants in Germany.[66] Pumped storage hydropower plants represent the only available facilities for storing electricity on a large scale in the medium term. The problem is that this technical success story offers only limited potential for expansion: a densely populated country like Germany has hardly any space for new reservoirs; and in the few places that could be suitable locations there is frequently a conflict of interest with the concerns of nature conservation.

Compressed air energy storage (CAES)
The basic principle behind compressed air energy storage is that electric energy is used to compress air during the charging process; in other words, the electric energy in the air molecules is converted into kinetic energy. The compressed air is stored in underground caverns. During the discharging process the compressed air is burned with natural gas in a gas turbine combustor. The expansion of the hot flue gases in the gas turbine drives a generator, which produces electric energy.[67] The Huntorf plant (Lower Saxony) commissioned in 1978 is one of only two compressed air energy storage gas turbine power plants in the world. The other is located in McIntosh in the US State of Alabama. The Huntorf peak-load power plant – operated by energy group E.ON – produces compressed air and power alternately: at off-peak times when demand for electricity from the grid is low, the power from base-load power plants is used to pump air into two salt caverns at Huntorf. Situated at depths of 600 and 850 meters, the two cavities hold 300,000 cubic meters. As demand for electricity from the grid rises, air is released from the underground caverns and burned together with natural gas. The combustion air drives a gas turbine that generates electricity at 3,000 revolutions per minute and reaches a capacity of 312 megawatts.[68]

GOLDISTHAL – POWER FOR 350,000 HOUSEHOLDS

The pumped storage hydropower plant at Goldisthal (Thuringia) supplies more than 350,000 households with power. Boasting total capacity of 1,060 megawatts, the installation commisioned by Vattenfall Group in 2003 is one of the largest plants of its kind in Europe. A mountain peak was flattened to form the upper reservoir; it covers 55 hectares and contains 12 cubic kilometers of water. 800-meter pipes span a 302-meter drop to connect the upper reservoir with the underground powerhouse and its four turbines. They use surplus power from lignite power plants to generate power and pump water from the lower reservoir to the upper one. When the demand for power rises during on-peak periods, the water from the reservoir plunges down through the pipes and back into the underground powerhouse. Once there, it drives the four turbines that generate electricity.

Source: Vattenfall Europe AG, (2011a)

66 See Bundesministerium für Wirtschaft und Technologie (2009), p. 13
67 Oertel, D. (2008), p. 31
68 See E.ON Kraftwerke GmbH (2012)

CLEAN GAS FROM WIND POWER

RH2-WKA – This is the acronym of the RH2-Werder/Kessin/Altentreptow demonstration project in which WIND-projekt GmbH is working on integrating a CO_2-free hydrogen storage system in a wind farm. The farm consists of 28 wind turbines with a total installed capacity of 140 megawatts and is capable of supplying the electricity needs of around 100,000 households.

The project – with a total budget of EUR 9.4 million and a term running from 2009 through 2014 – is in receipt of EUR 4.5 million of funding under the National Hydrogen and Fuel Cell Technology Innovation Programme (NIP). The milestone for the first phase of the project is for the hydrogen system to supply the wind farm with electricity from its own production. The hydrogen system has an electrolysis capacity of one megawatt.

Source: WIND-projekt (2011)

The problem with **CAES in relation to electricity** is the (currently) **low conversion efficiency**: 40 percent at Huntorf, 54 percent at McIntosh. A project called ADELE could provide a remedy here. RWE Power, General Electric, Züblin and the German Aerospace Center (DLR) are working together to refine conventional compressed air energy reservoirs. Adiabatic (thermally insulated) compressed air energy stores use the heat that is produced as air is compressed by initially storing the heat in a buffer. When the compressed air is discharged into the turbine, the stored heat brings it up to a high temperature – which can increase the conversion efficiency to as much as 70 percent. Scientists from the DLR plan to demonstrate that the concept works in practice by building a demonstration plant scheduled for commissioning in 2013. The pilot project achieves a storage capacity of one gigawatt-hour and has a power output of 200 megawatts. [69]

Chemical storage

Hydrogen and "clean" gas

Hydrogen is also suitable for use **as a storage medium** (electrochemical storage). Electricity from wind or solar power plants sometimes cannot be integrated into the grid because the power is not always generated at the same time as the demand is received. The "power surplus" can be used to produce hydrogen: water is split into oxygen and hydrogen by a process of electrolysis. The power produced from regenerative sources can be stored long term as "clean" hydrogen in places like the natural gas grid. The gas is then reconverted to meet demand or used for heating purposes. Another area where hydrogen can be used is to power fuel cell vehicles. The reconversion of hydrogen into electricity can be done by conventional gas turbines, combined cycle power plants or CHP plants. Conversion efficiencies are still relatively low, however, at 35 to 40 percent. Higher conversion efficiencies (50 percent) are achieved when hydrogen is converted into electricity in a fuel cell. And if the reaction heat is used, conversion efficiencies as high as 90 percent are possible. [70] The "clean" hydrogen also finds application in industry, where it is used as a process gas, replacing hydrogen produced from natural gas.

The storage concept involving **natural gas from clean power (methane)** entails separating water into hydrogen (H_2) and oxygen by means of electrolysis using surplus power generated from wind energy or photovoltaics. When hydrogen reacts with carbon dioxide it produces methane, making a kind of synthetically produced natural gas. It can be stored in existing gasometers and gas pipes and can be used when required to power cars that run on natural gas, operate gas heating systems and produce power. The big plus point of the concept of **natural gas from clean power** is the amount of storage capacity that already exists: Germany's natural gas grid spanning 400,000 kilometers has a storage capacity of 200 terawatt-hours, much greater than that of the electricity grid (0.4 terawatt-hours).

This storage technology is currently being field tested at a pilot plant in Stuttgart developed by the Zentrum für Sonnenenergie und Wasserstoff-Forschung Baden-Württemberg (ZWS), the Austrian company Solar Fuel Technology and the Fraunhofer IWES. There are plans to commission a second, much larger demonstration plant in 2012 with an output of ten megawatts. [71]

Batteries

The great-grandfather of all batteries was the voltaic pile, invented by the Italian physicist Alessandro Volta in 1800. A **battery** serves **as an energy store and an energy converter**: as it is discharged, a reduction oxidation (redox) reaction converts the chemical energy it stores into electric energy, which is delivered to an attached consumer. There are primary battery

69 See Deutsches Zentrum für Luft- und Raumfahrt (DLR) (2010)
70 See German Trade & Invest (2010c), p. 14
71 See Zentrum für Sonnenenergie und Wasserstoff-Forschung Baden-Württemberg (ZWS) (2010)

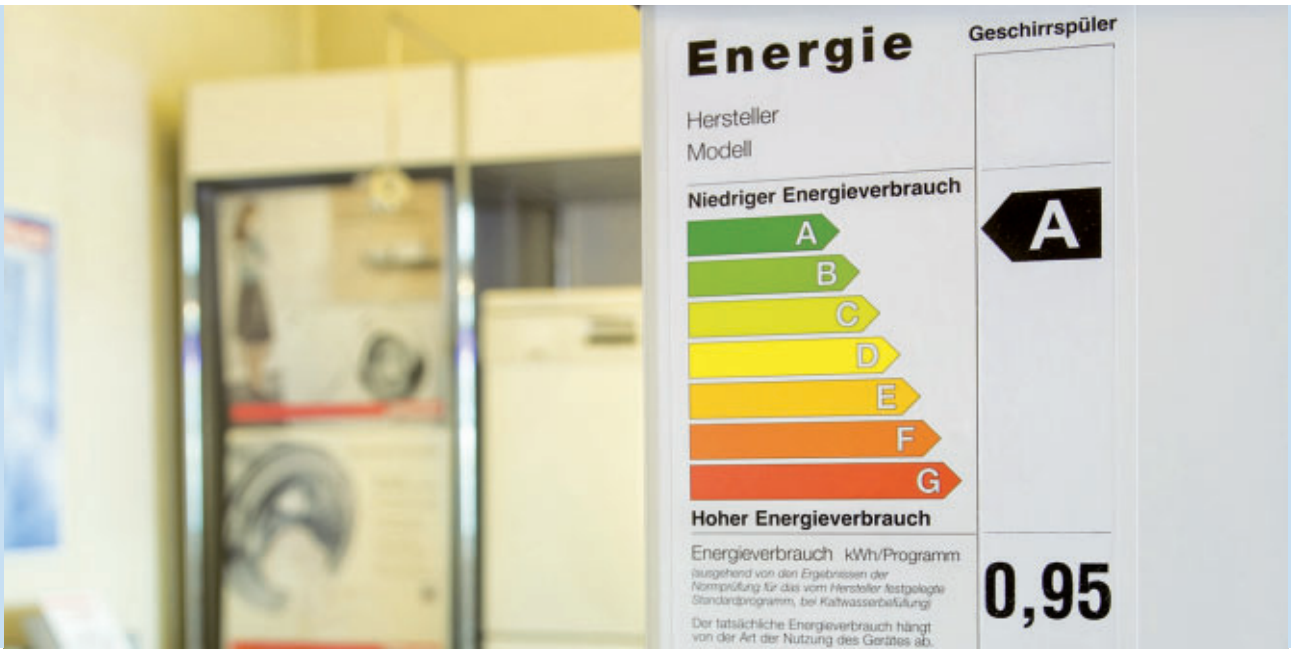
cells, which need to be disposed of when they are flat, and there are secondary battery cells known as accumulators, which are rechargeable. For decades, people have been using batteries on a daily basis in radios, flashlights and other electrical appliances intended for use far away from an electrical outlet. But now battery technology faces challenges of a brand new dimension. What is needed are pay-per-use technical solutions that successfully manage to balance energy supply and demand by storing electricity in the face of fluctuating feed-in of renewable energies.

Most of the battery types available today are not suitable for use as large stationary storage media.[72] But one thing a consortium of three Fraunhofer institutes is working on is the development of redox-flow storage systems. **Redox-flow batteries** get their energy from two liquids (electrolytes) stored in large tanks. The bigger the tanks, the more energy redox-flow batteries can absorb – making them relatively easy to "customize" for different storage capacities. The two tanks are connected by discrete conduit systems and pumps, each with half of a galvanic cell. A thin film separates the two halves and its surface plays host to chemical reactions: when the battery is being "charged" with surplus power, the dissolved salts in the electrolytes change and absorb energy. The reverse chemical reaction takes place when it is discharged, with the stored energy being released.

Scientists from the participating Fraunhofer institutes presented their discovery at Hannover Messe 2011 and demonstrated that their **redox-flow battery works** – though the demonstration plant had an output of just two kilowatts. The researchers plan to use the **vanadium liquid batteries** to construct a battery system the size of a handball court, with a capacity of 20 megawatt-hours that can supply around 2,000 households when the photovoltaic system stops generating power at night. But they still have a long way to go: the Fraunhofer redox-flow lab is set to start up a 20-kilowatt system in 2012. That research team hopes to reach the megawatt threshold in about five years.[73]

72 Battery technologies employed in *Distributed power supply structure* are described in detail in the chapter of that name
73 See Fraunhofer-Gesellschaft (2011)

Energy efficiency



Global demand for energy is set to rise in the coming decades. The **growing demand for oil and gas** as (finite) **fossil fuels** is causing energy prices to escalate. At the same time, CO_2 emissions need to fall if we are to keep global warming below the critical two-degree barrier. This evolution in trends is what predetermines the **challenges facing the energy supply** of the future: **sustainability, environmental compatibility and safety**. Energy policy needs to pursue two pre-eminent goals if it is to master these challenges: **raising the proportion of renewables in the energy mix** and **increasing energy efficiency**.

Increasing energy efficiency means cutting energy consumption as energy intensity declines (see figure 40). Given that more than 80 percent of all greenhouse gas emissions in Germany come from energy consumption, every kilowatt-hour we can save is a contribution toward climate protection. [1] Only by increasing energy efficiency will Germany be able to meet its ambitious climate target of cutting CO_2 emissions by 40 percent (over the 1990 figure) by the year 2020.

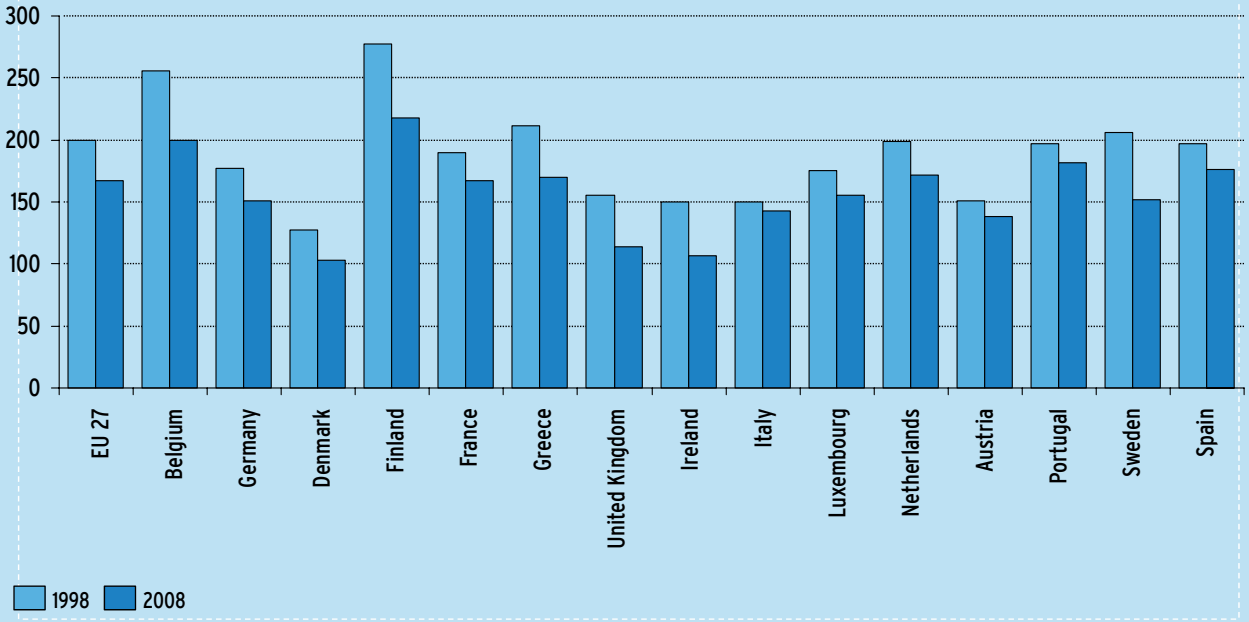
Increasing energy productivity is one of the indicators of sustainable development in environmental accounting. Energy productivity [2] has risen continuously in the last two decades, as shown in figure 41. Between 1990 and 2010, energy productivity rose 38.6 percent. [3] However, this increase in efficiency had very little effect on the trend in primary energy consumption, with the latter falling just 5.7 percent in the same period.

Given this trend, the further improvement of energy efficiency is an important political issue for the German government and the European Union. **The government's energy strategy envisages a 2.1 percent average rise in energy productivity every year through 2050**; primary energy consumption is to be reduced by one-fifth by 2020, and by 2050 the figure shall be just half of what it is today. If all of the cutting-edge actions to improve energy efficiency were taken to the full extent in all consumption sectors, the reduction in the amount of final energy consumed would cut CO_2 emissions by 110 to 113 million tons. [4]

Saving energy is not only good for the environment; it also benefits the economy and the companies and consumers within it: with energy prices high and

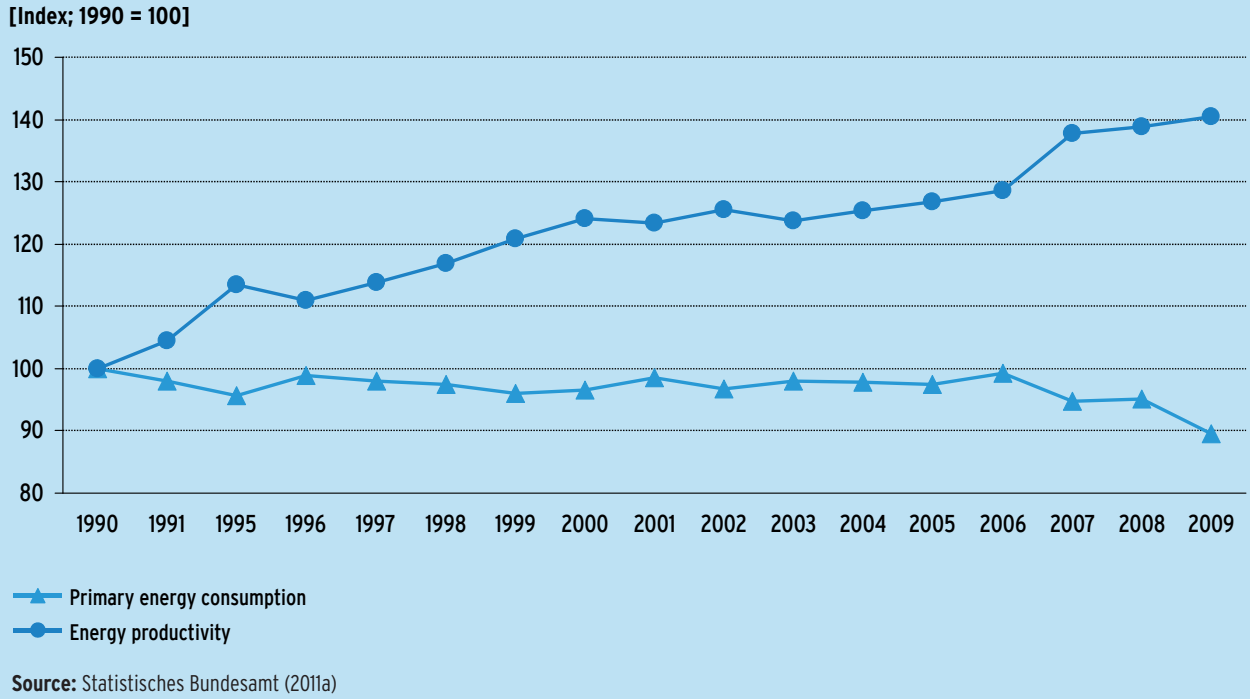
1 See Umweltbundesamt (2011f)
2 Energy productivity is defined as real gross domestic product per unit of primary energy consumption
3 See Statistisches Bundesamt (2011a), p. 4
4 See Bundesumweltministerium/Umweltbundesamt (2012), p. 127

Figure 40: Energy intensity in EU-15 countries 1998 and 2008 (in kgoe/EUR 1,000)



Source: Eurostat

Figure 41: Energy productivity and primary energy consumption in Germany 1990 through 2009



Source: Statistisches Bundesamt (2011a)

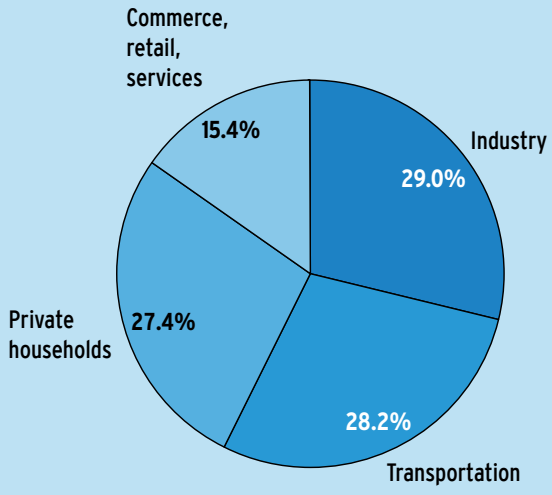
likely to rise even further, **improvements in energy efficiency are necessary to keep costs competitive**. The cheapest energy is and always has been energy that is not consumed in the first place. This lead market describes the levers that need to be applied in order to increase energy efficiency. The market segments are classified according to the biggest energy consumption categories in Germany (see figure 42): industry, transportation, private households and commerce, retail, services.

Actions to increase energy efficiency in transportation are presented in detail in the lead market on sustainable mobility. The "industry" and "commerce, retail, services" categories are each made up of companies; on this basis the **lead market for energy efficiency** has been **classified** into **four market segments**: the market segments concerning **energy-efficient production processes** and **cross-application technologies for industry and commerce** describe only energy-saving approaches for the business world; the **energy-efficient buildings** market segment encompasses both companies and private households as consumer groups. The **energy-efficient appliances** market segment also represents a cross-section, in that it considers applications for both consumers and businesses.

The **energy-efficient production processes market segment focuses on the core processes of "traditional" industries**. The levers that companies can use to counteract the rising cost of energy with optimized processes are the central aspects here. Predominantly energy-efficient production processes in energy-intensive branches of industry are presented in this section, along with some energy-saving approaches for the service sector.

When companies embark on a determined policy of energy-saving measures, they are not only making an important contribution to the protection of the environment and the climate, but also improving their own balance sheet. Cutting energy consumption reduces costs and attenuates the impact of the rise in the price of fossil fuels. Under the energy-efficient production processes market segment, we present the energy-saving measures that companies can take in their core business processes. In the **market segment** concerning **cross-application technologies for industry and commerce** we examine the **saving potential that exists in auxiliary processes**. These include such industry-spanning cross-application technologies as electric drives, compressed air, pumps, heating, refrigeration, etc., which are needed to produce an end product – in other words, these are the things that enable the actual core processes within companies. These auxiliary processes, also known as production subsystems, are instrumental in increasing energy efficiency: the provision of power and heat involves cross-application technologies that account for 65 percent of all final energy consumption from industry in Germany. A study by Fraunhofer ISI found that efficiency actions in these cross-application technologies can achieve energy savings amounting to some 150 PJ by 2020. [5]

Figure 42: Final energy consumption by category



Source: Statistisches Bundesamt

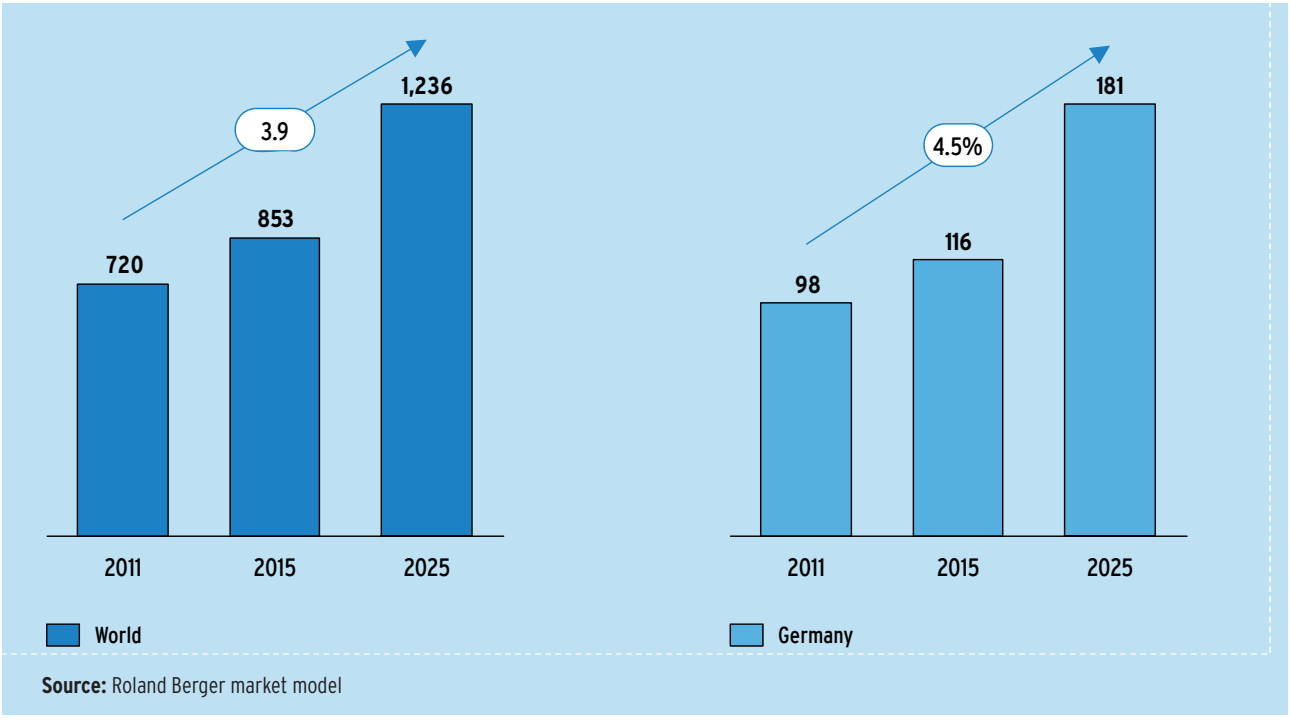
5 See Pehnt, M. et al. (2009), p. 13

The **description of the market segment for energy efficiency in buildings** does away with the misconception that "energy efficiency" is all about saving electricity. In Germany, heating makes up 38 percent of final energy consumption. Heating and hot water account for more than 80 percent of the energy consumption of private households. Buildings and the use of them consume some 40 percent of total final energy and are responsible for one-third of CO_2 emissions in Germany. These figures underline the **importance of energy saving in the building sector** as a lever for realizing the energy transition: the energy footprint of buildings, especially those that have already been built, must be improved dramatically if Germany is to reach its targets for reducing CO_2 emissions and increasing energy efficiency.

The **energy efficiency of appliances market segment highlights** the **opportunities for companies and consumers to save energy in the use of electric appliances**. Whereas "green IT" relates to both consumer categories, the topic of **domestic appliances** is concerned mostly with efficiency technologies for private usage. EU studies indicate that the average household could save between EUR 200 and EUR 1,000 a year by taking all possible energy-efficiency actions within their own four walls.

Against the backdrop of rising global demand for energy and looming price rises in the energy sector, the lead market for energy efficiency will grow by an average of 4.5 percent per year in Germany in the period through 2025, while the average annual growth rate will be 3.9 percent globally (see figure 43).

Figure 43: Market forecast for energy efficiency, 2011, 2015 and 2025 (in EUR billion, average annual change 2011-2025 in percent)



Source: Roland Berger market model

Energy-efficient production processes market segment

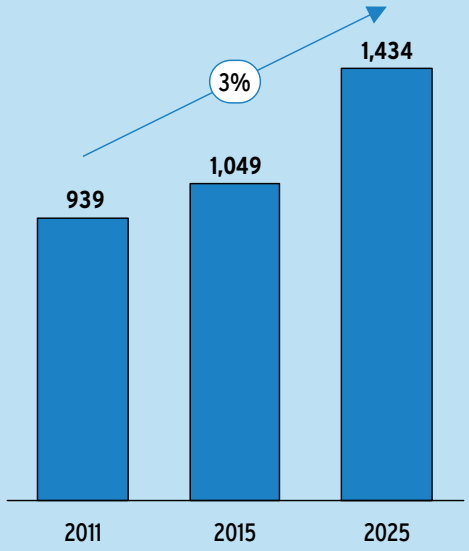
This **market segment is concerned with energy efficiency in the core processes of goods manufacturing and service provision**. The focus is on energy-saving production methods in four energy-intensive industries: paper and cardboard manufacturing, metal production, minerals processing, and basic chemicals. Combined electricity costs in these industries came to EUR 5.8 billion in 2010. [6]
Total energy costs make up a significant portion of these industries' gross product (basic chemicals: 3 percent; paper and cardboard manufacturing 5.7 percent; metal-producing industry: 5.5 percent; minerals processing: 6 percent). Given that the degree of automation is likely to rise in these industry sectors, a further increase in power consumption is anticipated. Furthermore, electricity prices are expected to rise in the coming years.

Companies in these four energy-intensive industries will be compelled to press ahead with energy efficiency actions in their core processes if they are to counteract the negative impact of rising energy costs.

The **hugely energy-intensive process of manufacturing paper and cardboard** indicates that there would be enormous scope for optimizing energy aspects. The energy-saving potential can be found especially in efficient methods of processing raw materials, in optimized stock preparation processes (such as cooking and bleaching) and in improved system control. The first link in the paper production chain is the processing of wood as a raw material. Producing the pulp involves debarking the wood and making chips. Chip making, in particular, requires large amounts of electrical energy. But substituting recycled paper for pulp production helps reduce the demand for energy. Improving the milling process in stock preparation can bring about a 10 percent electricity saving. [7]

The drying section, the last stage of paper production, is where the most energy is consumed. This is where heat is fed in to evaporate the water in the paper. The evaporation rate shows how effective the process is; it indicates the difference in paper moisture before and after drying. Whereas paper contains about 40 to 50 percent moisture before drying, the figure after drying is around 2 to 8 percent. This enormous discrepancy can be reduced by modifying the process step immediately before the drying section, for instance by using new units such as shoe presses in the press section. This type of press works with higher

Figure 44: Market forecast for energy-efficient production processes, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

6 See Roland Berger Strategy Consultants (2011)
7 See Oberschmidt, J. et al. (2007), p. 145

pressure and wider press nips. If the dryness in the press section can be increased by 1 percent, the energy consumed in the drying section will be up to 5 percent lower. [8] Taken as a whole, the potential for improving efficiency in paper and cardboard manufacturing is 16 percent in the period through 2020, rising to 31 percent by 2030. The penetration rate of modern efficiency technologies in this industry is currently around 52 percent. [9]

Efficiency improvements of up to 37 percent can be achieved in the period through 2050 in the **metal-producing industry** by employing efficient casting machines and heating and holding furnaces. As in paper and cardboard manufacturing, the penetration rate of the latest efficiency technologies is around 50 percent. [10]

When **metals are hot rolled**, a layer of scale forms on the surface that needs to be removed by pickling. This stage of the process creates a huge amount of pollution in the waste water. There is now an industrial-scale machine that can handle all four steps of hot rolling, descaling, straightening and pickling in one integrated process. It cuts the extent of scale formation by up to 90 percent, thereby reducing both the length of the pickling process and the amount of pickling solution required. [11]

The Corex/Finex process developed by Siemens for the **production of pig iron** has the advantage of consuming less energy and therefore producing fewer emissions. Whereas conventional blast furnaces require the use of coke and sinter, a Corex plant produces liquid pig iron straight out of coal, lump ore or pellets. Doing away with the coke and sinter plants eliminates two energy-intensive steps in the process. [12]

Not so much optimizing the processes but rather optimizing the design of machines used in the sphere of **basic chemicals** is what creates efficiency improvement potential of 37 percent in the period through 2050. For example, **optimized extraction systems** hold a potential of around 10 percent in the next decade. At 70 percent, the deployment of cutting-edge efficiency technologies is relatively high in comparison with other industries. [13]

Furthermore, the latest **new process technologies** are also capable of cutting CO_2 emissions in basic chemicals. 70 percent of all chemical products worldwide are produced with the use of chlorine or caustic soda. These substances are produced from sodium chloride by means of electrolysis, necessitating large amounts of electric energy. A new process technology – membrane electrolysis – is set to enable these substances to be manufactured in a way that is more energy efficient and therefore produces lower emissions. It can cut the demand for energy by around one-third. [14]

As mentioned above, this market segment for energy-efficient production processes is not only about improving energy efficiency in the core process of goods manufacturing; we also outline **ways of saving energy in the services sector**. After all, "commerce, retail, services" account for some 15 percent of the total consumption of final energy in Germany. Accordingly, the potential for saving energy in this category should on no account be neglected. The following section **picks out two** closely interrelated **industries, logistics and retail**, by way of example.

Logistics accounts for 14 percent of global CO_2 emissions. Then there are the additional burdens on the environment associated with freight distribution, such as particulate emissions, noise and land consumption. Logistics can be divided into four segments: transportation, intralogistics, logistics facilities and planning and strategy. The majority (75 percent) of energy consumption – and therefore the majority of greenhouse gas emissions – occurs during transportation. This sector therefore offers a number of important levers that can be used to make logistics chains more environmentally friendly. These include route optimization, energy-efficient vehicle fleets, switching to environmentally friendly modes of transport, and driver training. Only when actions in these areas have been exhausted will the foreseeable growth in the volume of freight traffic stop leading to an increase in CO_2 emissions. Though greenhouse gas emissions have fallen in other sectors in Germany in the last two decades, CO_2 emissions in the freight transportation sector have risen to 44 million tons. Given that the volume of freight traffic is likely to be 28 percent higher by 2025 (versus 2004), continuing with business as usual will result in a marked increase in CO_2 emissions from logistics. [15]

8 See Arbeitsgemeinschaft Branchenenergiekonzept Papier (2009), p. 49
9 See Roland Berger Strategy Consultants (2011)
10 See ibid.
11 See EnergieAgentur.NRW (2009)
12 See unattributed (2010a)
13 See Roland Berger Strategy Consultants (2011)
14 See Institut der deutschen Wirtschaft Köln e.V. (2011)
15 See Initiative „2° - Deutsche Unternehmer für Klimaschutz" (Hrsg.) (2011), p. 8

Keen to try to reverse this trend, some companies in Germany have looked at their logistics chains from the point of view of energy consumption and CO_2 emissions and set in motion a number of actions. One example is Deutsche Post DHL, whose CO_2 emissions totaled 24.1 million tons in 2009. [16] The logistics group set itself the target of cutting CO_2 emissions by 10 percent in the period 2007 through 2012. The target for 2030 is a 30 percent decrease. Deutsche Post DHL is concentrating on actions in its networks, fleets and buildings in a bid to reduce its CO_2 footprint.

The considerable complexity inherent in DHL networks presents a great deal of potential for cutting fuel consumption. For example, intelligent route planning, intermodal transportation strategies and models for more efficient capacity utilization can avoid route duplication and make better use of existing routes. DHL's own SmartTrucks have already achieved enormous success: employing an innovative communication and information system, they now cover 15 percent less distance during the collection and delivery of express mail in Berlin.

The vehicle fleet operated by Deutsche Post DHL represents another important lever in improving the company's CO_2 footprint. DHL does not restrict itself to investing in new fleets. It also deploys more and more alternative-drive or alternative-fuel vehicles. Between 2008 and 2010 alone, the number of alternative-drive vehicles rose from 544 to 1,121. It also conducts driver training to make employees more aware of environmental aspects in their driving; this resulted in 4.8 million fewer liters of diesel being consumed in 2010 than in 2008.

Energy-efficient logistics is also central to the operations of retail company REWE, which handles in excess of 35 million transportations originating from more than 20 storage facilities. Like Deutsche Post DHL, REWE focuses on route optimization. **Computerized route planning** ensures that trucks are at least 90 percent full as they travel between the depots and supermarkets. In managing the flow of commodities between suppliers and retail, they aim to reduce the number of empty runs and thus avoid unnecessary CO_2 emissions. Added to that, the company employs **fleet renewal and modernization** measures combined with training on economical driving to help cut fuel consumption. [17]

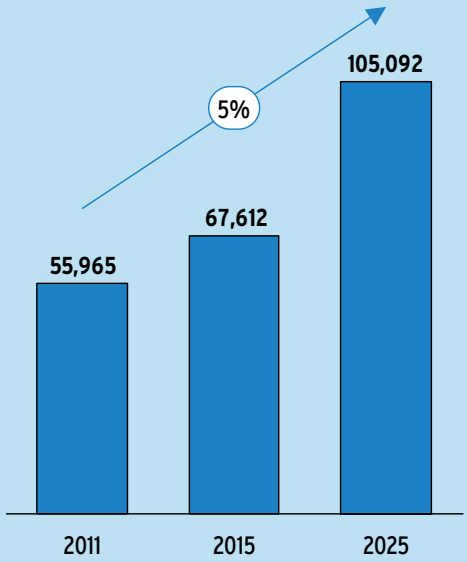
Cross-application technologies for industry and commerce market segment

The **market segment for cross-application technologies for industry and commerce** provides particularly clear evidence that energy-efficient technologies and methods are called for in every branch of industry. Indeed, energy efficiency emphasizes the cross-application nature of environmental technology. This market segment can only be fully understood if we go beyond the close confines of the product-based view. **Product innovations** are not the only means of achieving energy efficiency. **Modifying production processes or individual aspects of them**, for instance after conducting an energy check, can often have a significant effect on energy savings. The sum total of professional advice received and improvements made to components and processes is what leads to optimization of the entire production system.

Electrical drives, compressed air and pump systems, process heat, and heating, cooling and air conditioning are used in many different branches of industry and commerce. These **auxiliary processes involved in the production of goods** harbor **a great deal of potential for increasing energy efficiency**. Consider the following: electrical drives alone, whether for machines, compressors or pumps, consume more than two-thirds of the total electricity demand from German industry. The consistent use

16 This figure relates to the business activities of Deutsche Post DHL and includes the CO2 emissions of subcontractors
17 See Rewe Group (2011)

Figure 45: Market forecast for cross-application technologies for industry and commerce, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

of variable speed control would reduce consumption by 15 percent or 4,000 megawatts, equivalent to the output of three to four large power plants.

Measurement and control instrumentation plays a key role as a technology enabler in the lead market for energy efficiency. True to the motto "You can't manage what you can't measure" it lays the foundations for energy-saving actions by measuring relevant physical parameters like temperature, pressure and voltage. Instrumentation engineers develop and manufacture a wide range of devices and systems for measuring and controlling different parameters and processes. Some of the devices produced include thermal, optical, mechanical and biochemical sensors, whose precise measurements form the basis of numerous applications in environmental technology. **Process control instrumentation** is closely linked to measurement and control instrumentation. As the overarching automatic control system, this is what controls the process steps in production on the basis of sensors and handles production control. Process control instrumentation is to measurement and control instrumentation what software is to hardware.

It is the devices and systems involved in measurement and control instrumentation that make production machinery work more efficiently in all different industries, from chemicals and pharmaceuticals to power plants. If cutting-edge measurement and control instrumentation were employed consistently in Germany, energy savings of up to 25 percent could be achieved. Optimized automation, for example, could significantly cut CO_2 emissions in the manufacturing sector in particular.

The positive effects achieved by employing cutting-edge measurement and control instrumentation would enable substantial CO_2 reductions in **cement manufacturing**, an energy and emissions-intensive industry. The dried and ground raw materials that go into cement (limestone, clay, sand and iron ore) are fired into bricks in rotary kilns heated to 1,450 degrees Celsius. Precise measurement of the oxygen, carbon monoxide, carbon dioxide, nitrogen monoxide and sulfur dioxide is necessary to make this process step as efficient as possible (model-based online optimization). Via a continuous analysis of the content of the above elements, the measuring systems identify reference values for the rotary kiln to ensure that the chemical reactions occur with minimum energy input and produce a high-quality product. More than 200 rotary kilns around the globe already employ this engineering technique, which has cut CO_2 emissions by 20 million tons per year.

Another area in which measurement and control instrumentation is used as cross-application technology is in **identifying leaks in conduit systems.** Here, highly sensitive thermal flow sensors (turndown ratio of up to 1:1,000) help identify leaks at an early stage. Acoustic sensors are also capable of identifying leaks in valves, pumps and compressors because the sensitive measuring instruments can pick up and analyze the sound of leaking gases or liquids.

Electrical drives
Electrical drives are responsible for some 70 percent of power consumption in industry and commerce. More than **90 percent of the total cost of an electric motor results from power consumption**. According to the German Electrical and Electronics Manufacturers' Association (ZVEI), around EUR 5.5 billion could be saved across the board in Germany if companies used more efficient electric motors. The Federal Environment Agency claims that switching to more efficient electrical drives would reduce power consumption by around 27 billion kilowatt-hours, equating to a CO_2 reduction in the order of 16 million tons.

Variable speed controls could make a major contribution here. If just 35 percent of electric motors employed in Germany were fitted with variable speed controls, the savings would amount to EUR 1.2 billion. [18]

There are various ways of raising the **conversion efficiency of electric motors** – defined as the ratio of mechanical output to electrical input. One of them is by minimizing winding losses (larger wire cross-section; improved wire-wrap technique), others include optimizing airflow, using electrical sheet steel with improved magnetic properties and reducing production tolerances. [19]

The installation of frequency inverters for synchronous and asynchronous machines and the precise coordination of components are also among the approaches. Besides improving quality, the latter also ensures optimum machine utilization.

Energy is often lost because dimensions do not correspond to actual needs. Drive systems are not adjusted to actual performance requirements. And people often forget that drive motors can be operated at reduced capacity if production output is lower. In cases where requirements fluctuate, **intelligent control systems** can help optimize this process to avoid wasting energy.

Electrical drives are usually put into efficiency categories depending on their conversion efficiency and power consumption. The standardized, globally applicable IE codes that replaced EFF classifications in 2010 cover almost all three-phase AC motors with an output of between 0.75 and 375 kilowatts. Categories range from IE1 (standard conversion efficiency) to IE4 (super premium conversion efficiency). Though efficient electrical drives in category IE3 – also known as high-efficiency motors – already make up 16 percent of the American market, Germany and Europe lag considerably behind with market shares of just 1 percent. [20]

The environment is not the only thing to benefit from the use of highly efficient electric motors. Companies' balance sheets are also improved: operated for 3,000 hours a year, their acquisition would pay off in two years.

Compressed air systems
Figures from the German Energy Agency (dena) indicate that German industrial and commercial businesses operate some 62,000 compressed air systems. They consume around 14 billion kilowatt-hours of electricity per year. [21] **Compressed air is one of the most expensive carriers of energy**: air needs to be raised to a higher pressure by compressors; the process uses up a great deal of energy, not least because the thermal energy it produces goes unused. For many companies, compressed air is an indispensable aid in the production process; they use compressed air as a transportation medium, for pneumatic applications or as process air.

Given the considerable energy input that goes into producing it, the **use of compressed air** is an area that offers companies **considerable potential for energy saving**. Improving the overall efficiency of compressed air systems can cut energy costs in half in the ideal case scenario. But this potential is rarely exploited to the full: in many cases, conversion efficiencies of around 5 percent are achieved despite 50 percent being possible in theory. [22]

Nevertheless, the greatest energy saving potential can only be realized by **optimizing the compressed air system as a whole** – from generating the compressed air to its processing and distribution and finally its application. This kind of optimization includes installing high-efficiency motors, eliminating leaks (using ultrasound measuring instruments, for example), improving air treatment (such as by employing different drying methods after compression) and improving air flow to minimize friction. Compressor dimensioning is another area of optimization potential lying fallow. Compressors with electric motors boasting high conversion efficiencies are not the only things that can help increase the efficiency of compressed air installations. Systems that reduce transmission losses by better synchronizing the speed of the drive motor and the airend are also very useful.

18 See Bundesumweltministerium (2009a), p. 8
19 See Deutsche Energie-Agentur (Hrsg.) (2010a)
20 See ibid.
21 See Deutsche Energie-Agentur (2011a)
22 See Koll, S. (2011)

Another key method of increasing the efficiency of compressed air systems is to computerize their control with the help of compressed air control solutions.

The Hamburg plant of Greif Germany GmbH presents an example of the energy savings that can be achieved by optimizing compressed air. The international supplier of industrial packaging produces steel barrels at this plant and is therefore reliant upon compressed air. To be able to produce it more efficiently, Greif replaced two components in the system with a speed-controlled rotary screw compressor and a highly efficient refrigerant dryer. A 55-kilowatt base load compressor now replaces the old 75-kilowatt one. Thanks to a heat exchanger, the new compressor can use the waste heat to provide heating and prepare process water. The total energy saving achieved by these actions amounts to 126,000 kilowatt-hours of electricity per year; heating oil consumption has gone down by 8,400 liters. [23]

Pump systems

In their **"Showcasing energy-efficient pump systems in industry and commerce"** project, dena demonstrated the wealth of savings companies can make by **optimizing their pump systems**. Savings ranging between 18 and 90 percent have proved achievable. [24] Steel producer ArcelorMittal in Bremen cut its annual power consumption by 2.5 million kilowatt-hours by improving just one pump system. Neue Torgauer Brauhaus GmbH, which also took part in the showcase project, saw the annual power consumption of its pump systems fall 73 percent (55,400 kilowatt-hours).

Four things are important in optimizing the energy consumption of pump systems: the entire system consisting of the pump and the installation(s) must always be considered, not only the pump and its components. The pipes need to be analyzed, as their length and shape affect power consumption. It is very important to choose the right type of pump in the right size. Using oversized pumps has a significant negative impact on overall efficiency. Energy-efficient motors are an important part of an economical pump system. Pump controls are also a crucial element: in many cases there is a degree of fluctuation in the volumes pumps needs to convey. Yet if they are always working at full blast power is wasted. Installing variable speed control is one way of avoiding this and making sure that the pump's output matches the actual requirements. Power consumption in pump systems can, according to dena, be reduced by 30 percent on average.

Lighting

Lighting makes up about 5 percent of electricity bills in industry and commerce. A large proportion of lighting costs – in some cases as much as 75 percent – can be saved by phasing out old lighting systems and replacing them with **modern lighting concepts**. These include daylight-controlled lighting. Motion detectors and timer switches help ensure that the lights are only on when they are needed in low-traffic parts of a building.

Efficient lamps are a major lever for reducing energy consumption. Energy-saving lamps consume up to 90 percent less electricity than conventional lightbulbs. One innovative example is the T5 fluorescent tube used in combination with an electronic ballast. This new generation of fluorescent lighting uses significantly less energy than a T8 or T12 fluorescent tube with a conventional ballast. T5 fluorescent tubes consume up to 40 percent less electricity, depending on the lamp wattage. [25]

Steel manufacturer ArcelorMittal is one company saving energy by these means. Replacing conventional metal halide lamps, which are very energy- and maintenance-intensive, the company is able to save around 40 percent of the energy it used to consume with lighting – without compromising its lighting levels of 350 lux. Furthermore, it expects to reduce CO_2 emissions by 1,500 tons per year. **T5 lamps** have a lifespan of three years, making them relatively durable compared with conventional metal halide lamps. T5 lamps can have small optimized reflectors fitted inside them, boasting an efficiency rate in excess of 90 percent. [26] In deploying this technology, ArcelorMittal itself becomes a shining light in industry; previously, ceiling heights of around 30 meters in industrial halls had prevented this type of T5 fluorescent lamp from taking off. [27]

Cooling and refrigeration systems

Refrigeration and air conditioning systems account for around 14 percent of energy consumption in Germany. The Research Council for Refrigeration Technology puts the saving potential in air conditioning and refrigeration systems at 32,000 gigawatt-hours per year in Germany. [28]

23 See Freie und Hansestadt Hamburg (Hrsg.) (2008)
24 See Deutsche Energie-Agentur (2011f)
25 See Dienstleistungsgesellschaft der Norddeutschen Wirtschaft mbH (Hrsg.) (2010), p. 45
26 See ABH Elektromontage GmbH (2011a)
27 See ABH Elektromontage GmbH (2011b)
28 See Freie und Hansestadt Hamburg (Hrsg.) (2010)

Cooling and refrigeration systems are used in a range of different applications: they keep offices, factories and warehouses air conditioned and they keep foodstuffs cool (commercial refrigeration). Many companies are dependent upon process cooling in manufacturing and need cooling systems to keep IT equipment and machinery working. Industrial-scale refrigeration systems (from 100 kilowatts to 1.5 megawatts) are used in industry and logistics.

Generating and supplying refrigeration devours huge quantities of energy. Companies would therefore do well to inspect and, where necessary, optimize their refrigeration machines and cooling systems. There are a number of ways to do this. As one of several organizations that have recognized the need, the EU Commission has prepared an extensive benchmark project involving best-practice examples for the retail industry (EU Commission, draft dated June 2011). Basically, a **refrigeration system** should always be **adjusted to meet actual needs**. It is not uncommon for excessive output to send energy consumption levels skyrocketing. When goods are kept in cold-storage warehouses, coolers or cold-storage cells, the insulation of walls, doors and pipes are among the most important energy-saving measures.

One method with major potential to cut energy consumption is **optimizing the systems used for refrigeration**. The main components of such systems are a powered compressor for raising the temperature and pressure, a condenser for heat dissipation, a flow-control element for bringing the temperature and pressure down and evaporators for heat absorption. [29] The individual components and how they work together represent one of the keys to increasing the efficiency of a refrigeration system. The ability to adapt the output to the actual performance required is material. This is an advantage offered by flexibly switchable integrated systems that offer easily controllable compressor capacity. Setting the condensation and evaporation temperature is another major lever for increasing the energy efficiency of refrigeration systems. Controlling the cooling water pumps in a refrigeration system is also instrumental: if their output is precisely aligned to the refrigeration requirements and the resulting quantity of cooling water, the pumps use no more energy than necessary.

Utilizing waste heat is another way to dramatically increase the energy efficiency of refrigeration systems. The law of thermodynamics provides the backdrop here: in order for cooling to occur, heat must be discharged. Heat recovery, which happens when a heat exchanger transfers the thermal energy to another process, enables the reuse of heat as a waste product of the refrigeration process.

The **use of renewable energies in refrigeration** will open up interesting perspectives in the future. Solar cooling is a technology in which solar power from solar collectors is used to operate sorption chillers. Buildings and rooms are cooled by removing water from the ambient air by means of adsorption. The evaporative cooling that results keeps the room temperature down. Supply and demand are perfectly in tune in **solar cooling**: the solar thermal air conditioning system works the hardest when the sun's radiation is at its strongest.

Waste heat recovery and utilization

Process heat is needed in many technological processes and methods in industry and accounts for a considerable share of companies' energy consumption – and makes up a large part of their CO_2 footprint as a result. Energy costs and greenhouse gas emissions can in many cases be cut by optimizing the use of energy in heat supply systems. According to data from dena, the total amount of final energy consumed by thermal processes in industry and commerce in Germany comes to around 400 terawatt-hours. Some 30 terawatt-hours of that can be saved each year. **Waste heat recovery** is a key technology here.

So-called **OCR (organic rankine cycle) systems** specialize in just that: they utilize the waste heat that results from the use of industrial machinery and plant to generate power. Not only do such systems increase the economic efficiency of the installations in doing so, they also reduce CO_2 emissions. At the heart of the technology is the fact that a certain thermodynamic process, in which an organic liquid serves as a working medium, is capable of generating electricity efficiently at low temperatures and low pressures. The technology is often also used in biogas plants and geothermal power plants.

Viessmann Group, manufacturer of heating technology, provides an example of **waste heat recovery in manufacturing** with the optimization of energy use at its Allendorf plant (Hesse). Central heat recovery was instrumental in the company's "Effizienz plus" initiative: first the waste heat from compressed air production, the data center and the test rigs in production and R&D is collected. Then the heat recovery center uses it to pump heat throughout the

29 Definition by Deutsche Energie-Agentur (Hrsg.) (2010b), p. 12

plant. Central heat recovery saves Viessmann around 8.5 megawatt-hours of electricity per year, cutting its CO_2 emissions by 3,000 tons. [30]

Heat recovery can also be **combined with exhaust air purification**, as exemplified by Dürr Group's regenerative oxidation plant, used in the mixing and roasting process for coffee and cocoa beans. This plant is capable of capturing the strong smells and the emissions of solvents and other gaseous substances that result from the process. An inbuilt electric filter then separates the particles and aerosols. The fats contained in the exhaust air can thereby be recovered and the condensate disposed of through the purification plant. [31]

The **use of heat exchangers** is especially worthwhile in energy-intensive sectors like the steel, construction materials or chemicals industries, where high temperatures are involved. This technology can bring the conversion efficiency of the primary energy input up as high as 90 percent. There is huge market potential in Germany particularly for components that are directly required for the utilization of waste heat (heat exchangers and heat pumps).

Energy-efficient buildings market segment

When people speak of energy efficiency, saving electricity is often the first – and sometimes the only – thing they are thinking of. But just one-fifth of final energy consumption in Germany comes from electricity, whereas heat provision accounts for almost 50 percent. [32] From the consumers' perspective, heating and hot water supply carry even more weight: bringing rooms and water up to a comfortable temperature is responsible for 83 percent of private households' energy consumption. The **average heating requirement for residential buildings in Germany is 160 kWh/m²a**, which means that an average of 160 kilowatt-hours of energy from electricity, gas and oil is consumed each year to heat one square meter of living space.

The government's energy strategy has the declared goal of making **existing buildings almost carbon neutral by 2050**. This entails drastically cutting buildings' energy consumption – the aim is to reduce primary energy demand by 80 percent – and having the remaining requirements covered by regenerative energies. [33]

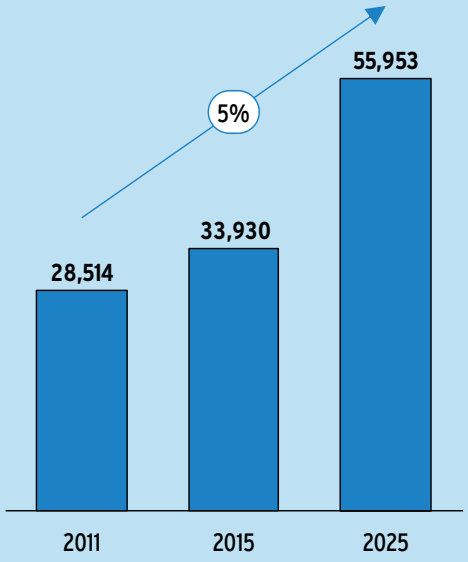
There are **four basic levers** for increasing the **energy efficiency of buildings**. First, we need to avoid losing more energy than necessary through the **building envelope**. The way to do this is by insulating the walls and installing high-tech windows that do not form a thermal bridge. Second, **building services** need to be at the cutting edge of technology: modern heating, air conditioning and ventilation systems are now much more efficient than they used to be. Third, the **operating phase** is crucial: even the smartest technology in the heating system will not help if the window above the radiator is open. Besides educating consumers, **building automation** has an important role to play here. And fourth, **lighting** is of great importance in the mix of energy-saving concepts in the building sector.

Insulation and windows

An average house loses 70 percent of its heat due to poor insulation of the external walls and roof. That's why it is important to remember that the more impermeable the envelope, the better. The outer walls of passive houses (also known as ultra-low energy houses), for example, are insulated to a depth of between 25 and 40 centimeters.

30 See Viessmann (2011)
31 See Dürr AG (2011)
32 See Umweltbundesamt (2011f)
33 See Bundesministerium für Wirtschaft und Technologie/Bundesumweltministerium (2010), p. 22

Figure 46: Market forecast for energy-efficient buildings, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

To date it is mostly mineral substances (including expanded clay, mineral rock wool or foam glass) and polymer-based materials like Styrofoam that find application here. But **renewable resources** are currently penetrating the market to an increasing degree in forms such as cellulose, sheep's wool, wood-fiber insulating materials and flax. The latter has some of the best thermal properties of any environmentally friendly insulation material, boasting a thermal conductivity of 0.04 W/mK. [34] Thinner materials with even lower heat transfer coefficients will be at the forefront of future research and development activities. Innovative systems like **vacuum insulated panels** can be relevant solutions here. Though this technology is already on the market, it is still relatively expensive compared with other insulation materials.

Effective insulation alone is not enough, however. Thermal bridges to the outside also need to be broken. What is needed are **energy-efficient frames and glazing**. Depending on the coatings applied, the spacing between the panes and the gas used to fill the space, triple glazing can achieve U-values in the range of 0.4 to 0.7 W/(m²K). A comparison with the 1970s shows just how well these windows insulate: the U-value of windows back then was 5.8. One thing about multi-glazed windows is that they are fairly heavy; the triple and quadruple-glazed windows of the future are set to be lighter.

Admittedly, glazing can only unfold its full potential in combination with a suitable window frame. The insulated window frames currently in use today have conversion efficiencies of 0.6 to 0.8 W/(m²K), leaving plenty of room for improvement.

Heating, ventilation, air conditioning (building services)

Almost one in four of the 18 million heat-generating plants in Germany is not at the cutting edge of technology. [35] By the end of this decade, ten million boilers will require modernization. If they were replaced by more efficient technology, a 70 million ton reduction in CO2 emissions would result. **There are many different variants that can be used for the energy-efficient and environmentally friendly heating of buildings**: the range extends from condensing oil and gas boilers, cogeneration plants and wood pellet boilers to solar thermal collectors and heat pumps. There is an emerging **tendency to combine different heating systems** in heat-generating plants, for instance using solar thermal energy to back up a gas or oil-fired heating system. It is also possible to combine a heat pump with fossil fuel heating; and solar thermal energy can cut electricity consumption in a heat pump system.

34 Especially good insulating materials have a low thermal conductivity (λ, lambda value) of no more than 0.035W/(m²K)
35 As of 2010; see unattributed (2010b)

Among the heating systems powered by fossil fuels, condensing oil and gas boilers lead the pack in terms of efficiency. **Condensing boilers** make use of the energy contained in the waste gas produced during combustion. This energy is channeled back through the heating circuit. It makes the energy yield of condensing boilers about 10 percent higher than that of low-temperature boilers. A significant role in efficient heating technologies also falls to **cogeneration plants**, which operate on the **principle of combined heat and power generation** to recycle the thermal energy produced during electricity generation to provide heating and hot water. [36]

Wood, the power of the sun and geothermal energy can also be used to heat buildings to comfortable temperatures. The **use of renewable energies to provide heat** not only cuts CO_2 emissions, it is also easy on the budgets of building owners and tenants: heating their properties on the basis of regenerative sources shields them from the rising price of heating oil and natural gas.

Heating with wood is almost carbon neutral; burning wood releases only as much CO_2 as the tree absorbed. Wood pellet systems convey the pellets automatically to the combustion chamber.

Solar thermal collectors make it possible to generate heat from the power of the sun. Such systems can cover all of a building's hot water needs. [37] On their own, however, they would be unable to heat a house subjected to the kind of temperatures Germany experiences in the winter. But they can support a heating system and reduce the need for other fuels by almost one-third.

A **heat pump** could be described as little more than a fridge operating in reverse. A fridge removes heat from an object and then emits the heat. A heat pump works on the same principle, drawing the thermal energy it needs for heating from the ambient air, exhaust air, the earth or groundwater. Heat pumps have an inbuilt compressor that can be operated with electricity or gas to bring the heat up to the required temperature. Heat pumps are real **multitaskers**: not only can they provide heat, they can also be used for refrigeration, air conditioning and dehumidification purposes.

Cooling rooms with air conditioning systems is really just like heating them, only the flow of heat is reversed. A heat pump can therefore become an air conditioning system in summer by drawing thermal energy out of the ambient air. The **demand for air conditioning systems has picked up greatly** in Germany in recent years. This tendency is likely to be sustained given that our part of the world is liable to see more hot spells as climate change continues. Then there is the side-effect of improved insulation: well insulated buildings release less heat at night, meaning that they barely cool down at all, even in the cooler night-time temperatures. This can mean that many buildings need to be cooled mechanically even when the outdoor temperature is 26 degrees Celsius. [38] In view of the looming growth in demand, it is becoming increasingly important **for air conditioning systems to be operated on environmentally friendly and energy-efficient principles**. It has to be said that the energy efficiency of air conditioning systems has already improved dramatically in recent years. Making use of the ambient air is a method that consumes few resources. The cool night air is used as a cooling source on the basis of day/night storage. Cooling ducts in the floor and ceiling emit the cool air that was stored at night.

Ventilation is closely related to room cooling. Ventilating a room means replacing the air in the room with air from outside to maintain the air quality indoors. The traditional and simplest method of doing so is to ventilate naturally by opening a window. However, if it is cool outdoors this obviously releases large amounts of heat into the garden or the street. An alternative is to use **fresh air and exhaust air systems with heat recovery**, which draw fresh air from outside into the house. The air flow passes through a heat exchanger, which transmits the heat from the exhaust air to the cooler fresh air coming in. Compared with ventilating conventionally by opening a window, causing a heat loss of some 50 kWh/(m²a), the heat lost in using an exhaust air heat recovery system is less than 5 kWh/(m²a). [39]

Hybrid ventilation concepts promise high levels of energy efficiency. These methods combine mechanical and natural ventilation. Mechanical ventilation is used to cope with extreme winter or summer temperatures, while natural ventilation is used in the temperate spring and autumn months.

36 See a more detailed description in the *Distributed power supply structure* chapter
37 See a more detailed description in the lead market for environmentally friendly energies and energy storage
38 See Bauer, M./Mösle, P. (2010), p. 117
39 See Deutsche Energie-Agentur (2011b)

Building automation

Almost one-third of energy demand incurred in the use of buildings can be cut by employing **innovative building automation**.[40] The heating, ventilation and air conditioning system can be controlled centrally, along with the lights, blinds and other systems. Linking all of these systems together is not only more convenient for a building's residents and users, it also saves energy. For instance, the heating would switch off during the day as soon as the sun's rays were strong enough to bring the room up to a pleasant temperature. If the heat of the sun became too intense, blinds would automatically block unwanted heat out of the room.

Building automation also helps identify leaks in any of the systems at an early stage on the basis of fault reports. Furthermore, displaying consumption data can make consumers more aware of their own energy consumption.[41]

Lighting

LEDs and their new sister technology, OLEDs, are a way for lighting to help make the building sector more sustainable through lower energy consumption, fewer CO_2 emissions and longer lifespans.

With continuous **improvements in color stability and luminous efficacy** achieved in recent years, the LED (light emitting diode) has long since become a technological mainstay of projects large and small. This method of lighting was used, for instance, in the renovation of the entrance area to the subway station at Munich's Karlsplatz and the "Stachus Passagen" underground shopping center there, where a total of 65,000 LEDs have been installed to create pleasant lighting conditions.

Yet there is still more scope for **optimizing LEDs**: just recently an LED capable of matching a 75 watt incandescent bulb without limitation was presented. Not only does it reduce energy consumption by more than 80 percent, is also has a lifespan of 30 years. And its 340° angle of radiation makes it special from a design perspective. As a result, the technology will represent an attractive option for use in areas other than dimmable and directional lighting without UV and heat radiation.[42]

An equally promising energy-saving lamp of the future is the **OLED (organic light emitting diode)**, which consists of organic semiconducting materials. Whereas LEDs create points of light, OLED panels generate an illuminated surface. The luminescent layer of an OLED is just 400 nanometers "thick", one hundredth of the diameter of a human hair. This extreme thinness means that these lamps open up brand new room-lighting possibilities, including luminous wallpaper.[43] The only company with facilities to produce OLEDs and LEDs in Europe, Osram, has already set a record of 87 lm/W in OLED prototype tests[44] – this is about the same output as fluorescent lamps[45]. The first pilot production plant for this technology in Germany has now been put into operation in Regensburg.[46]

PASSIVE HIGH-RISE BUILDING IN FREIBURG

As part of the modernization of the Weingarten West quarter of Freiburg, a 16-story high-rise building demonstrates that passive house standards can be met even in renovating an existing building from the 1960s. A wide range of innovative technologies were applied in this demonstration building. They included the use of new aerogel-based insulation materials with minimal heat conductivity (lambda = 0.013 W/m²K), the lowering of system temperatures for the heating, and an elaborate ventilation system. The latter consists of a central ventilation unit with heat recovery, high-efficiency ventilators and two-stage control of the ventilation system with thermal actuator. These measures reduced the high-rise building's heat requirement to 35.7 kWh/(m²a).

Source: BINE Informationsdienst (2011)

40 See Siemens AG (2011c)
41 See the *Distributed power supply structure* chapter for more details
42 See Sonepar Deutschland GmbH (2011)
43 See Osram (2011a)
44 The efficiency of a light source is measured in lumens per watt (lm/W)
45 See Osram (2011b)
46 See Osram (2011c)

New dimensions in energy efficiency

The sections above presented the various levers that can be applied to increase the energy efficiency of buildings significantly. Taken together, these measures mean that houses can now be built in efficiency categories that would have been wishful thinking a few years ago. Below we describe the **implementation of energy standards in practice** and highlight areas with room for improvement. Though the political instruments of the Energy Saving Ordinance and the Renewable Energies Heat Act have put a stop to energy waste in newbuilds, urgent action is required when it comes to energy efficiency in existing buildings. According to the German Energy Agency (dena), energy demand in existing buildings is three times as high as in newbuilds. The **energy-related renovation of existing buildings** can help here by reducing the buildings' need for heating and cooling by as much as 80 percent.

The minimum energy standards for newbuilds are defined in the Energy Saving Ordinance (EnEV): this ordinance, last amended in the autumn of 2009, defines the annual primary energy demand for heating, ventilation and hot water, expressed as a value per square meter, as the parameter to be applied when measuring the energy efficiency of buildings. The Energy Saving Ordinance is scheduled to be tightened in 2012 in a move that will raise the required standard of energy efficiency in the building sector by a further 30 percent.

Energy-efficient buildings can be categorized into different groups depending on their energy consumption: **low-energy houses, passive houses, zero-energy houses and energy-plus houses**.

Low-energy houses [47] are all buildings that meet the standards for newbuilds under the Energy Saving Ordinance. The **heating requirement must not exceed 70 kWh/m²a**. Excellent insulation is therefore essential for low-energy houses to prevent heat from escaping through windows, walls, floor or roof. This reduces their need for heating, with the result that a low-energy house has less than 55 percent of the average energy demand of a German home. Low-energy houses are heated by very effective heating systems, often powered by biomass (wood pellets), geothermal energy or solar thermal energy.

In the **passive house concept**, the heat loss through the building envelope is reduced to such an extent that the **energy required to heat the building is just 15 kWh/(m²a)**, one-quarter of what is needed by a KfW Efficiency House 100. The primary energy demand of a passive house is less than 120 kWh/(m²a), including hot water and domestic electricity. The passive house is so named because passive sources of heat are used to warm the building, such as solar power and heat recovery. Only on freezing cold winter days does a passive house need additional heating. The extremely low energy demand of a passive house is achieved by a number of different measures. These include excellent exterior insulation (heat conductivity coefficient of less than 0.15 W/(m²K)), special glazing (usually triple) with a heat conductivity coefficient below 0.80 W/(m²K) and ventilation with heat recovery. The Freiburg example demonstrates that the passive house standard can be achieved in all kinds of buildings, not just detached houses, and even in renovations (see box).

A **zero-energy house** beats even the economy of a passive house. The name says it all – the demand for energy in these buildings is virtually zero. This means that **no external sources of energy** are present in the **annual energy footprint of this type of house**. A zero-energy house covers its entire energy need independently, for instance with the use of solar power. The energy needed to build a zero-energy house is "amortized" – after several years, the energy saved is equal to the energy used to construct the building, giving the house a positive energy footprint over its entire lifespan. The **concept of an energy-plus house** goes one step further. This kind of house is capable of generating more energy than it actually needs – mostly with solar power – and it feeds the excess into the national grid.

47 KfW Efficiency House 100

ZERO-ENERGY TOWN ON FORMER MILITARY LAND

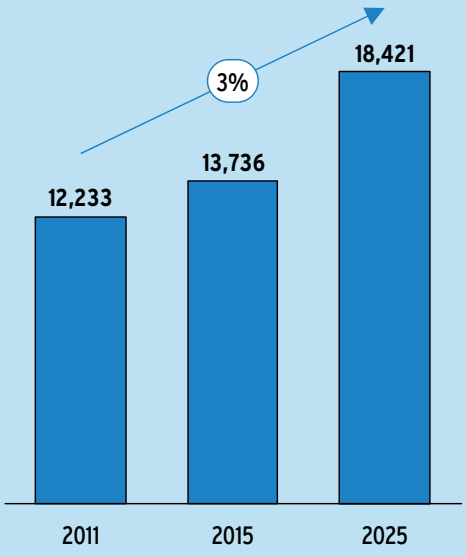
In the town of Bad Aibling in Upper Bavaria, a zero-energy town is being built on land formerly owned by the US Army. The project, subsidized by the EnEff:Stadt research initiative, involves redesigning the former apartments, recreation and leisure building, workshops and the army's school and hospital complex – a total of 72,000 square meters of floor space in 52 building complexes – to produce a sustainable quarter with a CO_2-free, distributed energy supply. B&O Group, which purchased the vacant land once the US Army had moved out, bases its energy concept on a mixture of biomass, solar thermal energy and photovoltaics combined with improved energy efficiency. The newbuild projects on the 134-hectare site in the town's Mietraching district include low-energy wooden houses: the foundation stone for an eight-story wooden building was laid in the summer of 2011. When completed, it will be one of the tallest timber constructions in Europe.

Source: B&O Stammhaus GmbH & Co. KG (2011)

The energy-efficient appliances market segment

Like the market segment for energy-efficient buildings, the **energy-efficient appliances** market segment has two main groups of consumers: companies and private households. For those in commerce and industry, **information and communication technology (ICT)** is now indispensable to business. But for individuals, too, the PC, laptop and smartphone have become a fixed part of their lives. Unfortunately, the ubiquitous nature of ICT also has a drawback, namely a constant rise in the demand for energy. Trying to arrest this trend is one of the key challenges in the context of energy efficiency, which is why the topic of **green IT** is presented here in detail. **Domestic appliances** make up the second focus of this market segment. The **energy efficiency of white goods and consumer electronics in private households** presents considerable potential for saving energy overall and can therefore make a major contribution to reducing energy consumption.

Figure 47: Market forecast for energy-efficient appliances, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

Green IT

Information and communication technology (ICT) has long been the backbone of the modern economy. ICT created the basis for new business models and innovative products and processes; it is impossible to imagine companies and most private households getting by without computers.

ICT has a significant part to play in energy efficiency, both as an enabler **("green with IT")** and in application **("green in IT")**. As a cross-application technology, ICT fulfills an instrumental role in cutting energy consumption – and with it CO_2 emissions. ICT solutions reduce demand for energy by means of **dematerialization**, in other words replacing physical commodities with digital ones, through **intelligent control of power grids and power supply ("smart grid")**, with **building automation** and in many other ways. [48] "Green in IT", or "green IT" for short, is the name given to the energy and material-efficient manufacturing and use of ICT equipment such as PCs, notebooks, smartphones and the operation of infrastructure like cell phone networks, servers and data centers. In essence, green IT is about how the use of modern hardware and software can help keep energy expenditure constant or even reduce it as demand rises. And the issue looks set to become even more topical in view of the trend over the past decade.

The increased penetration of ICT in all spheres of work and life has led to rapid **growth in energy demand** in recent years. Guzzling around 55 terawatt-hours of electricity, the operation of ICT equipment and infrastructure accounts for about one-tenth of Germany's total power consumption, 55 percent more than at the start of the century. According to a study by the Federal Environment Ministry, servers and data centers consume 10.1 terawatt-hours of electricity alone and have therefore seen energy demand almost double since 2000. [49] This development is predominantly a consequence of the fact that the increasing use of the Internet, telecommunication services and IT applications has driven up the number of servers and their energy demand. If this trend continues, servers and data centers in Germany will be consuming almost 15 terawatt-hours of electricity in 2013.

But there is an alternative to business as usual: if the majority of companies could get around to using energy-efficient ICT solutions, Germany could save 25.8 terawatt-hours of electricity by 2013. This would cut out 15.3 million tons of CO_2 emissions. Not only would this saving benefit the environment, it would also be good for companies' balance sheets, given that **electricity is an enormous cost driver** in the operation of server systems and data centers: electricity costs totaled EUR 1.1 billion in 2008.

Since energy costs are rising, companies are becoming more motivated to improve the **energy efficiency of their ICT equipment and infrastructure**, given that a lifecycle assessment shows around three-quarters of costs are incurred as a result of energy consumption in the operating phase. The arsenal of energy-saving measures can be divided into two categories to reflect their focus: firstly, servers and data centers; and secondly, IT in the workplace.

THINK TANK FOR GREEN IT SOLUTIONS

1.3 – this is the ambitious PUE value Deutsche Telekom wants to achieve in its DataCenter 2020. What this ratio – the power usage effectiveness – tells us is that 1.3 kilowatts of electricity needs to be fed into the data center for each kilowatt of electricity used to operate the servers. The Green IT Lab, operated by T-Systems – Telekom's corporate customers arm – in conjunction with Intel, has already achieved a PUE value of 1.41. This takes Telekom that little bit closer to its goal of achieving a PUE value of 1.4 in new data centers and 1.6 in existing ones in its land line business. The average in T-Systems data centers is currently 1.75.

Model "green" data centers are already trialing various ways of increasing energy efficiency. One of the things they discovered is that a temperature of 27 degrees Celsius does not diminish computing capacity. So cooling the room to 22 degrees, as is commonly done, consumes unnecessary energy. Findings such as these from the DataCenter 2020 project will show the way when it comes to renovating and building new data centers.

Source: Deutsche Telekom AG (2011a)

48 The topic of „green with IT" is presented in detail in the *Smart Cities* chapter
49 See Bundesumweltministerium (2009b), p. 4

Most companies are faced with the problem of rising numbers of applications and service offerings necessitating **substantial growth in their server systems**. The rapidly increasing performance of the components involved drives electricity consumption to new heights, which in turn augments the need for air conditioning. Empirical evidence suggests that half a kilowatt-hour of cooling is required for each kilowatt-hour of IT performance. This relationship makes it immediately apparent why optimizing heating, air conditioning and ventilation systems is a key area for actions to increase energy efficiency in data centers.

DCiE is a **parameter for measuring the energy efficiency of data centers**. It stands for **data center infrastructure efficiency**. The EU Code of Conduct for Data Centers defines this as the ratio of energy consumption in IT to total energy consumption of the data center multiplied by 100 percent. This formula results in an ideal DCiE value of 100 percent. The highest achievable value for large data centers is currently 75 percent. [50] To attain such a high level, companies need pull out all the stops in terms of modern cooling technology. This includes **loss-free air circulation, separate cold and hot aisles and efficient cooling equipment**. Cooling production is an especially important point to consider when a data center is going green: achieving a higher share of free cooling is fundamentally good for the energy footprint. And instead of the widespread use of compressor cooling, alternative cooling technologies could be applied, such as geothermal energy, absorption chillers and solar cooling.

There is also **intelligent architecture**, which ensures low temperatures inside the building housing the data center – for instance by shading the facade. Another way of improving the energy footprint is to **utilize the waste heat from the data center**. Logistics service provider Dachser, for example, meets 50 percent of the heating requirements for the main building (300 workstations) it moved into in 2010 with the waste heat from the data centers.

Virtualization or consolidation is a promising approach for reducing the energy consumption of servers and data centers. The aim here is to reduce the amount of hardware deployed and the quantity of power consumed through consolidating IT in high-performance systems. Put simply, it means replacing hardware with software. Better use is made of IT resources by increasing the capacity utilization of the servers in a data center. Kulmbach hospital's modernization of its information and communication technology provides an example of the saving that can be achieved through server virtualization. The project involved logically merging 25 physical servers in the Upper Franconian town into four virtual servers. The freed-up server capacity was then able to be used for additional tasks. This virtualization, part-funded by the government's Climate Protection Initiative, cuts electricity consumption by 76,000 kilowatt-hours per year and keeps 45.3 tons of CO_2 emissions out of the atmosphere. [51]

In addition to this, the **use of energy-efficient equipment and components** makes a major contribution to cutting the energy consumption of a data center. State-of-the-art servers, processors, power supply units and fans now consume much less energy than they used to while still performing at a level that is the same, or better, than before. **Standby optimization for servers** is another aspect that increases energy efficiency: energy management software can put intermittently used servers, such as storage or print servers, into standby mode, for example; their energy consumption on standby is much less than in operating mode.

Energy efficiency at the user's workplace is an essential element of any green IT strategy. Around 26.5 million workplace computers are in use in German companies, public authorities and educational institutions; they consume about four terawatt-hours of electricity per year. [52] Besides the use of energy-efficient equipment and components and standby optimization, the deployment of **thin clients** offers enormous saving potential. The "clients" are the terminals themselves as physical layers of computing. [53] Under the thin client concept, computing-intensive applications are executed from a central computer (the "fast client") via a network, whereas the computer workstations of the users are mainly used for data input and output. The energy footprint of the "thin" terminals is about 50 percent better than that of conventional PCs, and thin clients also have a longer lifespan. The progression of the thin client is the **zero client** – this terminal is really "just" an intelligent front-end monitor with a power supply and network access. Since no fan or cooling system is needed, the energy saving is even higher than with a thin client. [54]

50 Another way of expressing the DCiE value is the PUE factor (power usage effectiveness), which is the ratio of total energy consumption of the data center to energy consumption of IT (servers, memory, network infrastructure)
51 See Bundesumweltministerium (2009c)
52 See BITKOM (2011a)
53 See Kosch, B./Wagner, H. (2010), p. 210
54 See ibid.

Something that cannot be left out in the context of green IT is **cloud computing**. Within this concept, IT services (software, platforms for application development and operation, basic infrastructure) are provided over the Internet on a flexible basis. [55]

Users – private and corporate alike – can access computing capacity and software in cloud data centers over the Internet. Cloud computing offers users the advantage of replacing capital expenditure with variable costs that reflect actual needs. The benefit of cloud computing from an energy-saving perspective is that workplace computers can run as thin clients. Virtualization/ cloud computing also cuts energy consumption in data centers because the number of physical servers can be reduced. In Germany this would mitigate greenhouse gas emissions to the tune of 2.7 megatons of carbon dioxide equivalent. [56]

Domestic appliances
The energy efficiency of domestic appliances has increasingly moved into the spotlight in recent years. The reason for this is their high energy consumption. After heating and hot water, **domestic appliances** (including communication) in German houses and apartments **rank third in terms of domestic energy consumption**, accounting for just under 10 percent of the power used. Cooking, drying and ironing account for about 5 percent and lighting 2 percent. [57] All in all, domestic energy consumption amounted to 656 billion kilowatt-hours in 2009, reflecting a fall of 6.7 percent since 2005.

However, if we take a differentiated look at the figures, we can see that the categories of "domestic appliances" and "cooking, drying and ironing" buck the overall downward trend. Domestic appliances saw a 5.3 percent increase in energy consumption in this period, while ironing etc. consumed 2.9 percent more power in 2009 than in 2005. This trend in energy consumption is due to the **increase in appliance numbers and the rise in household numbers**. At the end of the day, these two phenomena serve to cancel out the improvement in energy efficiency that has been seen in individual appliances in recent years. To counteract this **rebound effect**, additional measures will need to be taken to improve the energy efficiency of electrical appliances. The Ecodesign Directive (see box on p. 84) presents some initial approaches, as do the actions being taken to **inform and raise the awareness of consumers through energy labels and eco-labels** like the "Blue Angel". With labels like these, any consumer can see at a glance how energy efficient the appliance they are looking at is.

How technologically advanced the latest generation of domestic appliances already is can be seen in examples like the combined fridge-freezers from Siemens, which consume 75 percent less energy than a similar appliance did 15 years ago. The use of new materials is what makes this improvement in energy efficiency possible. To cite but one example, **zeoliths** – also known as boiling stones – have drying properties that enable them to replace the heating elements in a dishwasher. The water that the stones contain after the wash can even be heated up and used for the prewash cycle of the next load.

Organic light emitting diodes (OLEDs) are going to be hugely important in the **consumer electronics** of the future. OLEDs offer the advantage of having more efficient drivers, higher efficiency than a plasma screen when converting power to light, and lower energy consumption generally – light is supplied only to those pixels that are meant to be illuminated. [58]

The **energy efficiency categories** that had applied up to 2010 were **revised** to reflect the advances made in energy efficiency in recent years. Whereas the categories A through G had been sufficient to describe energy consumption in the past, the categories now only run A through D, with the addition of A+, A++ and A+++ at the top end. Appliances in categories E, F and G were banished from the market. By way of illustration, a normal category A washing machine uses an average of 300 kilowatt-hours of electricity per year, whereas appliances in the new A+++ category get by on just two-thirds of that energy. [59]

These highly efficient appliances can achieve an optimum of economy when they have a control unit that enables them to conduct an intelligent dialog with a smart meter. This is the key to shifting the use of domestic appliances to off-peak times, when electricity companies offer cheaper tariffs. [60]

Measurement and control instrumentation plays an important role in achieving higher energy efficiency from domestic appliances. Though their roots and principal applications lie firmly in industry, these cross-application technologies also serve private

55 See BITKOM (2011b)
56 See SMART 2020 Addendum Deutschland, p. 23
57 See Statistisches Bundesamt (2010)
58 See Bockhorst, M. (2011b)
59 See energie-sparen-aktuell.de (2011)
60 See the *Distributed power supply structure* chapter for more details

households well in their quest to save energy. **High-tech sensors**, for instance, can help optimize water use in dishwashers and washing machines, precisely adjusting volumes to actual needs.

Hobart GmbH won the 2011 Environmental Technology Award for its application of this principle to flight-type dishwashers in commercial kitchens. A special sensor technology in the extra-large dishwashers enables them to save 30 percent of energy, 50 percent of water and 80 percent of detergent. [61] The highlight of the technology is the dishwasher's "intelligence": it can even tell what kind of dishes it is washing and what type of washing they need.

BACKGROUND: THE ECODESIGN DIRECTIVE

On track for environmental compatibility right from the start: the planning and design phase determines the carbon footprint of all other stages in a product's lifecycle. Ecodesign is the name given to a "systematic and comprehensive way of looking at and designing" a product with the objective of "mitigating the environmental impact throughout the entire lifecycle by improved product design" (Umweltbundesamt, 2011b).

The Ecodesign Directive marks the first time the European Commission has enshrined in law requirements for the environmentally sustainable design of products. Having entered into force in 2005, the Directive was transposed into German law in 2008 in the form of the Energy-using Products Act (EBPG). This first version covered energy-using products (except vehicles) and products for generating, transmitting and measuring energy. The European Union's Ecodesign Directive (2009/125/EC) was amended in October 2009; its scope was extended from energy-using products to energy-related products. The revised version has now also been transposed into national law: the amended Act became effective in November 2011 and its title was changed to the Energy-related Products Act (EVPG).

One of the aims of the Ecodesign Directive is to accelerate the market penetration of energy-efficient products in the European Union by setting minimum standards. Only products that meet these criteria receive marketing approval. Products that miss the energy-saving targets, on the other hand, can neither be produced nor marketed.

Requirements under the Ecodesign Directive can be set in two ways: either through legal provisions of the European Union – so-called implementing measures – or through industry self-regulation (Umweltbundesamt, 2008). Implementing measures have been defined for more than ten product categories (see overview in table 4), regulations for a further 20 categories are being prepared.

Among the first measures to come in under the Ecodesign Directive was the 2008 setting of ceilings for the power consumption of electrical appliances in standby mode. The objective is to cut standby losses, which amount to 51 billion kilowatt-hours in the European Union. The Commission Regulation (1275/2008/EC) aims to save up to 35 terawatt-hours of electricity per year in the period through 2020. This would make eight large power plants redundant; 14 million tons of CO_2 emissions would be saved.

The Ecodesign Directive is known but not necessarily loved by consumers primarily for putting an end to traditional lightbulbs. They were replaced by energy-saving lamps ("compact fluorescent lamps"), which consume only about one-quarter of the power of conventional lamps. With the demise of the 100 and 75 watt lightbulbs already effected, the manufacture and sale of the standard 60 watt bulb were finally switched off for good in September 2011.

61 See Hobart GmbH (2011)

Table 4: Overview of product categories so far included in the Ecodesign Directive

Product category	Implementing measure	Regulation takes effect
Simple digital receivers (set-top boxes)	Regulation (EC) 107/2009	Feb 25, 2009/Feb 25, 2010
Boilers and combi boilers	NN	NN
Water heaters	NN	NN
PCs (desktops, laptops), monitors, digital photo frames	NN	NN
Appliances with a print function (scanners, printers, photocopiers)	NN	NN
Televisions	Regulation (EC) 642/2009	Aug 12, 2009/Jan 7, 2010
Standby losses	Regulation (EC) 1275/2008	Jan 7, 2009/Jan 7, 2010
External power supply	Regulation (EC) 278/2009	Apr 27, 2009/Apr 27, 2010
Office lighting	Regulation (EC) 245/2009	Apr 13, 2009/Apr 13, 2010
(Public) street lighting	Regulation (EC) 245/2009	Apr 13, 2009/Apr 13, 2010
Domestic air conditioning and ventilation	NN	NN
Electric motors	Regulation (EC) 640/2009	Aug 12, 2009/Jun 16, 2011
Circulation pumps	Regulation (EC) 641/2009	Aug 12, 2009/Jun 16, 2011
Water pumps	NN	NN
Ventilators	NN	NN
Commercial refrigerators and freezers	NN	NN
Domestic refrigerators and freezers	Regulation (EC) 643/2009	Aug 12, 2009/Jul 1, 2010
Domestic washing machines	Regulation (EC) 1015/2010	Nov 11, 2010/Dec 1, 2011
Domestic dishwashers	Regulation (EC) 1016/2010	Nov 11, 2010/Dec 1, 2011
Small furnaces for solid fuels	NN	NN
Tumble dryers	NN	NN
Vacuum cleaners	NN	NN
Complex digital receivers (set-top boxes)	NN	NN
19a Domestic lighting/general lighting	Regulation (EC) 244/2009	Apr 13, 2009/Sep 1, 2009
19b Directional light sources (reflector lamps)	NN	NN
Refrigerators	NN	NN
Transformers	NN	NN
Audio/visual equipment	NN	NN
Single-room heaters	NN	NN
Warm air central heating (without cogeneration)	NN	NN
Domestic and commercial ovens for food, incl. microwaves	NN	NN
Domestic and commercial ovens and grills	NN	NN
Commercial dishwashers	NN	NN
Commercial washing machines and dryers	NN	NN
Non-commercial coffee machines	NN	NN
Networked standby	NN	NN
Domestic UPS	NN	NN
Furnaces and ovens for industry and laboratories	NN	NN
Machine tools	NN	NN
Air conditioning and ventilation systems	NN	NN
Water-using devices	NN	NN
Medical imaging devices	NN	NN

Source: Umweltbundesamt; as of 12/2010

Material efficiency

Ballooning demand and shrinking supply – this, in a nutshell, has been the trend in the **international raw material markets** since the turn of the century. The consequence is a dramatic **rise in prices**; only the financial and economic crisis of 2008/2009 caused a brief slowdown in the rocketing cost of raw materials. Prices have since taken off again and their upward trajectory is set to continue in the years to come, driven by a combination of global population growth and rising demand for raw materials in emerging nations. Against this backdrop, scarce resources represent one of the megatrends set to shape economic developments in the medium and long term.

Projecting current levels of resource consumption into the future, five planet Earths would be needed to cover humanity's need for raw materials in 2050. It is essential that we **decouple economic growth from resource consumption**. This is the express objective of "ProgRess", the German resource efficiency program enacted by the government in February 2012. Billed as a "master plan for sustainable growth", the program employs market incentives, research, innovation and consultancy as instruments to increase the raw material productivity of the German economy. ProgRess describes approaches that can be adopted, measures that can be taken and examples that showcase best practice along the value chain.

The ideal way of decoupling growth from resource consumption is by increasing resource efficiency. This can be achieved through product and process innovation, for instance by using new materials or applying principles from biotechnology or nanotechnology.

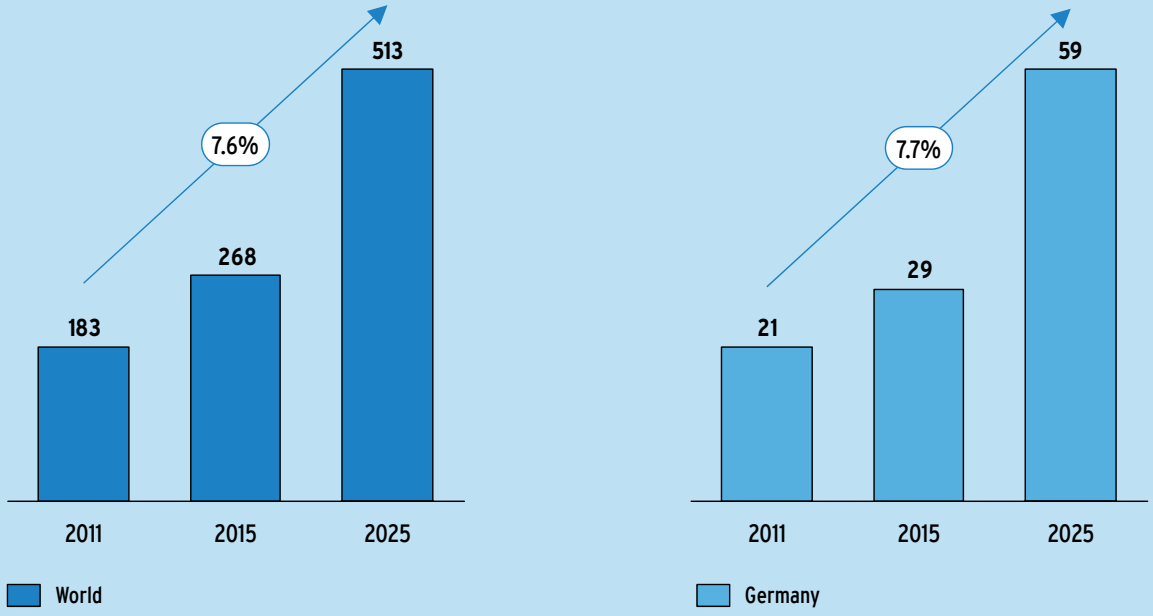
The lead market for material efficiency encompasses technologies and methods that reduce the consumption of non-energy resources and materials. Resource efficiency is the overriding theme in both energy efficiency and material efficiency. The technologies and methods employed in achieving energy efficiency constitute their own lead market and are described in detail from page 64 onward. The lead market for material efficiency is concerned with **non-energy raw materials** with the exception of food and water, such as metals, mineral deposits and so on. **Resource efficiency refers to efficiency in extracting raw materials, while material efficiency means efficiency in processing raw materials.**

Our description of this lead market focuses on the production of goods in industry and commerce. The immense importance of raw material supplies for German companies validates this choice of focus. Every year, companies process materials to the value of EUR 500 billion in Germany. This figure reveals the extent of the savings that can be made through actions to increase efficiency: a **20 percent rise in material efficiency would equate to a saving of EUR 100 billion**. [1]

Savings in this order of magnitude bring home the significance of material efficiency to companies and therefore to the national economy. This is reflected in the arrangement of market segments in this section of our study.

1 See Deutsche Materialeffizienzagentur (2011a)

Figure 48: Market forecast for material efficiency, 2011, 2015 and 2025 (in EUR billion, average annual change 2011-2025 in percent)



Source: Roland Berger market model

In our discussion of the market segment **material-efficient processes** we include a number of examples from "traditional" industry segments illustrating how businesses not only cut costs but also protect the environment by improving production processes and using new materials. The second market segment we deal with is the **cross-application technologies** of biotechnology and nanotechnology in the context of material efficiency. We highlight these two key technologies because they are already demonstrating their ability to open up brand new perspectives for husbanding resources in numerous products and applications. Replacing finite fossil resources with **renewable resources** is one of the key levers in ensuring the sustainability of resources, and this forms our third market segment. Here, we look at the various ways in which industrial crops and their constituent parts can be used. Renewable resources already cover one-tenth of raw material requirements in the chemicals industry in Germany, and the tendency is rising.

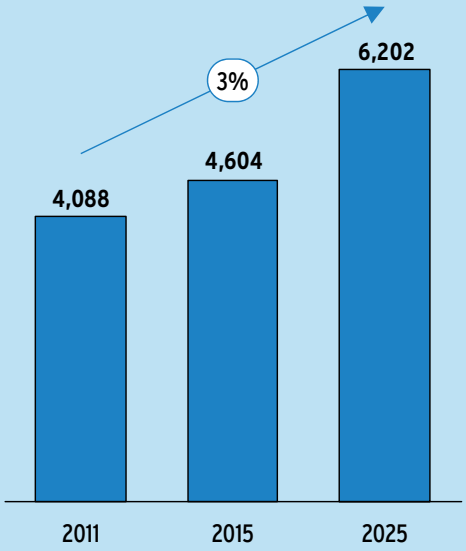
Material-efficient processes

Material costs make up almost 43 percent of a manufacturing company's cost structure, making them the **biggest cost block** by far, exceeding personnel costs by more than 20 percent (see figure 50). Capping material expenditure helps companies keep costs low and be more competitive. Yet companies seem reticent to apply this lever: Although targeted measures have been taken to improve productivity, raising it by a factor of 3.5 since 1960, material efficiency has only increased by a factor of 2.

The actual potential is much greater, however. At a corporate level, the German Agency for Material Efficiency (demea) values the **potential savings in material consumption to be on average EUR 218,000 per year per business** – an average material saving of 2.4 percent. The market segment for material-efficient processes highlights solutions that can help companies increase their material efficiency by employing innovative methods and materials.

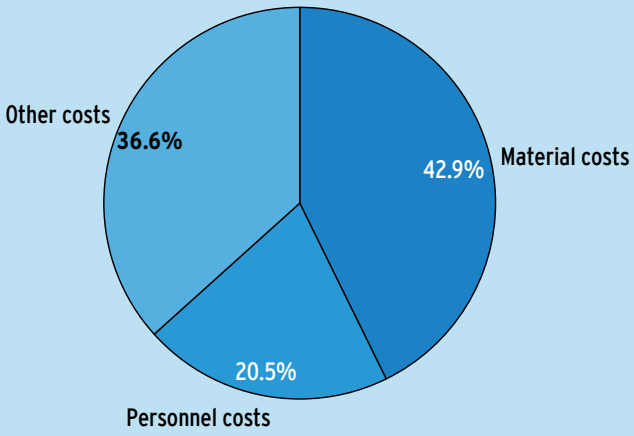
There are opportunities to save materials in almost all "traditional" industries. **Some 20 percent of current raw material input could be dispensed with if material efficiency were higher.** There are a

Figure 49: Market forecast for material-efficient processes, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

Figure 50: Cost structure in manufacturing enterprises



Source: demea, Deutsche Materialeffizienzagentur (2011b)

number of different approaches that can be taken to make optimal use of resources. The range of efficiency measures encompasses the **optimal use of raw materials** through higher purity or concentration levels, the **greater use of regenerative resources for operating supplies**, the **recycling of materials** in production and **material substitutions**. All branches of industry are faced with the need to use resources sparingly. So the general rule is, the more resource-intensive the industry, the greater the savings potential. Companies in the metal industry, construction material production and chemicals sectors have come up with different approaches to increase their material efficiency.

Metal and steel industry

The **metal and steel industry** is by nature one of the commodity-based branches of industry that has high levels of energy consumption. There are several **approaches that can be taken to improve material efficiency** through process innovation and the use of new materials.

BETTER PROCESS PLANNING, HIGHER MATERIAL EFFICIENCY

EUR 345,000 per year is what Schürholz GmbH & Co. KG saves by improving process preparation and planning and by recycling punching waste. The company, an SME from Plettenberg (Lower Saxony), specializes in sheet forming and manufactures metal parts and components for the automotive and electrical industries and rail vehicle applications. It wanted to cut its material costs in production by reducing kerf loss and recycling punching waste. A consulting project, supported by the Federal Ministry of Economics and Technology's VerMat funding program, showed Schürholz how to go about achieving its savings target. The adjustment in materials was optimized to suit the working width of the machines and the process controls were improved. The punching waste is now used for other products, including round blanks and plain washers.

Source: demea, Deutsche Materialeffizienzagentur (2008)

Optimizing existing processes can substantially cut material input. Trumpf GmbH + Co. KG developed a method to reduce kerf loss from punching to zero. The method earned the Swabian engineering company second prize in the material efficiency category in the 2011 Baden-Württemberg Environmental Technology Award. The punching machine, software and smart tools are so precisely aligned that nothing remains of a metal sheet after punching. The concept increases material efficiency by an average of 10 percent. The production of metal sheets requires considerable energy input, 30 to 80 times more than operating a punching machine for an hour. This shows the importance of skeleton-free processing for resource efficiency. [2]

Obtaining a **higher material yield** is also the **goal of a new method of extracting valuable metals from slag**. Most metals are made by smelting in a furnace. The process produces the byproduct slag in addition to the desired metal. Slag usually contains other valuable metals. A collaborative research project by Aurubis AG, SMS Siemag AG and the Institute for Metallurgy and Electrometallurgy at RWTH Aachen is hoping to develop a better method for recycling the nickel, cobalt, molybdenum, zinc, tin, antimony, lead and copper contained in slag. The objective is to be able to extract around 90 percent of these valuable metals. The researchers plan to use an electric furnace and a stirred tank reactor whose magnetic field will extract the fragments of valuable metal from the slag. [3]

The immense **importance of process planning for increasing material efficiency** is demonstrated by VHW Metallpresswerk GmbH. The company, based in the town of Spaichingen in Baden-Württemberg, specializes in forged metalwork, producing more than half a million molded components out of steel. The company wanted to reduce the amount of waste material from production. They achieved their aim by examining their production process from top to bottom – from tooling times and tool design to tool life and maintenance – and making appropriate changes. The package of actions they implemented enabled total savings of around EUR 2 million per year. [4]

Reducing the need for operating supplies such as lubricants, wearing parts and additives is an important step on the road to achieving greater material efficiency. In many cases, innovative methods can make the use of consumables superfluous. Diebold Goldring Werkzeugfabrik, a company based in Jungingen, Baden-Württemberg, developed a method that requires no drilling oil, for instance. A spindle adaptor is attached to the milling machine; the compressed air from its nozzles not only blows the shavings away immediately, it also cools down the workstation. It can spray air, a mixture of coolant and air or a mixture of oil and air, depending on the requirements. Lubricants can now be finely dosed, whereas before, hundreds of liters of oil were needed every day to wash away the shavings. The company spent EUR 30,000 retrofitting its system to facilitate the new process, but it is an investment that pays for itself in less than a year: no more drilling oil, less money spent on cleaning and maintaining milling machines, and less money spent on recycling waste oil. [5] Companies from Germany are global leaders in dry machining technology, a method that enables them to cut production costs by as much as 16 percent.

2 See Trumpf GmbH + Co. KG (2011)
3 See Fraunhofer-Institut für System- und Innovationsforschung ISI (2010), p. 22
4 See Csapo, L. (2010)
5 See Deutsche Materialeffizienzagentur (2010a)

Greater material efficiency can in many cases also be achieved by **using new or improved materials**. For example, high and ultra-high tensile steels and tailored blanks reduce material input. Tailored blanks are plates of sheet steel that, as the name suggests, have been tailored, or customized. Individual steel sheets with different properties (thickness, strength, surface coating) are laser-welded together. Combining them in this way enables the plate to meet the specific requirements exactly. [6] Using valuable metals sparingly is also the name of the game with metal foams, for instance those made of aluminum. They are 85 percent air and are therefore considered lightweight. [7] Yet they still boast high strength, making them ideally suited for use in brake cylinders and catalytic converters in the automotive industry.

Lightweight construction methods are especially important in the quest for material efficiency. The Association of German Engineers (VDI) defines lightweight engineering as the sum of innovative material, process and design concepts. This description itself shows the range of areas in which material savings can be made. Building with lightweight materials is all about using the right alternative materials: ones that are lighter than conventional materials and offer the same properties, if not better.

Metals such as aluminum and magnesium are lighter than conventional steel and are therefore finding increasing application as a means of reducing weight. [8] **Sandwich construction** is a significant area, a crucial element in lightweight engineering. Sandwich construction normally consists of two thin outer layers with a core material in between. Metawell GmbH from Neuburg developed an aluminum sandwich for the floor tiles of the subway system in the Indian metropolis of Delhi: The thickness of the skin panels is 1.2 millimeters on the side covered by flooring and 1 millimeter on the underside; in between there is a corrugated aluminum core with a thickness of just 0.3 millimeters. The tile can support a distributed load of up to 650 kilograms per square meter with widely spaced supports in the substructure. This sandwich is 75 percent lighter than a solid aluminum construction. [9]

Construction sector

Many different **approaches can help increase resource efficiency** in the construction industry. This goes both for the manufacturing of basic resources for construction applications, such as non-metallic minerals, and for the use of new construction materials.

Cement manufacturing is a very energy-intensive process that produces substantial CO_2 emissions: Cement plants are responsible for 5 to 7 percent of the world's CO_2 emissions, or 3 billion tons. Celitement®, a new method of cement manufacturing developed at the Karlsruhe Institute of Technology (KIT), looks set to halve energy consumption. Moreover, Celitement® does not need as many raw materials: Limestone consumption is one-third lower and there is no need for gypsum as an admixture. The resource-efficient method is currently being made ready for the market by Celitement GmbH, a company founded by Schwenk Group, the Karlsruhe Institute of Technology and researchers from KIT. A pilot plant on the KIT campus produces 100 kilograms of the cement a day. [10] If the project goes to plan, in about five years a plant with an annual production volume of 30,000 tons will start production. Celitement® has already won numerous awards including the demea Material Efficiency Prize in 2010 and the Baden-Württemberg Special Environmental Technology Award in 2011.

Cobiax Technologies GmbH also won the demea Material Efficiency Prize for its innovative construction method. The company, based in Darmstadt, reduced the weight of reinforced concrete floors by more than one-third. Hollow bodies replace the concrete in places where the load-bearing capacity does not necessarily require concrete. This makes the supporting structure lighter. The **use of hollow bodies** brings the required quantity of concrete down by 35 percent; not only that, 20 percent less reinforced steel is needed. [11]

Chemical processes

Research and development departments are working closely on ways to use **regenerative resources as base materials for chemical**

6 See ThyssenKrupp Tailored Blanks GmbH (2011)
7 See Hessisches Ministerium für Wirtschaft, Verkehr und Landesentwicklung (2009), p. 21
8 For more on lightweight engineering see the section *Sustainable mobility*
9 See Müller-Wondorf, R. (2010)
10 See Karlsruher Institut für Technologie (2011)
11 See Deutsche Materialeffizienzagentur (2010b), p. 4

processes. Researchers from the Institutes of Organic Chemistry and Physical Chemistry at the University of Regensburg are developing catalytic chemical processes that convert easily available renewable resources into fine chemicals.

A chemical catalyst turns regenerative raw materials such as sucrose, fatty acids and amino acids into useful synthetic chemicals. Put simply, it alters the function of a natural raw material without sacrificing any of its core properties or capabilities. [12]

Gas phase oxidation of hydrogen chloride (the DEACON process) is a material-efficient method of **producing chlorine in the chemical industry**. In conventional industrial processes, chlorine is produced by electrolysis from an aqueous solution of sodium chloride or hydrochloric acid. Electrolysis is a highly energy-intensive process, consuming vast amounts of electricity. The DEACON process is a substitute for hydrochloric acid electrolysis. In a project supported by the Federal Ministry of Education and Research, five partners [13] are working on making this process not only energy efficient but also material efficient: Both electrolysis and gas phase oxidation require catalysts with a higher concentration of rare noble metals, especially ruthenium, for the reactions that take place during the processes. The scientists involved in the project, coordinated by Bayer MaterialScience AG, set themselves the objective of reducing the consumption of these noble metals and developing low-ruthenium or ruthenium-free catalysts. This, they hope, will lead to 50 to 80 percent lower consumption of noble metals in the production of chlorine. [14]

Cross-application technologies

Cross-application technologies is the name given to technologies that are relevant for a wide range of industries rather than one specific industry. The clearest example is information and communication technology, now indispensable in every branch of industry. **Biotechnology** and **nanotechnology** are also classed as cross-application technologies. They are key to the refinement of material-efficient products and processes and **form the focus of our discussion of the market segment for cross-application technologies**. [15] Below, we first outline the basic principles of biotechnology and nanotechnology before going on to demonstrate the resource savings made possible by these technologies.

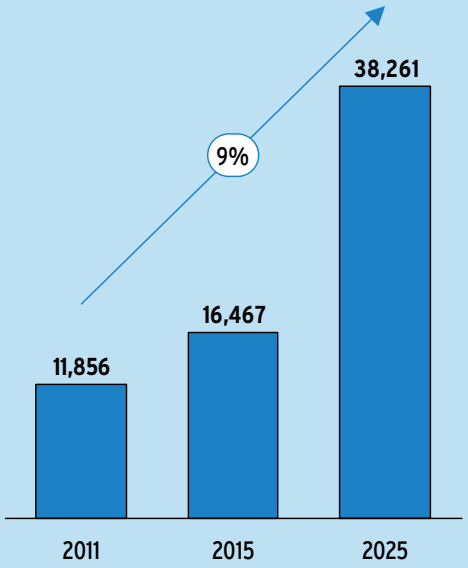
Biotechnology

Biotechnology is a **classic cross-application technology**, encompassing a wide range of products and processes. The Organisation for Economic Co-operation and Development (OECD) defines biotechnology as "the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services." [16] **Biotechnology's areas of application** are color coded: red biotechnology refers to diagnostic and therapeutic methods in medicine, green biotechnology is concerned with agriculture, and white biotechnology is the name given to the application of biotechnology in industrial production. There is also blue biotechnology, which makes use of maritime organisms for biotechnological processes or products.

White biotechnology plays a key role in the context of resource efficiency. It can be said to use "nature's toolkit" for industrial applications. [17] Microorganisms or their constituent parts are used to manufacture industrial products ranging from special and fine chemicals to agricultural and pharmaceutical intermediates, foodstuffs and food additives. The use of microorganisms in the food production process is not new in itself: wine, sour dough and cheese have been around for centuries, after all. But in the 1980s

12 See Bayerisches Staatsministerium für Wirtschaft, Infrastruktur, Verkehr und Technologie (2011)
13 Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Faculty of Engineering, Chair of Metals Science and Technology (WTM); Justus Liebig University Giessen, Faculty 08, Biology and Chemistry, Institute of Physical Chemistry; Ruhr-Universität Bochum (RUB), Faculty of Chemistry and Biochemistry, Chair of Analytical Chemistry; Technische Universität Berlin (TU Berlin), Faculty II, Institute of Chemistry; Saarland University, Faculty 8, Natural Sciences and Technology III, Subject 8.1, Chemistry
14 See Fraunhofer-Institut für System- und Innovationsforschung ISI (2010), p. 28
15 "Green IT" is also an important cross-application technology. This topic is presented in detail in the section Energy efficiency (see pp. 64ff.)
16 Quoted from biotechnologie.de; see biotechnochlogie.de. Die Informationsplattform (2011)
17 See Bundesministerium für Bildung und Forschung (2008), p. 4

Figure 51: Market forecast for cross-application technologies, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

industry became increasingly interested in white biotechnology: The oil crisis meant that everyone was looking for production processes that consumed fewer scarce and ever more expensive resources.

From a sustainability perspective, **white biotechnology** has the advantage that its methods can **reduce the consumption of energy and raw materials** or can **replace finite resources with renewables**. White biotechnology is currently experiencing a boom as a result of this potential. This field of application has been seeing disproportionately high growth for several years now. There are also signs of an intensification of research and development: In 2011, TUM in Munich opened a technical school for white biotechnology. Similarly, the Federal Ministry of Education and Research has launched the "Industrial Biotechnology Innovation Initiative", which is set to receive EUR 100 million in funding. [18]

In practice, it is companies from the chemicals industry that are driving the **refinement of biotech methods**. BASF SE considers white biotechnology one of five "growth clusters", each covering topics expected to deliver answers to the challenges of global megatrends. [19] One example of the application of industrial biotechnology at BASF is in the manufacturing of phytase. This enzyme controls the release of the phosphorus contained in plant-based animal feeds in the form of a substance known as phytate. The phytase enzyme is not present in the organism of pigs and poultry so the phytate goes unused and is excreted, polluting the groundwater. One way of avoiding this is to add phytase to the feed. BASF uses a type of mold called Apergillus niger to manufacture this enzyme. They have genetically modified the mold to produce phytase in large quantities.

Henkel AG is working on using enzymes to efficiently enable cold washing. What they were looking for were bacteria that produce enzymes active at tap water temperature. The plan was for these enzymes to improve the performance of liquid detergents. The research at Henkel, conducted in cooperation with BRAIN AG, was successful: The cold-active enzymes of soil bacteria can get dirt out of fabrics at 20 degrees Celsius instead of 40. Given that this difference of 20 degrees equates to an energy saving of about 50 percent, **low-temperature protease** is a way of helping households use resources sustainably. [20]

Another area in which white biotechnology is being applied is in the **production of biofuels**. Süd-Chemie AG has built Germany's largest plant for manufacturing second generation bioethanol, known as cellulosic ethanol, in the town of Straubing

18 See Bundesministerium für Bildung und Forschung (2011)
19 See BASF SE (2011a)
20 See Henkel AG & Co. KGaA (2011)

in Bavaria. The demonstration plant for the specialist chemicals company's sunliquid® technology produces up to 2,000 tons of bioethanol a year from agricultural residues. The process involves converting cellulose-based plant components (wheat or corn straw, bagasse from sugarcane or energy crops) into their constituent sugars with the help of enzymes. Bioethanol is then extracted from them. The enzymes needed for this process are manufactured in the production plant. According to Süd-Chemie, the sunliquid® technology is extremely productive: Ethanol production is 50 percent higher than with conventional technologies because so-called hemi-celluloses in the plants are also turned into ethanol along with the cellulose itself. [21]

Nanotechnology

Nanotechnology is one of the **key technologies of the 21st century**. It is typically cross-application in nature, encompassing many different processes and methods from a range of industries. Nanotechnology is all about producing solids on the nanometer scale. Nanoparticles are particles that are no bigger than 100 nanometers (millionths of a millimeter) in one of the three spatial dimensions. **Nanoscale materials** are particularly qualified for use as enablers in innovative product solutions and processes because they can exhibit different mechanical, optical, electronic and magnetic properties than the same material with a structure on a larger scale. These special properties are what make it possible for nanotechnology to improve materials and products. A typical feature of nanomaterials is their high surface-to-volume ratio. [22]

Nanotechnology has already found its way into certain industries. It plays an important role in today's automotive and chemicals industries, for instance. Although **still in its infancy when it comes to commercial utilization**, the prospects for the deployment of this cross-application technology are promising indeed – especially in environmental technology. In this sphere, nanotechnology is used for coating and synthesis processes as well as for filtration and catalytic cleaning.

One example of the **application of nanotechnology in green technology** is in raising efficiency levels in photovoltaics, where quantum dots can increase the conversion efficiency of solar cells. Nanoscale materials will also be able to improve insulation in the future. Bayer MaterialScience is working with the Institute of Physical Chemistry at the University of Cologne to develop polyurethane (PUR) nanofoams with a pore size of less than 150 nanometers, which could be used in applications such as refrigerators. Given that the thermal insulation performance of a polyurethane hard foam depends essentially on the size of the foam pores – the smaller the diameter, the lower the thermal conductivity – PUR nanofoams provide substantially superior insulation to conventional PUR foams. This would reduce the amount of electricity consumed by refrigerators. [23]

Molecular nanotubes made of carbon and featuring diameters of 1 to 50 nanometers hold the promise of innovations in materials technology that could increase resource efficiency. Carbon nanotubes (CNT) are notable for their special material properties – electrical conductivity, thermal conductivity and low density coupled with high tensile load capacity. Thanks to these qualities, CNT can help scientists develop brand new materials. For this reason, carbon nanotubes are considered a key material technology market of the future. [24]

The interdisciplinary CNT innovation alliance (Inno.CNT), incorporating some 90 partners from German industry and academia, is running a large number of projects aimed at establishing Germany as a global lead market for innovative carbon nanomaterials. One of these projects is "CarboCat", whose objective is to produce **catalysts made out of CNT** that are cheaper and more environmentally friendly than the conventional noble metal catalysts; the latter are, of course, very resource and energy intensive, so an alternative to the conventional process would have very positive effects on the eco-balance. The significance of CarboCat becomes clear when one realizes that around four out of five of the products made in the chemicals industry are manufactured using catalytic processes.

Surface-protective layers made of carbon compounds represent another example of how nanotechnology can increase material efficiency. These nanolayers are distinguished by their extreme toughness and low friction coefficient, which substantially reduces material wear. They increase the lifespan of appliances while decreasing the amount of maintenance and repair required. Such nanoscale surface-protective layers are applied to tools, motors, gearboxes, other machine components and oil-free components in the textiles and food industries. [25]

21 See BioM WB GmbH (2011)
22 See Fuchs, W. (2011)
23 See Bayer AG (2011)
24 See Innovationsallianz Carbon Nanotubes (2011)
25 See Leson, A. (2007)

There is no question that nanotechnology holds the promise of new approaches that can increase material efficiency and therefore ease the burden on the environment. What we **do not know enough about**, however, is **the possible impact of nanoparticles** on the health of human beings and the environment. There are as yet no suitable, standardized instruments and methods for detecting and analyzing nanoparticles in the natural environment. It is therefore difficult at present to assess the risks associated with synthetic nanomaterials entering the Earth's soil, water and air. [26]

The challenge is to use the potential of nanomaterials and at the same time to develop a "culture of innovation rooted in the precautionary principle." [27] Letting ourselves be **guided by the paradigm of "sustainable nanotechnologies – green nano"** can help us master this challenge. This green nanotechnology paradigm was formulated by the government's NanoKommission. It is based on the **design principles** published by the NanoKommission, which are as follows: [28]

- Biomimetics (use of local resources and energy sources, self-organization as a principle of manufacturing, where possible physiological manufacturing conditions – soluble materials, pH-neutral, low pressure and temperature)
- Minimal risk (prevention and reduction of hazardous structures, morphologies, substances, functionalities and potential exposures)
- Energy and environmental technology (emissions reduction, environmental monitoring and remediation, and switching to renewable materials and energy sources)
- Resource efficiency (preventing/minimizing side reactions, wastes and emissions, low material intensity, energy efficiency throughout the lifecycle, recyclability).

Renewable resources

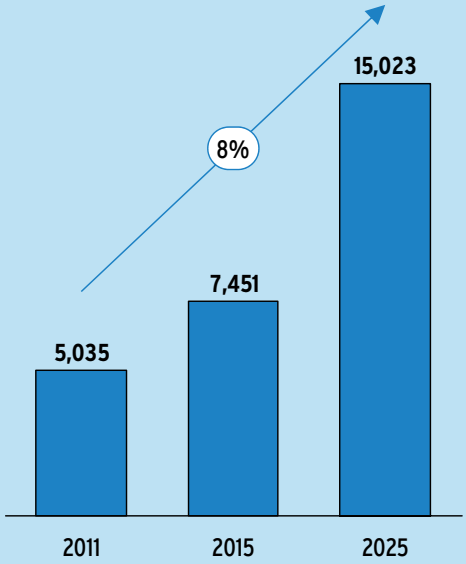
The renewable resources market segment comprises technologies that can be used to replace finite fossil resources with renewable biogenic resources. Substitution of this kind is important in the effort to increase resource efficiency. We look at three different areas below – use in industry, composite materials and bioplastics – to demonstrate the broad spectrum of applications that exist for renewable resources.

Renewable resources are "products of agriculture and forestry that are not used as foodstuffs or animal feed." [29] They can be used for energy, in other words for power generation, and for materials. The plants are called energy or industrial crops, depending on what they are used for. An area of land covering 2,151,000 hectares was used for the cultivation of renewable resources in Germany in 2010. Industrial crops took up around 317,000 hectares of that area. Industrial crops produce the raw materials that go into industrial starch, industrial sugar, technical rapeseed oil, technical sunflower oil, technical linseed oil, plant fibers, pharmaceutical substances and dyestuffs. [30]

Renewable resources have a number of advantages. They are not finite, ensuring security of supply. During their growth phase they bind carbon dioxide; when used as materials they conserve this greenhouse gas. Renewable resources therefore offer an attractive alternative to petroleum-based raw materials, especially for the chemicals industry. Industry used around 3.6 million tons of renewable resources in 2008, with around three-quarters of that total going into the chemicals industry. [31] Renewable resources thus account for around one-tenth of the total raw material requirements of the German chemicals industry. [32]

26 See Umweltbundesamt (2011d)
27 See Bundesumweltministerium (2010), p. 6
28 The NanoKommission was established by the German government in 2006 as a "national platform for dialogue." Its members represent a variety of stakeholder groups (business, academia, public authorities at the national and Länder level, environmental and consumer organizations, unions and churches). The NanoKommission set up a working group to address the concept of "sustainable nanotechnologies – green nano". The initial results of its dialogue appeared in a paper entitled "Responsible Use of Nanotechnologies. Report and recommendations of the German NanoKommission 2011"; see Bundesumweltministerium (2010), p. 11
29 Fachagentur Nachwachsende Rohstoffe e.V. (2011a)
30 See Fachagentur Nachwachsende Rohstoffe e.V. (2011b)
31 Ibid.
32 See Fachagentur Nachwachsende Rohstoffe e.V. (2011c)

Figure 52: Market forecast for renewable resources, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

Use in industry

Numerous examples exist of the use of renewable resources in industry. Here, we focus on surfactants, paints and varnishes, adhesives and lubricants by way of illustration.

Surfactants are detergent substances that are used in washing and cleaning agents and cosmetics. They were previously manufactured mainly from oil, and they left behind substantial quantities of pollutant in the water. Surfactants made from renewable resources are completely biodegradable and kinder to the skin than oil-based versions. The main vegetable oils used are coconut oil and palm kernel oil, but sugar and corn and potato starch may well be used in the near future: A number of research projects are making progress on the use of domestically available raw materials for surfactant manufacture.

Paints and varnishes made from renewable resources perform comparably to conventional chemical paints. Common flax, also known as linseed, is where we get linseed oil from. Containing as much as 67 percent linolenic acid, it is a drying oil that is used to manufacture paint and printing ink. [33]

Hot-melt adhesives (also known as hot glue) are applied to surfaces hot; as they cool down, they set. Polyamide hot-melt adhesives with a fatty-acid basis can be manufactured using renewable resources.

Lubricants mainly produced from renewable resources have many different areas of application. They can be used not only as a lubricant to minimize friction but also as a hydraulic oil for power transmission and as a gearbox oil. Both animal fats and vegetable oils can be used as the basis for biolubricants; the most commonly used material in Germany is rapeseed oil. Vegetable oils can be used in their native form or be converted into synthetic esters. Biogenic lubricants are non-toxic, free of heavy metals and quick to biodegrade. Despite these enviable properties, they make up a relatively small portion of the total lubricant market in Germany – only about 4.6 percent or 46,500 tons.

Composite materials

Combining natural fibers with plastics results in materials that are not only one-third lighter than conventional fiber composites but also highly stable. For example, natural fiber reinforced plastics (NFRP) are popular in automotive manufacturing. Fibers that can go into doors, rear shelves, trunk linings, the dashboard and exterior of the vehicle include hemp, flax and exotic fibers such as jute, kenaf, sisal and abacá. The average car made in Germany contains about 16 kilograms of natural fibers.

33 For more on the examples below, see Fachagentur Nachwachsende Rohstoffe e.V. (2011c)

KETCHUP IN A SUGARCANE BOTTLE

Having already been recognized as pioneers back in 1983 when they introduced plastic packaging, Heinz are doing it again with the launch of their PlantBottle®. Consumers will not notice the change, however, as the new composition of the bio-based bottles is not visible from the outside. The resin that the bottle is made out of is produced from 30 percent sugarcane ethanol. This enables an enormous reduction in the quantity of mineral oil that usually goes into manufacturing plastic. The bottle is made out of 50 percent recyclable plastic (PET).

Heinz say they would not have been able to launch the PlantBottle® without their close cooperation with Coca-Cola. The beverage corporation started using bio-bottles in 2009; since then they have saved 14 million liters of mineral oil. But both companies are keen to go a step further and plan soon to bring to market a bottle made of 100 percent regenerative resources.

Source: SSPKommunikation (2011b)

Bioplastics

This is an important area for the use of renewable/sustainable resources. Bioplastics are so named partly because they are predominantly manufactured from renewable resources such as corn, starch, wheat or potatoes. But the "bio" part of the name also relates to their biodegradability. Indeed, it is this attribute that represents the big plus point for bioplastics, given that plastic waste stays around for hundreds of years and is particularly damaging for the ocean ecosystem.

The history of bioplastics actually began in the 19th century – with a competition: People were asked to come up with a material to replace the ivory used in billiard balls. The winning invention was celluloid. In 1869, the Hyatt brothers established the first factory in the US for manufacturing this material out of cellulose, which they extracted from wood, and camphor.

The advent of the oil era and the industrial-scale manufacturing of the standard plastics polyethylene and polypropylene caused interest in bioplastics to wane dramatically. Only the oil crises of the 1970s and 1980s could revive the field. Ethylene, propylene and styrene are extracted from oil and natural gas; the prices of these basic chemicals therefore rose at the same pace as oil prices, providing the motivation companies needed to up their research and development activities in bioplastics. As a result, bioplastics are now able to replace conventional plastics in many areas of application.

Bioplastics are today used predominantly in packaging, products for landscape gardening and horticulture, disposal tableware and medical products. The "ecoplastic" product spectrum in the consumer segment ranges from fruit bowls to compostable flowerpots and even absorbable screws and nails to help broken bones mend.

The packaging industry has long used bioplastics, for instance for food packaging, grocery bags and garbage bags. Experts expect 70 percent of packaging to be made from bioplastics in the long term. [34] Rewe and Aldi already offer compostable grocery bags. Puma, too, launched its Clever Little Shopper at the end of 2011 – a bag made completely out of corn. Once composted, is completely dissolves within three months. If you put it in hot water, it takes just a few minutes. Puma plans to save 192 tons of plastic and 293 tons of paper per year with the new bag.

The first fully compostable mineral water bottle was launched in Italy recently, made out of a plastic produced from corn. It rots within 80 days of being thrown away. Moreover, no oil is needed to produce the bottle. Manufacturing 50 million of these bottles rather than the usual PET version would save enough energy to supply 40,000 people with electricity for a whole month. [35]

Bioplastics are finding increasing application in industry, too. In automotive engineering and the electronics industry, for instance, they are used to make such products as cell phone casings and computer hardware. Fujitsu brought a bio-keyboard onto the market in 2010, made out of 45 percent bioplastic. [36] Toyota plans to use the bioplastic known

34 See SSPKommunikation (2011a)
35 See SSPKommunikation (2011b)
36 See Wissens- und Informationsnetzwerk Polymertechnik (2011)

as "bio-PET" for interior trim and other materials inside its vehicles. The sugarcane-based material premiered in the Lexus CT. They intend to start marketing a model with an interior trim consisting of 80 percent bio-PET in 2011. According to the car manufacturer, the better heat stability, durability and shrink resistance offered by this material are what distinguish it from the bioplastics used to date. [37] Toyota has been using bioplastics in automotive engineering since 2000. In the Sai hybrid model launched in 2009, 60 percent of the interior surfaces are made from bioplastics. As far as bio-PET is concerned, Toyota is confident that the cost gap between conventional and biological plastics will diminish as production volumes increase.

It is true to say that bioplastics currently cost between two and four times as much to make as petroleum-based plastics. But this gap will narrow. On one hand, the price of bioplastics will fall as production volumes rise due to economies of scale and learning curve effects. At the same time, the difference in price will become less marked if the price of fossil fuels continues to rise. In light of this trend, the market share of bioplastics is set to grow substantially.

37 See Otterbach, B. (2011)

Sustainable mobility

The mobility of people and commodities is the grease that makes the wheels of modern societies and economic systems go round. Moreover, a person's ability to get to any place at (almost) any time is an important element in their individual quality of life. But mobility comes at a price, and that price is increasing damage to the environment and growing resource consumption.

In 2010 there were around one billion vehicles on the roads across the globe. Transportation experts predict 2.5 billion cars worldwide by 2050. These forecasts of a surge in traffic volume set alarm bells ringing with respect to climate change: **mobility by land, sea and air currently accounts for around 23 percent of global CO_2 emissions.** The share is 24 percent in the Member States of the European Union and 30 percent in the US. [1] A **majority (73 percent) of transportation-related CO_2 emissions are caused by road traffic.**

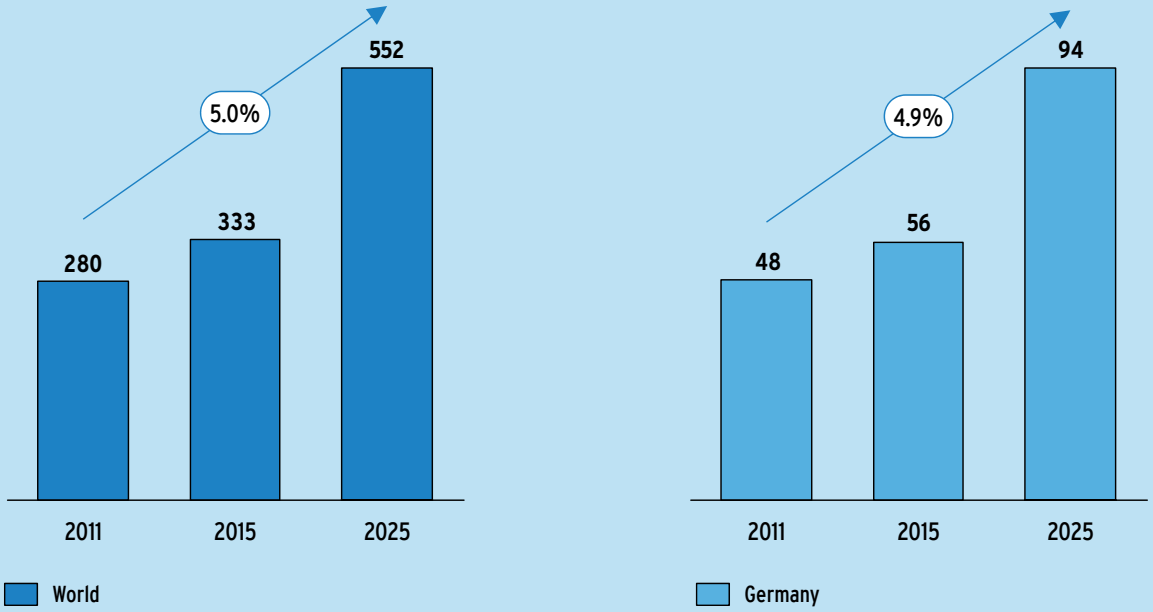
In Germany, the transportation sector consumes around one-third of final energy and causes about one-fifth of CO_2 emissions. [2] The federal government has set reduction targets in its energy strategy: final energy consumption in the transportation sector has to fall 10 percent by 2020 and about 40 percent by 2050 (compared to 2005 levels). [3]

Concepts and technologies for resource-sparing and environmentally friendly mobility are called for if we want to make the transportation sector fit for the transition to a low-carbon economy. The players in the lead market for sustainable mobility will be instrumental here. The market is subdivided into **four main areas of action**, which also constitute the principal market segments. The **market segment concerned with increasing efficiency and reducing emissions** continues to play a crucial role within this lead market, given that cars with conventional drive systems will still make up the bulk of vehicles on the roads worldwide over the coming decades. That is why the carbon footprint of transportation will improve only if diesel and gasoline engines also become more efficient.

The **market segment for alternative fuels** has an important function in reducing oil dependency in the area of mobility. Whereas the volume of traffic is increasing, especially in emerging nations, oil as the key resource for present-day mobility systems is becoming ever scarcer and more expensive. Forecasts by the International Energy Agency (IEA) indicate that crude oil will cost 113 US dollars a barrel in 2035 (at 2009 US dollar prices). Other estimates predict that prices will rise to as much as 204 US dollars. **The growing importance of the market segment for**

1 See International Energy Agency (2010b)
2 See Umweltbundesamt (2010b)
3 See Bundesministerium für Verkehr, Bau und Stadtentwicklung (2011a)

Figure 53: Market forecast for sustainable mobility, 2011, 2015 and 2025 (in EUR billion, average annual change 2011-2025 in percent)



Source: Roland Berger market model

alternative drive technologies is also grounded in the objective of decarbonizing mobility in the long term by moving away from oil-based fuels. And as the linking pin across all modes of transportation, the **market segment for transportation infrastructure and traffic management** illustrates how innovative measures and technologies can reduce mobility-related emissions. Smart transportation strategies that optimally link up different modes of transportation **have an important role to play** here. The focus lies on the expansion of rail transportation, which has a particularly good environmental record and carbon footprint.

Increasing efficiency and reducing emissions

The increasing volume of traffic is taking its toll: It is damaging the environment and endangering human health. **Noise, pollution and CO_2 emissions are the flip side of mobility.** There is no getting away from the fact that greenhouse gas and other traffic-related emissions need to be cut. Besides alternative drive technologies and alternative fuels, this objective is also served by more efficient internal combustion engines, environmentally friendly vehicle engineering and design, and technologies to reduce emissions.

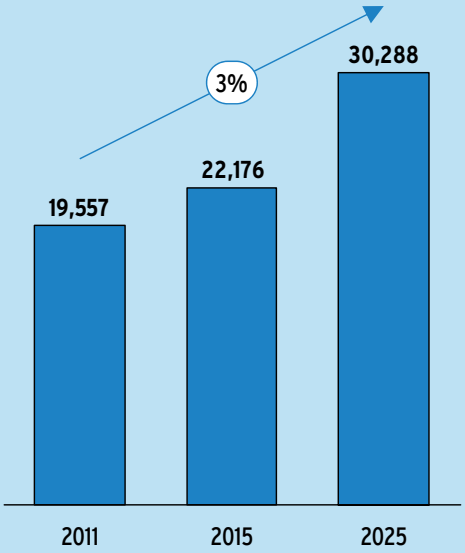
Increasing the efficiency of internal combustion engines

Increasing the efficiency of internal combustion engines cuts fuel consumption in vehicles and reduces emissions of CO_2 and other pollutants (see figure 55). According to the German Association of the Automotive Industry (VDA), **average consumption by internal combustion engines in German vehicles fell 10 percent between 2007 and 2010.** [4] A number of technical measures helped bring about this reduction:

- **Direct injection:** The fuel is injected directly into the combustion chamber of the engine with a pump. In gasoline engines this technology cuts fuel consumption by 8 percent on average, in diesel engines by 15 to 20 percent.

4 See Verband der Automobilindustrie (2011), p. 110

Figure 54: Market forecast for increasing efficiency and reducing emissions, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

- **Downsizing:** Engine size is reduced without impacting the power output. Turbocharging substantially boosts engine efficiency when cylinder capacity is lower: It increases the density of the intake air, thus reducing filling losses and improving the engine's efficiency. The smaller engine can then achieve the same power level and running performance as a large engine on up to 20 percent less gas. [5]
- **Automatic start-stop system:** This reduces fuel consumption by up to 3 percent, as the car consumes less fuel at traffic lights and in stop-and-go traffic.

Environmentally friendly vehicle design (including lightweight engineering technologies and drag reduction systems)

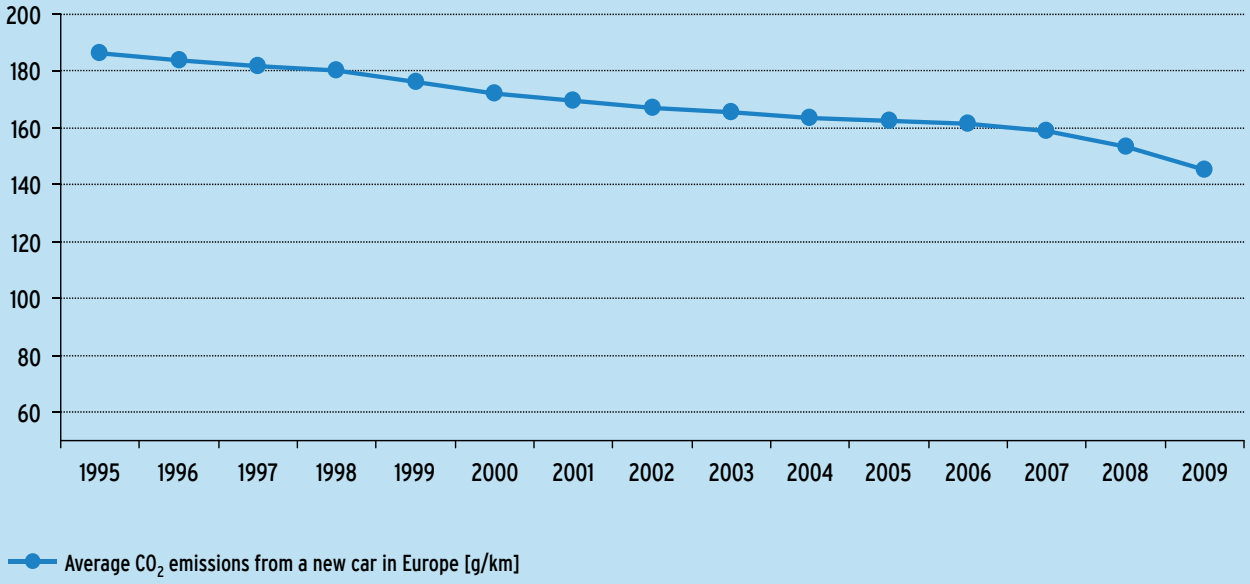
Consistent lightweight engineering can bring a vehicle's weight down by half compared with conventional engineering methods. And the lighter the car, the lower the fuel consumption: A standard-size car that loses 100 kilograms of weight consumes as much as 0.3 liters less fuel per 100 kilometers.

The **combination of lightweight engineering and electric drive systems** opens up new avenues in automotive manufacturing. At the 2011 Frankfurt Auto Show, BMW presented the "i3 concept" model from its new "i" sub-brand. The "i3 concept" was designed as an electric vehicle for city traffic; ultra-lightweight construction offsets the weight of the battery. The chassis is built of aluminum and the passenger cell is made of carbon fiber reinforced plastic. As a fourseater, the "i3" has a "live weight" of 1,250 kilograms. Its range is 130 to 160 kilometers and its top speed 150 kilometers per hour. The electric motor at the rear of the vehicle (170 bhp) is supplied by a lithium-ion battery. [6]

The weight of a car is not the only factor: **rolling resistance also influences fuel consumption**. Tires account for about 20 percent of a vehicle's total resistance. So reducing rolling resistance makes the car consume less gasoline or diesel. Economical tires are at higher pressure: the energy-saving tires on VW's BlueMotion models feature a tire pressure that is 0.3 bar higher than conventional tires. The development of energy-saving tires does, however, place automakers between conflicting priorities of safety and fuel economy. Clearly, reducing rolling resistance must not be allowed to impair the wheels' grip and braking performance.

5 See Deleker, J. (2010)
6 See BMW AG (2011)

Figure 55: Average CO_2 emissions of newly licensed vehicles in EU 15 states, 1995 through 2009



Source: Eurostat

THE POWERCAR – NEW DRIVE CONCEPT FOR INTERCITY TRAINS PROTECTS THE ENVIRONMENT

Deutsche Bahn (DB) is renewing its long-distance fleet. The rail operator signed a framework contract with Siemens in May 2011 for the construction of 300 electric multiple units. By 2016, the first 130 ICx trains are set to replace the Intercity and Eurocity trains built between 1971 and 1991.

The ICx enables highly flexible train configurations: A trainset can consist of between 5 and 14 compartments. It is the Powercar concept that makes it possible. This drive concept has all the components of the drive system (transformer, traction converter, cooler and four traction motors) in a single car, whereas in the ICE3 the drive unit is distributed between three cars. That is why Powercar brings greater flexibility.

The ICx also scores highly on climate protection. Its energy consumption – and therefore greenhouse gas emissions – are around one-third lower per passenger than the ICE1. It is chiefly the weight reduction in the ICx that makes it so economical: With seven compartments and a length of 200 meters, it is 20 tons lighter than its predecessors. This weight saving results from the inside bearing bogies and the extra-long compartments. An ICx compartment is 28 meters long; this makes an ICx with seven compartments the same length as another intercity train with eight compartments – and does away with two bogies and four axles.

Two variants of the ICx will be built initially: a seven-part multiple unit with three Powercars that has 499 seats and can reach top speeds of 230 kilometers per hour, which will mainly be used in the current IC network; and a ten-part ICx with up to five Powercars that can reach top speeds of 249 kilometers per hour, which will replace the ICE1 and ICE2 fleet.

Source: Siemens AG (2011d)

Technologies to reduce emissions

Although traffic-related emissions of nitrous gases, volatile organic compounds and pollutants such as diesel soot, PAH [7] and benzene have fallen in recent years, a **further reduction is needed to bring emissions down to the maximum levels prescribed for guaranteeing air quality**. Various technologies are being applied here.

For instance, the nitrogen oxide limits in the Euro 5 exhaust emission standard in place since September 2009 are now being achieved by measures inside the engines themselves, especially optimizations to turbocharging, exhaust gas recirculation and injection. Euro 5 sets the limit for nitrogen oxide emissions at 60mg/km for cars with a gasoline engine and 180 mg/km for diesel. [8]

Exhaust gas recirculation systems alleviate air pollution by directing some of the exhaust gases back to the engine, where they are mixed with fresh air and used in the combustion process. This reduces the formation of nitrous gases in the exhaust fumes.

Furthermore, **filtering techniques help restrict diesel soot emissions**, which are carcinogenic. Particle filters can be used to filter the tiniest of incompletely combusted carbon particles or hydrocarbon residues measuring just a fraction of a micrometer out of diesel engine exhaust fumes.

However, **adhering to the Euro 6 limits** – which are binding for all new vehicle types from September 2014 – **demands** increasingly **wide-ranging technology**, such as modern methods of exhaust gas after-treatment. [9] The two technologies used here, **SCR (selective catalytic reduction) and the NOx storage trap**, are capable of reducing nitrogen oxides in spite of the low oxygen content in the exhaust fumes in consumption-optimized diesel and lean-mixture gasoline engines.

Alternative fuels

Conventional petroleum-based fuels continue to dominate the transportation sector. Given the finite nature of oil reserves, the pollution of the environment and damaging CO_2 emissions, there is a growing urgency and motivation to weaken the dominance of conventional fuels by increasing the use of alternative fuels. Alternative fuels are basically all fuels that present an alternative to conventional fuels such as gasoline and diesel. **Alternative fuels** can be subdivided into fuels that are extracted **from fossil energy carriers** and fuels made **from biogenic energy carriers ("biomass")**.

Biofuels offer the **dual advantage of preserving diminishing oil reserves and reducing our dependence on oil imports**. They also **emit fewer greenhouse** gases than conventional fuels. Nevertheless, the topic is still controversial in some respects, as in the "food versus fuel" debate. Cutting down rainforests or introducing biodiversity-reducing agricultural monocultures in order to grow energy crops undermines the climate policy advantages of biofuels. The government enacted the **Biofuel Sustainability Ordinance** in a bid to curb these negative effects. Accordingly, biofuels are only considered to have been sustainably produced if, throughout the entire production and supply chain, at least 35 percent less greenhouse gases are emitted than would have been emitted in the production of fossil fuels. And areas of land with a high carbon content or a large degree of biodiversity are also ruled out as locations for the production of biofuels.

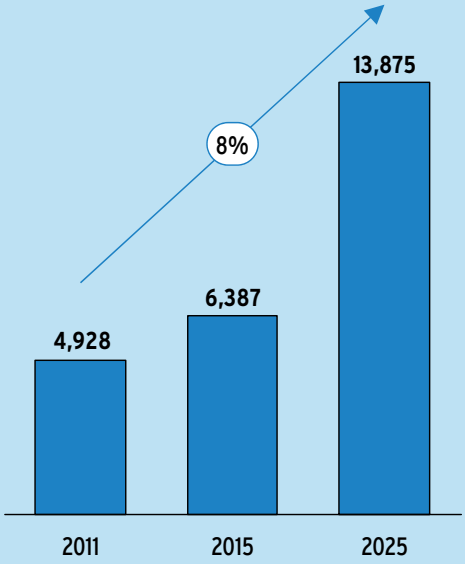
Only biofuels that meet these criteria enjoy tax breaks and can be included in the obligatory biofuel quota. Such fuels are weighted double for quota fulfillment purposes in order to give oil companies an incentive to make greater use of biogenic waste and residues in the production of biofuels instead of concentrating on conventional biomass sources (corn, rapeseed, wheat, etc.).

Demand for biofuels in Germany picked up again **in 2010** after falling slightly for several years: **biofuel sales totaled 3.8 million tons** (following 3.5 million tons in 2009). [10] Bioethanol experienced the biggest growth, at 28 percent; biodiesel sales were up 3 percent, though vegetable oils played only a minor role in the biofuels portfolio, at just 61,000 tons.

The **manufacture of biofuels from plant sources takes place on the basis of various chemical processes**, including oil extraction and subsequent transesterification, fermentation and distillation.

7 Polycyclical aromatic hydrocarbons
8 See Umweltbundesamt (2011e)
9 See Honeder, J., et al. (2009)
10 See Bundesumweltministerium (2011c), p. 10

Figure 56: Market forecast for alternative fuels, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

Biofuels can either be used in their pure form or mixed with fossil fuels. **First, second and third generation biofuels exist.** Characteristic of first generation biofuels is the fact that only a small portion of the plant and its corresponding oil, sugar or starch content can be used to manufacture fuel. **First generation biofuels** include the following:

- **Vegetable oils** ("natural diesel") can be extracted from plants such as oilseed rape, sunflowers or false flax
- **Biodiesel** is made from vegetable oils by esterification with methanol. Since 2009, diesel fuel has had a 7 percent rather than 5 percent biodiesel admixture.
- **Bioethanol** can be extracted from sugar beet, sugarcane or wheat. Since December 2010, gas stations in Germany have been selling types of gasoline consisting of up to 10 percent bioethanol – E10 (the "E" stands for ethanol and the "10" for what percent admixture it contains). Prior to the launch of the E10 fuels, the proportion of bioethanol in gasoline was 5 percent.

Second generation biofuels can be extracted from plant residues and wastes. [11] Almost the entire plant can be used, including the cellulose in some cases, which increases the efficiency of these biofuels compared with the first generation. Second generation biofuels include the following: [12]

- Biogas, treated to the quality of natural gas, can be used as a fuel for cars running on natural gas.
- Biomethane is extracted from biomass and constitutes the largest fraction of biogas, at 50 to 70 percent.
- Biomass-to-liquid (BtL) fuel is made from biomass such as wood or straw. Work on this process is still in the research and testing phase.
- Scientists are currently studying processes for extracting cellulosic ethanol from plant-based biomass (bioethanol on a lignocellulose basis).

Biomass from algae or its individual constituents (lipids, carbohydrates, hydrocarbons) is used to make third generation fuels. The advantage here is that the biomass productivity per unit of area is higher than for plants. Furthermore, algae reactors are not in competition with food production, given that nutrient-rich waste water and otherwise worthless land can be used.

Nevertheless, alternative fuels based on algae are not yet ready for market due to the high costs of commercial utilization and the fact that the technology is still in the research and development phase. The current status of research indicates that third generation biogenic fuels would be especially suitable for biodiesel, biogas and bioethanol. [13]

11 See Umweltbundesamt (2010c)
12 Ibid.
13 See BiomassEnergie (2011)

TAKING OFF WITH VEGETABLE OIL

There is no alternative to the combustion engine in aviation. Given that the Earth's oil reserves are diminishing and becoming ever more expensive, plus the fact that they release damaging CO_2 when burned, the topic of alternative fuels for aircraft is becoming increasingly important. Lufthansa has bundled all of its activities in the renewable energies arena under the name "PureSky". Investigating biofuels is a particular focus area.

The airline initiated the "burnFAIR" research project in July 2011: Over a period of six months, an Airbus 321 will be flying regularly between Frankfurt and Hamburg with its engines powered by a 50-50 mixture of conventional and biosynthetic kerosene. It is hoped that this long-term test will provide answers to questions such as how the use of biofuels affects the maintenance and lifespan of the turbines.

Lufthansa fills the aircraft fuel tank exclusively with biokerosene derived from sustainably produced biomass. Its main components are vegetable oils made from jatropha or false flax and animal fats.

Source: Deutsche Lufthansa AG (2011)

Alternative drive technologies

Bringing CO_2 emissions in the transportation sector down to the extent required to reach national and international climate objectives cannot be achieved solely by improving the efficiency of conventional internal combustion engines. According to experts, actions to cut fuel consumption can realize a CO_2 reduction of up to 30 percent in diesel engines and up to 40 percent in gasoline engines. It is therefore **crucial for the extensive decarbonization of the transportation sector that the market penetration of vehicles with alternative drive technologies increase substantially**. This includes **hybrid technologies, electric drive systems (battery electric drives)** and **fuel cell drive systems**.

Hybrid engines

Hybrid, of course, means mixed. The engine in **hybrid electric vehicles** (to give "hybrid vehicles" their full name) consists of an electric motor plus a combustion engine. For starting the car and getting it going, the electric motor is the only means of power used, supplied with energy from the battery. Each of the two engines then kicks in at different times depending on requirements: In normal running, the gasoline engine operates on half power and the electric motor on full power; when the vehicle is accelerating, both systems run on full power; and when braking, the gasoline engine switches off and the electric motor charges up the battery with the kinetic energy from the braking process.

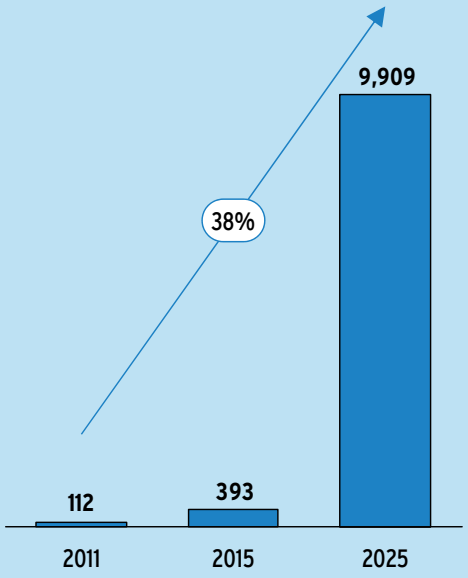
Plug-in-hybrids (PHEV) can be charged up not only by the vehicle's battery but also by electricity from the grid. Given sufficient battery capacity, they can travel up to 80 kilometers on electric power only.

A hybrid drive system offers numerous advantages. First, the car runs on its electric motor in stop-and-go traffic. That means the environment is spared the emissions generated by a combustion engine. And second, the combustion engine in a hybrid vehicle is in a favorable torque range, which makes it highly efficient. This cuts fuel consumption by up to 50 percent compared with a conventional gasoline vehicle.

All of the major international and German automakers now **mass produce hybrid vehicles**. Daimler was the first European car manufacturer to market a mass-produced car with a hybrid engine: the hybrid version of the Mercedes Benz S 400, launched in 2009. The car is based on the concept of a space-saving lithium-ion battery and a 15 kilowatt (20 bhp) electric motor to support the gasoline engine in city traffic in particular. [14]

14 See Daimler AG (2011)

Figure 57: Market forecast for alternative drive technologies, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

Electric drive systems (battery electric drives)

The energy to drive a vehicle of this type comes from a battery that can be charged up with electricity from the grid. **Instead of gasoline or diesel, the car's "fuel" is electricity: This drives an electric motor that converts electrical into mechanical energy.** The idea behind the electric drive system is not a 21st century invention: As long ago as 1899, the electric race car "La Jamais Contente" was managing speeds of over 100 kilometers per hour. And the electric version of the Ford Transit was already on the roads as a milk float in England back in the 1970s. Research and development work on electric vehicles was not taken forward, however, as the oil wells were still gushing. For a long time, progress was slow on solving the problem of how to store energy in large enough quantities to operate an electric motor. One of the first breakthroughs was the invention of the lithium-ion battery in 1991.[15] In view of the finite nature of oil reserves and the environmentally damaging greenhouse gas emissions caused by fossil fuels, electromobility is currently experiencing something of a renaissance.

The great benefit of e-mobility is that no CO_2 is emitted during the operating phase. A well-to-wheel analysis must take account of other parameters in the CO_2 footprint, however: How **environmentally friendly this drive technology is, is largely determined by the method employed to generate the electricity used to charge the batteries.** If electric cars are powered by electricity from renewable sources, electromobility represents a major contribution to sustainability in the transportation sector.

Electric vehicles have also been earmarked for an instrumental role in the transformation of Germany's energy system: Given strong market penetration, **fleets of electric vehicles** could be hooked up to the electricity grid to provide **mobile energy storage**. This presupposes the establishment of a smart grid and ICT solutions to enable the exchange of data between the vehicle, charging station and distribution grid. Electric vehicles could thus make an important contribution to integrating renewable energies into the grid because, by providing storage, they would absorb the fluctuating feed-in of fuels such as wind power or photovoltaics and thereby moderate peaks in electricity supply and demand **(vehicle-to-grid)**.

The German government considers electromobility "an important element in a climate-friendly energy and transportation policy" [16] and wants to establish Germany as a "lead market" and "lead provider" for electromobility. [17] The **government's electromobility program** adopted in May 2011 formulates the goal of one million electric cars on

15 See o.V. (2011c).
16 Regierungsprogramm Elektromobilität (2011), p. 5
17 Ibid., p. 7

UNLIMITED MOBILITY – OPEL AMPERA WITH PERMANENT ELECTRIC DRIVE

Europe's first electric vehicle with an extended range – the Opel Ampera – went into mass production at the end of 2011. The five-door car with permanent electric drive achieves top speeds of about 160 kilometers per hour with its 150 bhp electric motor. A lithium-ion battery (16 kilowatt-hours) can store enough energy for a range of 40 to 80 kilometers. And if you want to travel further, not being within reach of an electrical outlet is no obstacle: When the battery charge is low, an onboard generator switches on to continue supplying the motor with electricity (known as "extended-range electric vehicle technology"). The generator is driven by an efficient gasoline engine. This increases the car's range to about 500 kilometers without having to stop at a gas or charging station. Opel guarantees the built-in battery for eight years or 160,000 kilometers. According to the manufacturer, the Ampera emits less than 40 grams per kilometer of CO_2.

Source: Adam Opel AG (2011)

Germany's roads by 2020 and six million by 2030. The government is focusing its efforts to bring these plans to fruition mainly on supporting research and development (R&D) in the field of battery technology. Increasing the energy density of batteries is seen as a key step along the path to creating a mass market for electromobility.

Fuel cell drive systems (H_2 mobility)

Fuel cell vehicles do not get the power for their drive system from the electrical outlet or the charging station. Instead, their power is generated onboard: hydrogen (H_2) is split into protons and electrons inside a fuel cell consisting of two electrodes coated in a platinum catalyst. The **chemical energy released** in this process is **converted into electrical energy** that drives the engine. The byproduct of the reaction is water.

Vehicles with fuel cell drives have the advantage of being very similar to cars with combustion engines in terms of their range and refueling system. Like electric cars, hydrogen-powered cars are CO_2 free. However, a well-to-wheel analysis must also take into account that the **production of hydrogen** is **very energy intensive**. A "green" – in other words, virtually CO_2-free – option for achieving market penetration with fuel cell vehicles is to produce hydrogen with energy from regenerative sources. Hydrogen could then function as a storage medium and support the integration of renewable energies into the grid. [18]

According to the German government's declaration of intent, there are to be 500,000 fuel cell vehicles on German roads by 2020. To pave the way for meeting this target, the market penetration of fuel cell drive systems is being promoted under the National Hydrogen and Fuel Cell Technology Innovation Program (NIP). [19]

The individual elements in the alternative drive portfolio complement each other very well in respect of the different mobility needs of potential users. Whereas electric cars are ideal for city driving or distances of around 100 kilometers, fuel cell vehicles are better for longer distances. They are also fairly similar to conventional vehicles when it comes to refueling, which will make it easier for gasoline and diesel car drivers to make the switch. But the market penetration of hydrogen mobility is still in the early stages, so the choice of models and the filling station infrastructure is still limited. With plug-in hybrid and hybrid vehicles, on the other hand, drivers can already go the kind of long distances that they are used to.

18 See the sections *Distributed power supply structure and Environmentally friendly power generation and storage* for more details

19 The NIP was initiated in 2006 as a strategic alliance between business, academia, the Federal Ministries of Transport, Building and Urban Development (BMVBS), Economics and Technology (BMWi) and Education and Research (BMBF) and the Federal Environment Ministry (BMU) as part of the High-Tech Strategy for Germany. The objective of the ten-year initiative is to get products and applications that are based on hydrogen and fuel cell technology ready for market. The NIP's budget of EUR 1.4 billion comes half from the government and half from industry. See Bundesministerium für Verkehr, Bau und Stadtentwicklung (2008)

HYBRID STREETCAR SYSTEM – AUTONOMY FROM THE OVERHEAD LINE

It is not only cars that can have hybrid drives: they are also available for rail vehicles: Siemens has developed a hybrid streetcar that can travel 2.5 kilometers without contact with the overhead line – thanks to a hybrid energy storage system consisting of double layer capacitors and nickel metal hydride batteries. The high-tech streetcar converts some of its braking energy into electrical energy, stores it and uses it for power. This technology, which can also be retrofitted in existing streetcars, consumes 30 percent less energy than conventional streetcars and produces 80 tons less of CO_2 emissions per year.

These environmental benefits are coupled with another big plus: Where overhead lines are eyesores (along historical streets, say), they can be removed, as the hybrid streetcars can manage a limited distance without any external power supply. Overhead lines can also be removed in places where maintenance is difficult, for instance at busy road crossings or in tunnels.

Source: German Trade & Invest (2010c), p. 12

Traffic management and transportation infrastructure

Faced with climate change and scarce resources, it is becoming ever more important to get people and commodities from A to B not only quickly but also sustainably. Speed and cost are no longer the only things that count in logistics: environmental compatibility is essential, too (energy consumption, carbon dioxide and other pollutant emissions). **Efforts to realize environmentally friendly and resource-efficient mobility concepts require smart traffic management and a modern transportation infrastructure, one which enables the interconnection of different modes of transportation and new business models such as carsharing.** These areas for action on sustainable mobility form part of the market segment for traffic management and transportation infrastructure.

Traffic management

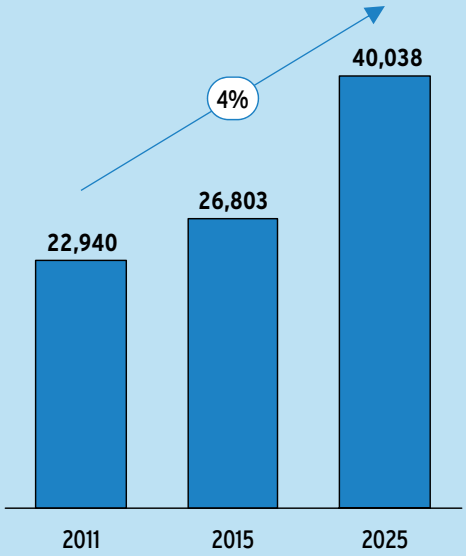
Smart traffic management systems are an important tool for efficiently controlling traffic flows and thereby avoiding congestion. Such **traffic management systems** measure the volume of traffic, specify alternative routes, adjust speed limits in line with weather conditions and traffic volume and warn drivers of tailbacks. In doing so, they reduce the risk of accidents and increase the safety of the people on the roads. **Avoiding or reducing congestion is an important means of protecting the environment** and improving quality of life for city dwellers who would otherwise be breathing in the high concentration of exhaust fumes emitted by stationary traffic. Traffic management systems also indirectly reduce CO_2 emissions and fuel consumption, which is particularly high in stop-and-go traffic.

Particularly outside of urban areas, **remote-controlled signs** are used today to regulate high volumes of traffic. These can indicate waiting times at highway rest stops or incidences of congestion, and speed limits can be adjusted to suit the situation. In this way they help avoid stop-and-go traffic, which is often what triggers tailbacks.

BMW is increasingly using **online networking** to make traffic management systems more efficient. In its Connected Drive system, all new vehicles since fall 2011 have been fitted with a traffic information system that uses real-time traffic information (RTTI) to calculate routes and recommend diversions, processing information on the actual traffic situation in real time. The system uses police traffic reports and a limited number of sensors on highways and expressways. In the future, the vehicles themselves will also act as information scouts, reporting on the current traffic situation: cell phones in the cars will create anonymous profiles of movements that will enable conclusions to be drawn about traffic density. [20]

20 See Pudenz, K. (2011)

Figure 58: Market forecast for traffic management and transportation infrastructure, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

Up to now, traffic lights have controlled the flow of traffic. But this could be reversed in the future. Scientists from TU Dresden and ETH Zurich are currently developing **a traffic light system with no supercomputer** to coordinate the traffic lights centrally. Instead, each traffic light uses detectors positioned at the beginning and end of a section of road to detect the number and speed of approaching vehicles. The traffic lights then communicate with each other, calculating when and for how long they need to be green in order to avoid interrupting the flow of traffic. According to a computer simulation for the city of Dresden, this technology could reduce traffic-light waiting times for public transportation by more than 50 percent, for cars and trucks by 9 percent and for pedestrians and cyclists by an impressive 36 percent. [21]

Traffic management in its broadest sense is also crucially affected by the choice or **combination of different modes of transportation**. Evaluating the ecological advantages and disadvantages of the different modes of transportation initially appears straightforward: A car with a lone driver struggling through stop-and-go traffic in the rush hour will obviously be worse for the environment than a train full of passengers. But in other cases it is much more complex. For instance, what is the best way from an environmental perspective to get from Munich to Hamburg: carsharing with three other people in an economical vehicle, flying on a fully booked plane, or traveling on a half-empty intercity train? As a rule, it turns out that the train and the bus are more environmentally friendly than the car for short journeys, and better than flying or driving for long journeys. **Software tools** can be helpful in making individual decisions. The www.bahn.de website offers a feature called "UmweltMobilCheck" that people can use to compare the energy consumption, CO_2 emissions, pollutant emissions and duration of trip for three different modes of transportation – train, airplane and car – for journeys within Europe.

There is an **environmental calculator** for freight traffic, too: **"EcotransIT World"** compares the transportation of goods by rail, road, water, air and combinations of the above from an ecological perspective around the world. The sophisticated IT program takes into account the parameters of energy consumption, CO_2 emissions and emissions of particulate matter, nitrous gases, non-methane hydrocarbons and sulfur dioxide.

By way of example, the environmental calculator comes up with two options for moving 100 tons of average freight from Ankara to Stockholm. Transportation by truck would entail a journey of 4,017 kilometers, consuming 447,531 megajoules of primary energy and emitting 28.28 tons of carbon dioxide. Transportation by train would mean a journey of 4,289 kilometers, consuming 139,667 megajoules of primary energy and emitting 6.38 tons of CO_2.

21 See Langbein, L. (2011)

Transportation infrastructure

Rail infrastructure

Here's a slightly different example. For transporting freight from Nuremberg to Prague, EcotransIT World comes up with the following answers: 100 tons of average freight will travel 297 kilometers between the two cities if it goes by truck, as against 624 kilometers if it makes the journey by train. That's because the train takes the freight to the Czech Republic via Austria. Rail transportation can have the best carbon footprint in the world but that's not much use if the **rail infrastructure is lacking**.

A study by the Federal Environment Agency (UBA) found that EUR 11 billion in investments would be needed for the German rail network to increase its capacity to 213 billion ton kilometers of freight traffic by 2025 (compared to 116 billion ton kilometers in 2008). The UBA study puts the new track and track expansion requirements at 725 kilometers, with 817 kilometers of track needing to be electrified. [22]

Noise protection

Around two-thirds of the population complain about noise levels. **Road traffic is one of the main sources of noise pollution, especially in urban areas.** Measures such as noise barriers and speed restrictions can offer some relief here. **Noise-reducing asphalt**, also known as porous asphalt (PA) or open-graded asphalt, is one of the technologies that can be used as a sound absorber. Unlike asphalt concrete, noise-reducing asphalt contains a high proportion of connected cavities. These absorb the road noise or prevent it being created in the first place. The noise level can be brought down by five to ten decibels by applying open-graded asphalt to a road surface. Having said that, the noise-absorbing effect of porous asphalt lasts only until the pores get blocked. The second generation of noise-reducing asphalt is already in use on Germany's streets. It is known as 2PA for short and consists of two layers.

But residents of busy streets are not the only ones to complain about noise. People who live near railroad tracks also have to cope with high noise levels from time to time, **especially along main lines or at freight traffic hubs**. Deutsche Bahn (DB) plans to halve rail-related noise between 2000 and 2020. This is one of the company's environmental targets; a number of different measures are being applied in an effort to achieve it.

RAILROAD SLEEPERS MADE FROM RECYCLED MATERIALS

Packaging materials that every household recycles could soon be being reincarnated as railroad sleepers. A consortium consisting of specialized waste management company PAV (Berlin), machine manufacturer NGR (Feldkirchen, Austria) and the Fraunhofer Institute for Chemical Technology ICT (Pfinztal) has developed a material that combines recycled plastics with waste glass-based fibrous materials. This material can then be made into railroad sleepers. The recycled railroad sleepers perform no worse in material and suitability tests than conventional concrete or wooden railroad sleepers. And their smaller mass makes them lighter, which means they are a good option for use on bridges.

Source: ShortNews (2011)

Each new freight train put into operation since 2001 has been fitted with **whisper brakes**, known as "K-blocks". Their brake pads are made not of gray cast iron but a special mix of plastics. What these do is prevent the wheel surfaces from roughening during the braking process, making squealing brakes considerably quieter. The **K-composite brake blocks** reduce rolling noise by as much as ten decibels – half as loud to the human ear.

Retrofitting the entire fleet of freight trains with K-blocks would be very costly, however, because the rail operator would have to change the entire brake system on existing trains. Given the tough competition in the market for European rail freight, customers are not prepared to pay more for noise protection. Together with a consortium of six manufacturers [23], Deutsche Bahn is looking for an economically viable solution to the problem of noise in a **research project** entitled **LäGIV**, a German acronym standing for **"noise-reduced freight traffic through innovative composite brake blocks"**. The partners plan to develop new LL-type composite brake blocks by 2014, which will be considerably cheaper to retrofit than K-blocks. The cost of the research project totals EUR 15 million, of which the Federal Ministry of Economics and Technology is contributing EUR 6.8 million. [24]

22 See Holzhey, M. (2010)
23 Wabtec/Becorit, Bremskerl, Honeywell, Federal Mogul, TMD Friction and the German Federation of the Friction Industry (VRI). See Deutsche Bahn AG (2011a)
24 See Deutsche Bahn (2011a)

Another innovation that can help with noise abatement is **rail dampers**. These are in use in the Middle Rhine Valley and in the Elbe Valley in Saxony, for example. The dampers reduce the vibration of the rails, which in turn decreases the rolling noise. Another measure to cut noise levels on the rails is to install acoustic barriers made out of gabions. These wire baskets filled with rocks are able to absorb the noise thanks to a special core of recycled material, thus providing a degree of sound insulation. **Gabion noise barriers** can be built to various heights: the smallest version is just 76 centimeters high and the tallest is five meters. [25]

25 See Deutsche Bahn (2010)

CARSHARING – DRIVE IT, DON'T OWN IT!

They'd rather have a cell phone than a car. For people around the age of 30, having your own four wheels is gradually becoming less of a status symbol than it used to be. A study by the University of Applied Sciences in Bergisch Gladbach found that 75 percent of respondents between the ages of 18 and 25 could not imagine living without a cell phone or Internet access for a month. Going without a car, on the other hand, was no problem for 60 percent of them (Honsel, G., 2011).

Though individual motorized transport continues to be the dominant form of traffic on our roads, there are some initial signs of a change in mindset – particularly in built-up areas where congestion is common and parking spaces thin on the ground. Using a car rather than owning a car is the new trend. Besides the carsharing pioneers who were already at it in the 1990s, major automotive manufacturers have recently discovered this business model, heralding a change in their role from selling cars to providing mobility services.

Under the "car2go" name, a joint venture between Daimler and Europcar offers carsharing in the cities of Austin (Texas), Ulm, Vancouver and Hamburg. The fleet in Hamburg consists of 300 Smart cars that can be used by anyone who registers as a car2go user and pays a rate of 29 euro cents per minute. Cars can be booked in advance or borrowed on the spur of the moment. The experience of the first three months showed that 60 percent of customers are 35 years old or younger. The cars are mostly used for short journeys of between 20 and 60 minutes, and often in addition to public transportation (automotiveIT, 2011).

Drive Now, the carsharing system operated by BMW and Sixt, is available in Munich and Berlin. The Drive Now fleet includes BMW 1 Series, Mini Cooper, Mini Clubman and Mini Convertible cars. As with car2go, the idea is that you can "pick it up anywhere and drop it off anywhere." Within the defined operating area – inside the Mittlerer Ring for Munich and inside the S-Bahn Ring for Berlin – customers can simply leave the car at the roadside upon arriving at their destination. Drive Now vehicles can be located and booked over the Internet or by Smartphone. The price of 29 cents per minute is all inclusive: gasoline, cleaning, road tax, parking charges and insurance are part of the package. Even Deutsche Bahn has carsharing in its portfolio of mobility services: Its "Flinkster" program has vehicles in 140 towns and cities across Germany. Smart technology is the key to modern carsharing models. Without intelligent accessories – ID, fleet management, apps for vehicle search, etc. – the use of rental vehicles would be more complex and therefore less attractive.

From an ecological point of view, carsharing is good because it makes better use of the vehicles already on our roads: one carsharing vehicle replaces 16 private cars. Carsharing can also pave the way for electromobility, like a kind of gateway drug for techno-savvy drivers keen to try out the new electric drive vehicles. Conversely, e-mobility can be expected to play an important role in the spread of carsharing. For example, car2go plans to put 300 e-Smarts each on the streets of San Diego and Amsterdam. And Deutsche Bahn is trialing 40 e-Flinksters and 40 electric bikes in Berlin as part of its "BeMobility – Berlinelektromobil" project (Deutsche Bahn AG (2011b).

Waste management and recycling

Mountains of waste threaten to touch the skies in many countries on Earth. Across the world, the volume of urban waste grew one-third between 2004 and 2008. Everywhere we look there is a clear **correlation between the wealth of an economy and the amount of waste it produces**: whereas developing nations produce 200 kilograms of garbage per capita per year, the figure in the EU 27 countries averages around 520 kilograms. With global population growth and rising income levels in most developing and emerging nations, we can almost take it for granted that the volume of waste produced around the globe will continue to grow.

In many places, this represents a considerable **risk to the environment**, given that the waste disposal infrastructure in many states is rudimentary or even non-existent. In particular, the rapidly growing metropolises in emerging and developing nations are already experiencing serious **problems with waste: unregulated storage, illegal dumping and open-air incineration** are par for the course there. Contamination of the soil, the groundwater and the aquatic environment threatens the health of mankind and the ecosystem. As we know, our oceans are misused as dumping grounds: six million tons of waste are thrown into the sea every year.

The **surging volumes of waste around the globe are also adding substantially to greenhouse gas emissions, which means there is a close connection between waste volumes and climate protection**. For one thing, the dumping of waste gives rise to landfill gases, produced as organic matter ferments. The methane emitted as a result of this process is 25 times more damaging to the environment than CO_2. Around a quarter of the world's methane emissions come from the landfill gases emanating from household refuse dumps. [1] Thus it follows that the lower the volume of waste disposed of, the less landfill gas is released. This causal relationship is what makes **waste management** a crucial element of **climate protection**.

Stemming the tide of waste is only possible through **sustainable waste management and recycling**. Germany was quick to set an appropriate course with a progressive environment policy, passing its first waste management act in 1972. The 1980s saw the establishment of the country's **waste management and recycling basic principle** in the form of the so-called **waste hierarchy – reduce, reuse, recycle**. The three Rs are the expression of a clear set of priorities: the best way of protecting the environment and reducing resource consumption is to avoid waste being created in the first place. [2] The **principle of sustainable waste management and recycling** calls for the reuse of as much of the waste as possible. The recycling of materials and the recovery of energy are instrumental in reducing resource consumption, with recycling materials taking precedence over recovering energy. Waste that cannot be recycled must be disposed of in an environmentally friendly way.

The European Union has taken numerous initiatives to support the transition to sustainable waste management and recycling, including the Directive on End-of-Life Vehicles, the WEEE Directive [3] and the 2008 amendment of the Waste Framework Directive. The latter is one of the key European directives in this context.

1 See Bundesumweltministerium (2011e), p. 32
2 The main levers for avoiding waste are presented in the lead market for material efficiency
3 Waste Electrical and Electronic Equipment

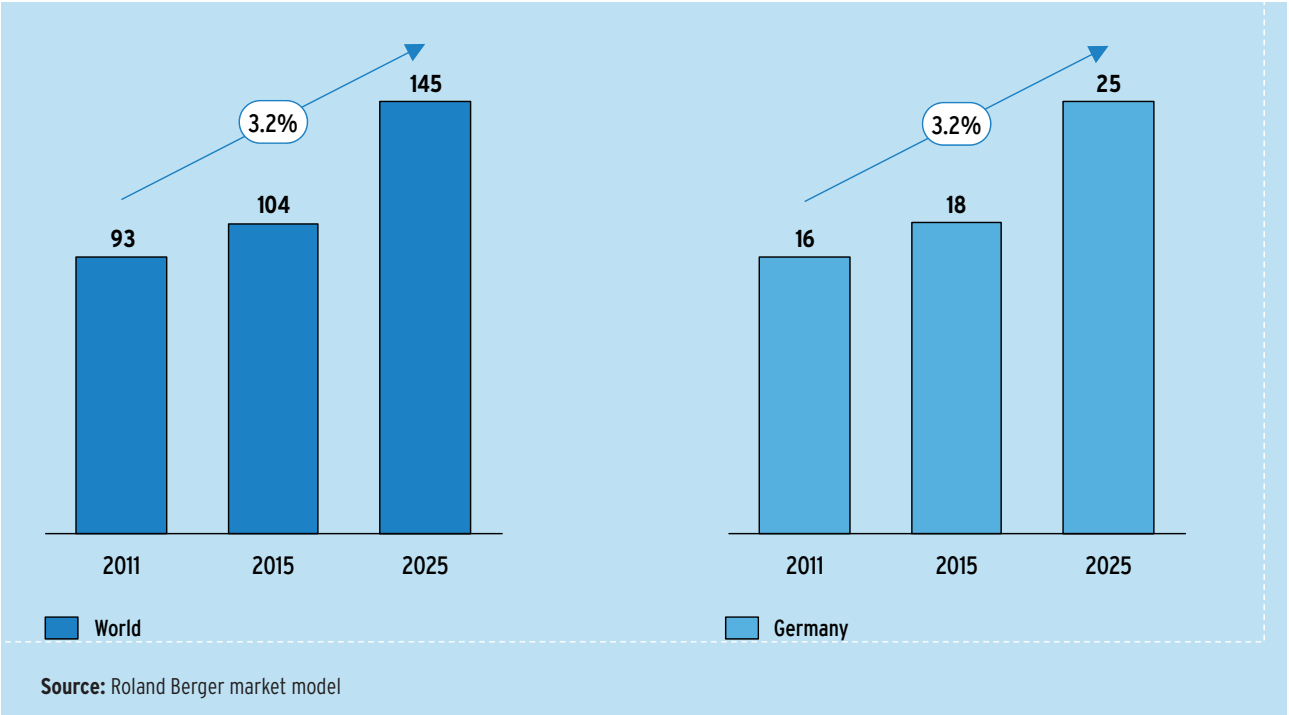
In October **2011, the German Bundestag passed the new Closed Substance Cycle Act**, which also serves to **transpose the EU's Waste Framework Directive into national law**. This amendment is another step toward making sustainable waste management and recycling a reality, with the reformulated version placing the focus of the Act more firmly on preparations for the reuse of materials and on recycling.[4] It **differentiates from the former waste hierarchy** in that it puts waste producers and waste holders under obligation to choose the most environmentally friendly option for each type of waste. The Act stipulates that biowaste as well as paper, metal, plastic and glass waste must be collected separately starting in 2015. This puts the conditions in place to enable Germany to **raise its recycling rates even further: by 2020, 65 percent of all urban waste and 70 percent of construction and demolition waste will be recycled**.

Germany's example demonstrates that, when **government policy and a growing environmental awareness on the part of consumers and companies concur**, it is possible to make the switch from a throwaway mentality to a closed cycle way of thinking about resources without there being any negative impact on wealth and quality of life. At the start of the 1970s Germany had some 50,000 landfill sites where waste could be dumped. Now there are no more than 100 landfill sites for municipal waste. This in itself illustrates the direction in which waste legislation has been going in Germany, giving precedence to recycling over landfill. Indeed, recycling is singularly important as a means of making efficient use of scarce resources and thereby keeping human intervention in the ecosystem as well as CO_2 emissions from the extraction and processing of raw materials as low as they possibly can be.

This focus on waste avoidance and recycling exemplifies the **ideal of the full-cycle concept**: this model of closed material cycles follows the principles of natural ecosystems by producing no waste, instead converting all materials into reusable resources.

This concept is reflected in the **arrangement of this lead market. The market segments of waste collection and transportation, waste separation and waste recycling represent the individual stages through which waste passes between the moment it is created and the moment it is recycled**. Even landfill is not a final destination in this concept: it is a supplier of raw materials. A number of examples in this market segment demonstrate how landfill gas can be used as a source of electricity and heat.

Figure 59: Market forecast for waste management and recycling, 2011, 2015 and 2025 (in EUR billion, average annual change 2011-2025 in percent)



Source: Roland Berger market model

4 See Umweltbundesamt (2011f)

Waste collection and transportation

Waste collection and transportation are services that form the foundations of sustainable waste management and recycling. This market segment includes the subsegments of refuse containers, the production and operation of refuse collection vehicles and the development and execution of logistics strategies for refuse collection. It involves not only the collection of domestic waste (residual waste, organic waste, waste paper and the "yellow bins" or "yellow bags" for collecting packaging waste), but also the collection of bulky waste, the disposal of hazardous substances and industrial waste and the operation of recycling depots.

According to the Federal Statistical Office, households in Germany produced some 43 million tons of waste in 2009. The volume of waste from manufacturing and commerce amounted to almost 53 million tons. If this amount of waste is to be disposed of or recycled there needs to be the proper **infrastructure in place for waste collection and transportation**. This market segment is therefore an important link in the waste management chain.

Municipal waste management departments and commercial waste disposal companies are the **players in this market segment**. The amended Closed Substance Cycle Act marks an attempt to balance the interests of municipal and commercial waste disposal operations while adhering to the rules of European competition law: [5] as public sector waste disposal organizations, local authorities retain responsibility for disposing of the waste from private households. Commercial companies may collect this waste, but if doing so they must notify the responsible authorities. A press release issued by the Federal Environment Ministry outlines the principle on which the system works. It says, "The principle will be the following: if a local authority can efficiently collect household recyclables and recycle them to a high quality itself, commercial collection companies should not hinder it in doing so. If the local authority cannot do so or chooses not to do so, it may not prevent commercial collection companies from providing households with a better service offering." [6]

As mentioned above, reducing the volume of waste is one of the key objectives of waste management and recycling; one way of making this intention a reality is by structuring waste disposal taxes, as Saarland has done. The ZKE (municipal waste disposal company) in Saarbrücken creates an incentive for people to avoid waste by hitting the consumer in the pocket. A new charging model was introduced at the start of 2011. Previously, the size of the bin and the frequency of collection determined the fee charged. Now, however, the weight is included as an additional factor. The organic and residual waste bins, which are fitted with an ID chip, are weighed after removal. To ensure that the charging regime is transparent, the invoice consumers receive for the collection of their waste containers specifies the precise weight of the bins; home owners and tenants who wish to be continually or occasionally informed of the weight of "their" bin can look up the figures in their user account on the ZKE website.

Though the infrastructure is available in all of Germany's cities and communities, not nearly everyone makes their way to the local recycling depots. A lot of garbage still ends up in the residual waste containers where it really shouldn't be. Some local authorities and their recycling depots make efforts to motivate their potential "customers". The Bergkamen recycling depot (North Rhine-Westphalia) does this with a strategy for which it was awarded the "VKS Creative Prize" from the association of municipal waste disposal and city cleaning operations (VKS). The prize is awarded mainly for customer friendliness. For example, the recycling depot, which opened in 2009, won praise for its convenient system of bulk boxes and a self-service vacuum cleaner that people can use to clean their cars after dropping off materials. And there is an outdoor handwashing basin for customers to use so that they don't sully their steering wheel with dirty hands. [7]

Another of the obstacles to people correctly separating their domestic waste was addressed by a **pilot project with compostable organic waste bags made of plastic**: keeping organic waste in the kitchen can be annoying because damp biowaste soaks through paper bags, smells bad and dirties the refuse container. The solution to these problems is provided by organic waste bags made of a compostable plastic called Ecovio® FS. The district of Bad Dürkheim (Rhineland-Palatinate) trialed the bags for three months, both to check household acceptance levels and to examine any possible reduction in the quality of the compost. The organic waste bags passed the test and were very well accepted by the consumers and the operators of the district's organic

5 See Umweltbundesamt (2011f)
6 Ibid.
7 See GWA – Gesellschaft für Wertstoff- und Abfallwirtschaft Kreis Unna mbH (2011)

compost plant. Ecovio® FS plastic is a BASF innovation consisting partly of the bioplastic (polyester) Ecoflex®FS and polylactic acid (PLA), which is derived from corn starch. Like the biowaste they contain, the Ecovio bags are broken down by microorganisms. [8]

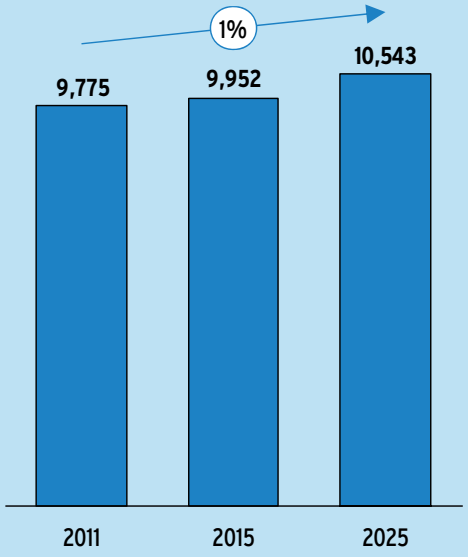
Private sector companies also have new ideas to help customers part with the recyclables in devices they no longer need. Deutsche Telekom puts the number of **discarded cell phones** in Germany at an estimated **60 million**. The company was keen to tap this wealth of raw materials and thus staged a major program to take back unused phones at Deutsche Telekom stores. The old cell phones handed in there were put back into use if they were intact and in working order, or they were taken apart and recycled. The proceeds of this campaign went to charities such as Médecins Sans Frontières and Deutsche Umwelthilfe (German Environmental Aid). [9]

Private households and companies collect residual waste, organic waste and often also waste paper in wheelie bins, which are taken away by the garbage collection service. **How energy efficient and environmentally friendly the vehicles are** is becoming an increasingly major consideration.

The immensely heavy garbage trucks consume enormous amounts of fuel due to their constant stop-and-go driving. A 26-ton vehicle can easily consume as much as 100 liters of diesel per 100 kilometers. As such, fuel consumption is a significant cost and environmental factor. In a bid to bring consumption levels down, the City of Offenbach, for instance, deploys a **vehicle type that runs on hybrid technology**. Their garbage truck is powered by a 260 bhp diesel engine in combination with batteries to feed the electric motor. [10]

Berlin's city cleaning team has embarked on a two-year **pilot project trialing fuel cell drives**. The world's first fuel cell garbage truck has been traveling the streets of the capital since June 2011. The vehicle emits neither nitric oxide, carbon dioxide nor particulate matter when loading the refuse containers. The diesel engine runs only when the vehicle is moving; it switches off when loading the bins because the fuel cell supplies the electric motor with energy during that procedure. The hydrogen-powered garbage truck therefore consumes one-third less diesel and is much quieter as well. Besides Berlin's city cleaning department, the companies involved in developing this fuel cell garbage truck were Heliocentris Energiesysteme GmbH and vehicle manufacturer FAUN.
The project received some EUR 800,000 in funding from the National Hydrogen and Fuel Cell Technology Innovation Program (NIP).

Figure 60: Market forecast for waste collection and transportation, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

8 See BASF SE (2011b)
9 See Deutsche Telekom AG (2011b)
10 See Hoven, B. (2011)

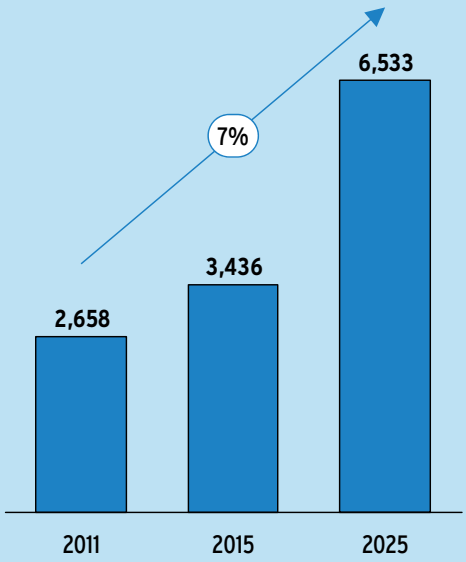
Waste separation

Waste separation is a key stage in the waste management lifecycle. **How well and how finely the recyclate is separated is the key to its quality** – and to whether the recyclables can be returned to the production cycle. The **market segment for waste separation incorporates the development, the operation and the maintenance of automatic sorting plants and the infrastructure for waste separation** – in other words, bulky waste collection depots, recycled glass containers, etc.

Black, green, yellow, brown, blue – the spectrum of colors in the recycling bins in the back yards and front gardens of Germany's homes is varied indeed. Just a few short decades ago, all domestic waste went into one container, with only returnable bottles and waste paper getting the chance of a new chapter in life. Those days are long gone, and **separating waste is now standard**, both in private households and in industry, commerce and retail. Separating waste into similar groups of materials is an important interim step in the process of waste management and recycling: separating lays the foundations for recycling. Households and businesses in Germany presort their waste prior to collection. They separate paper, biowaste, glass, metal, packaging, batteries and electrical appliances. That said, there are regional differences in separation methods and policies for the different types of waste – there are 600 different "varieties" in Europe.

A number of trials are under way to see whether and to what extent **modern sorting plants** could make sorting by consumers unnecessary. But at the moment presorting is vital. Automated processes make separating the different material streams much easier. It is important to note that the precision with which the individual material groups are separated within the streams is what determines the quality – and therefore the possible uses – of the recyclate. This requirement places significant demands on the sorting technology, depending on the material stream. One company that specializes in paper is Entsorgungstechnik Bavaria GmbH. Based in Unterschleissheim near Munich, this firm participated in an EU research project to develop a **waste paper sorting plant** to better separate waste paper into individual types (such as cardboard, printed paper, etc.). The waste paper sorting plant, which was delivered to a customer in the Austrian city of Linz, is fitted with a special sensor. This was developed by EVK DI Kerschhaggl GmbH in cooperation with paper technology specialists PTS from a sensor used in military applications. The **paper sensor** has an extended spectral range, which means it is better at recognizing molecular carbon, hydrogen and oxygen bonds. It is this ability that enables it to sort the individual types of paper more precisely. [11]

Figure 61: Market forecast for waste separation, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

11 See Entsorgungstechnik Bavaria GmbH (2010)

For other groups of materials, mechanical waste separation methods also make use of the waste's different material properties (density, strength) as well as its magnetic and spectroscopic properties. **Modern sorting technology can, for example, employ optical sensors fitted with laser technology, image recognition technology or near-infrared to recognize the different material groups on the basis of their size, shape, surface attributes, etc.** One of the world's sorting plant specialists is a company called Stadler Anlagenbau GmbH based in Altshausen (Baden-Württemberg). Their plants pull out all the stops when it comes to technological means of automatically separating recyclables, using every method from magnets to optical recognition devices and even **ballistic separators**. The plants thus use multi-stage screening systems for separating material streams into their different fractions, for instance "rolling and heavy" materials (hollow bodies, plastic bottles, stones, wood, cans, steel shapes) and "flat and light" materials (films, textiles, paper, cardboard boxes and fibrous products). Organic adhesions, such as the remains of a sandwich on aluminum foil, are screened off by the ballistic separators. [12]

Adamec Recycling GmbH from Fürth (Bavaria) is breaking new technological ground with the **recycling plant for electronic scrap** that it developed and put into operation in 2011. Capable of processing 35,000 tons per year, the plant crushes old electrical and electronic devices into pieces measuring just millimeters across. The process involves different degrees of crushing in different steps, with the various recyclables gradually sorted into more and more precise fractions. Not only does the plant enable Adamec Recycling GmbH to **recycle 95 percent of all of the raw materials** it receives, it is also able to identify and eject any plastic contaminated with halogenated flame retardants. The plastics obtained as a result of this process can be put back into the material cycle. [13]

Waste recycling

Recirculating waste back into the economic cycle reduces the consumption of raw materials, which generally helps cut CO_2 emissions. This makes **waste recycling** a crucial market segment within the lead market for waste management and recycling. The market segment encompasses aspects such as **the development, manufacturing, operation and marketing of waste incineration plants**. Another element of this market segment is the recycling of raw materials contained in the material flows of different types of waste.

Recovering energy from waste: Thermal waste treatment

Either the energy or the materials contained in waste can be recycled. One way of recovering the energy from waste is by incinerating it in a method known as **thermal waste treatment**. Energy released during the process is used to supply heat and generate power. A different form of energy recovery is used with biowaste and is usually conducted in **biogas plants.** [14]

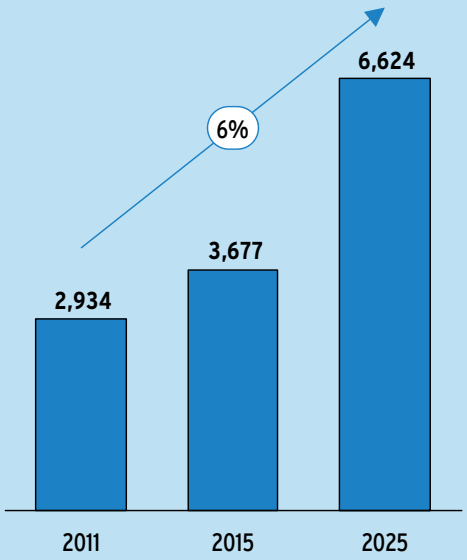
The biogas plant in Kisslegg-Rahmhaus (Baden-Württemberg) was recognized by the German Energy Agency in 2010 for its particularly innovative membrane process: the biogas extracted from food leftovers is treated with a brand new method. The biogas is energy-efficiently dried and desulfurized, and the carbon dioxide is separated using a membrane. This process produces biogas at the quality of natural gas, with can actually be fed into the natural gas grid. This **two-stage membrane treatment plant**, operated by Bebra Biogas GmbH, is the biggest plant of its kind in Germany. [15]

Recovering materials from waste: Recycling

Germany is an international pioneer in recovering materials from waste, which is given precedence over energy recovery by the Closed Substance Cycle Act. All in all, 35.2 million tons of waste are recycled (66.7 percent) out of a total of 52.8 million tons of waste produced by manufacturing and commerce. When it comes to urban waste – 48.5 million tons of it – the recycling rate is 63 percent. [16] Taking into

12 See Stadler Anlagenbau GmbH (2011)
13 See Bundesverband Sekundärrohstoffe und Entsorgung e.V. (2011)
14 See the lead market for environmentally friendly power generation and storage for more details
15 See Envio AG (2010)
16 See Statistisches Bundesamt (2011b)

Figure 62: Market forecast for waste recycling, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

account the entire volume of waste, Germany recycles almost 70 percent, against the EU 27's average of just over 47 percent. [17]

The examples of different groups of materials below illustrate the range of recycling possibilities that are available with the latest technology.

Fully 99 percent of all paper, pasteboard and cardboard waste is recycled, with a volume in excess of eight million tons. High-tech plants and processes are in use here. The particular challenge in this area of recycling is deinking, in other words **separating the printing ink from the paper**. A method called flotation deinking is used to get the inks off the paper. Though the residual printing ink is not present in particularly high quantities after the process, it does have a high calorific value, making it good for thermal recycling.

Recycling used PET bottles [18] is widely established in Germany and other European countries as a result of the deposit system and plastic collections. In the conventional recycling process, PET bottles are collected, crushed and then washed in multiple stages. However, the PET recyclate resulting from this process still contains aromatic substances and other unknown contaminants, making it unsuitable for food packaging and only usable for non-food items, such as fibers or thermoforming films. **Super-clean recycling processes** should be able to offer a solution to this problem. This method is of great significance, given the fact that raw materials make up 80 percent of the cost of manufacturing a PET bottle. There are various ways of making super-clean PET pellets, all of which demonstrate a similarly high level of cleaning efficiency. One method involves extruding the flakes and decontaminating them at temperatures in excess of 200 degrees Celsius. The technology should soon enable 50 percent of a PET bottle to be turned into recyclable materials. [19]

Material recovery is excellent when it comes to mass recyclables like glass and paper, which boast recycling rates of 99 and 100 percent, respectively. **There is, however, room for improvement with metallic and mineral resources like silver and gold, indium and gallium, copper and cobalt.** Particularly with regard to "strategic resources", those that key industries like information and communication technology, automotive and renewable energies cannot do without, the realization has yet to hit home in all quarters that, for a resource-poor country like Germany, recycling represents an essential form of procurement for costly and scarce raw materials.

17 See own calculations based on Eurostat (2011a), p. 146
18 PET: Polyethylene terephthalate, a thermoplastic of the polyester family
19 See Welle, F. (2010)

Crime statistics do already reflect this realization, however: 347,294 kilograms of copper, 675,570 kilograms of steel and 1,185,748 kilograms of other metals were stolen from Deutsche Bahn (DB) in 2010. These thefts caused the delay or cancellation of some 8,500 trains because overhead lines, rails and cables had been misappropriated. And metal theft is not only affecting rail operators. Construction sites and scrap yards across the nation are seeing anything that is not nailed down being stolen, especially copper. As far as DB is concerned, it is "clearly the drastic rise in raw material prices" that has caused the increase in such crimes.

The products of many different industries contain copper, from information and communication technology to the automotive industry and construction sector. **Copper** is especially **instrumental in electrical engineering**, where it is used for wires, cables and integrated circuits. A wind turbine contains around eight tons of copper, while an electric vehicle can have up to 100 kilograms of the metal built into it. Copper loses hardly any of its quality in processing, meaning that the metal can actually be 100 percent recycled. Copper can be recovered by mechanical, pyrometallurgical and hydrometallurgical means. Non-ferrous metals like copper can also be recovered by treating the slag from waste incineration plants and refuse-derived fuel power plants. The annual yield from this process amounts to 17,000 tons.

Discarded electrical and electronic devices are a rich source of raw materials. The volume of electronic scrap has risen continuously in Europe in recent years; forecasts indicate that there will be more than 12 million tons of electronic scrap in the European Union by 2020. [20] The Electrical and Electronic Equipment Act (ElektroG) enacted in 2005 makes the manufacturers and importers/exporters responsible for the entire lifecycle of these appliances. Producers and resellers are obligated to dispose of appliances properly at the end of their lifespan. They generally subcontract this task to specialist disposal companies. Disused electrical and electronic devices are not allowed to be disposed of with domestic waste – the raw materials they contain would be lost for one thing, and for another the domestic waste would be polluted. Consumers must therefore take their old devices to a local recycling depot or return them to the manufacturer for disposal.

This is what happens in theory. In practice, some **appliances** still end up in the residual waste bin. Or they are **disposed of by semi-legal or illegal means.** A study conducted by the Hamburg Institute of Ecology and Politics on behalf of the Federal Environment Agency found that more than 155,000 tons of electronic scrap from Germany makes its way beyond European borders. A large part of it ends up in Southeast Asia and Africa, where it is disposed of largely under conditions that meet neither humanitarian nor environmental principles. A Federal Environment Agency publication describes children melting down computer components on open fires, and women smashing up monitors and sorting the cables by hand. [21] A little better but still far from good are the conditions in many disposal plants in Asia. In China, for example, there are government-run operations with thousands of employees, where open recycling is conducted without any protective measures. The health of the workers is severely compromised by the release of heavy metals and other pollutants there. [22]

This type of disposal, which often takes place under the bogus label of serviceable appliance exports, is not only illegal, it is also unethical and immoral. **Improper disposal also means lost opportunities to extract raw materials, which, without recycling, then need to be imported at ever increasing prices.** By way of example, one ton of PC motherboards contains 300 grams of gold. And about 50,000 cell phones would need to be exploited to get one kilogram of gold.

Recycling electronic scrap is done on the basis of technologically challenging methods. Consider printed circuit boards (PCB): the PCB is first reduced to small pieces at almost 200 degrees Celsius to remove the metal. The high temperature is necessary to separate the tin solder. The mass is then placed into an etching solution, where chemicals ensure the transfer of the metals to the solution. This process results in solids such as glass or plastic and the solution containing the metals. A hydrometallurgical process then separates the metal out of the solution by means of electrolysis or ion exchange.

In the laboratories of the Institute of Waste Management at TU Hamburg-Harburg scientists are working on two methods for **recovering precious metals from electronic scrap**: in the "cold" method the electronic scrap is first shredded before the metals

20 See Kafsack, H. (2011)
21 See Umweltbundesamt (Hrsg.) (2010d)
22 See unattributed (2011d)

are separated from the plastic by mechanical means. The "hot" method involves incinerating the plastic at temperatures of up to 2,000 degrees Celsius until nothing but the metal remains. They are still a long way from seeing these methods realized on an industrial scale, however. [23]

Aurubis AG, on the other hand, is already running trials to test the practical application of precious metal recycling. The Hamburg-based company is one of Europe's biggest copper producers and is an international leader in copper recycling. In a pilot project, which is in receipt of more than EUR 300,000 in funding from the Federal Environment Ministry, Aurubis is testing a brand **new concept for recovering precious metals from anode slimes**. This byproduct of copper electrolysis contains precious metals like gold and silver. Recovering them used to be a three-stage, highly energy-intensive process. That can now be replaced with a process involving just one step and a membrane filter press. This innovation reduces the demand for energy by more than one-third. [24]

Biomining represents a new approach to the recovery of metals. Following on from positive experiences in resource extraction, it is now also being used for recycling in a number of pilot projects. In the mining sector, biomining dissolves metals out of the rock with the help of bacteria, in a departure from the previous use of furnaces to extract the metal. Sulfuric acid is added to the pellets of ore in the process of biomining. This serves as a nutrient solution for strains of bacteria that live in the rock. The microorganisms need food to grow and thrive – and their menu includes components of the ore, which they break down as they eat. What remains is an indigestible liquid from which metals can be extracted.

Biomining consumes a great deal **less energy** than conventional extractive metallurgy involving furnaces. And the **process is even economical for low metal concentrations**. These advantages are why biomining already began to be used for extracting copper and gold several years ago; the process can now be applied to other metals, including zinc, nickel and cobalt. Tests are currently ongoing to see how biomining can be used for recycling electronic scrap. Bacteria have achieved a good yield in their hunt for recyclable treasures under laboratory conditions: the microorganisms have successfully managed to extract as much as 95 percent of zinc, aluminum, copper, nickel and gold from disused appliances. [25]

There is an urgent **need for innovative recycling solutions for rare earths** in particular. 17 different metals make up the rare earth elements; [26] the word "rare" signifies not how commonly they occur but how low their concentration is in the mined metals. It is also the reason why rare earth metals can only be mined economically in a few regions of the Earth. The People's Republic of China has become the unchallenged number one place for mining rare earths, accounting for 97 percent of the world's production. China has restricted its export volumes in recent years, and prices have risen sharply. By way of illustration, the price of dysprosium (400 US dollars per kilogram) went up by a factor of ten in the space of one year. [27] Many companies in western industrialized nations are concerned by this development: rare earths are of immense strategic importance as raw materials because they are essential elements in high-tech products such as catalytic converters, fuel cells, computer monitors, metal alloys, superconductors and specialty glass.

Apart from substitution, recycling is the best way to ensure a continued supply of rare earths. Researchers at the University of Yale have identified enormous potential here: around 440,000 tons of rare earth metal oxides are contained in products around the world. This is four times the amount mined per year anywhere on Earth.[28] But it is not only the relative scarcity and cost that argue strongly for the recovery of rare earths. Environmental concerns are also a serious consideration. That's because mining these elements has a sizable ecological impact, releasing things like heavy metals, arsenic, fluorine compounds and acids into the environment.

The **processes for recycling rare earth metals are very cost intensive**. With a very few exceptions, such as neodymium magnets, they are not recovered on any significant scale [29] – at least not yet. Given the rising prices and the world's dependency on an export monopoly from a single state, innovative and profitable processes for recycling rare earths are likely to be developed. Some initial promising approaches can already be seen: a new recycling method for nickel

23 See Econitor (2011)
24 See unattributed (2011e)
25 See Donner, S. (2011)
26 Scandium, yttrium, lanthanum and the 14 lanthanides: cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium
27 See Titz, S. (2011)
28 Ibid.
29 See Deutscher Bundestag (2010b)

URBAN MINING – HUNTING FOR TREASURE IN LANDFILLS

The garbage dumps of yesteryear could be the gold mines of tomorrow – rising raw material prices and the looming scarcity of certain resources call for new strategies for resource procurement. Urban mining offers interesting perspectives here, defined as "the recovery of resources from anthropogenic stock in urban spaces" (Lucas, R./Fekkak, M., 2011). The treasure hunters of the future will no longer be searching for valuable raw materials in mines. They will be looking for them in cities, or more precisely in landfill sites and in buildings. Used materials from houses, landfill and infrastructure will be treated and put back into the economic cycle.

There is believed to be huge potential slumbering here: the quantity of ferrous and non-ferrous metals in domestic garbage sent to landfill is estimated at 32 million tons in Germany's case. The ten million tons of sewage sludge dumped has around one million tons of phosphate in it, and the 50 million tons of dumped iron slag is likely to contain 70,000 tons of zinc and 25,000 tons of lead. Real estate is also a great store of valuable materials. An estimated 100 million tons of metal is built into Germany's buildings along with 10.5 billion tons of mineral materials and some 220 million tons of wood (Lucas, R./Fekkak, M., 2011).

In spite of this potential, urban mining still does not take place in any systematic manner in Germany, at least not in the opinion of Rainer Lucas, project leader in the research group on material flows and resource management at the Wuppertal Institute (Uken, M., 2010). In order to improve the conditions for urban mining, he believes there should be a materials register for buildings. This would enable a record to be kept of which materials are built into which buildings. The Department of Waste and Resource Management at the University of Giessen is currently running a research project to study just what a wealth of raw materials domestic waste landfill sites contain. "Test drilling" is taking place at the landfills in Hechingen (Baden-Württemberg) and Reiskirchen (Hesse).

metal hydride batteries was developed at Leoben University of Mining (Austria), which is capable of separating rare earths. Rare earth metals actually make up between 7 and 10 percent of the total weight of batteries like these. [30] Research on the topic of recycling rare earths is being intensified in Germany, too. The government is supporting the recovery and substitution of rare earth metals with funding of EUR 1.5 million under a program entitled "r²: Innovative Technologies for Resource Efficiency – Resource-Intensive Production Processes". [31]

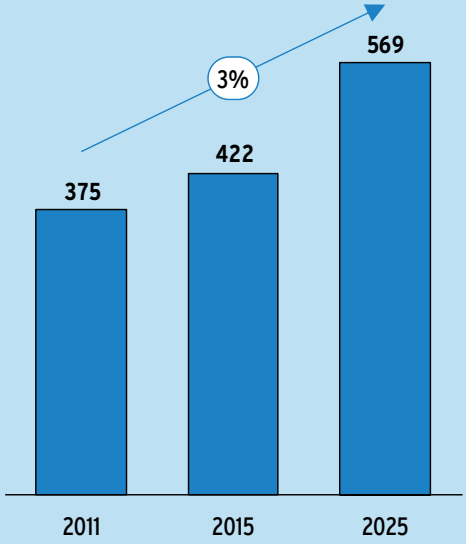
Landfill

This **market segment** encompasses the **construction and operation of landfill sites, making landfill sites safe and cleaning up pollution and contamination resulting from the operation of landfill sites.** Another significant aspect of this market segment is the **reduction and/or utilization of landfill gas.**

The importance of this market segment within the lead market for waste management and recycling becomes apparent when you look at the risks involved in improper or uncontrolled dumping. **Garbage dumps are potential ecological time bombs** that could pose a significant threat to human health: if landfill sites are insufficiently sealed, polluted water seeps down into layers of soil that lie below and contaminates the groundwater. Another **risk factor** is the **formation of landfill gas,** which is produced as the organic components in the waste are broken down by bacteriological and chemical processes. The main components in landfill gas are methane (CH_4) and carbon dioxide (CO_2). **Methane** as a **greenhouse gas** is the climate killer par excellence: one unit of CH_4 has an impact on the environment that is 21 times stronger than one unit of CO_2. Landfill sites the world over are the biggest emitters of methane besides the energy sector and agriculture. If the quantity of waste

30 See Cleanenergy Project (2011)
31 See Deutscher Bundestag (2010a)

Figure 63: Market forecast for landfill, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

disposed of in landfill sites across the world were reduced, waste management could be instrumental in the fight against global warming.

Though the **dangers of landfill have been eliminated or substantially reduced by legislation in most industrialized nations, the dumping of waste in landfill sites remains a serious problem in emerging nations and developing countries**: landfill rates of between 80 and 95 percent are not unusual there. By way of comparison, the landfill rate averaged 47.6 percent in EU 27 countries and 20 percent in Germany in 2008. [32] Germany's lead in waste management becomes even more apparent when you compare the amount of waste sent to landfill on a per capita basis: the EU 27 average is 192 kilograms per capita, according to Eurostat, whereas in Germany, only two kilograms of waste per head of population ends up in landfill. This low figure is also evidence of the positive impact that the Closed Substance Cycle Act has had: back in 2000, Germany was still sending 165 kilograms of waste per capita to landfill sites.

In order to keep the risks of landfill as low as possible, landfill sites in Germany are committed to a **multi-barrier concept**. This encompasses aspects like waste treatment, the construction and sealing of the landfill body and the capture of emissions. Old landfill sites are forced by legal regulations to meet these standards by upgrading and repairing where necessary.

Ever since 2005, the **Waste Landfill Ordinance** has stipulated that urban waste that is biodegradable or has a high organic content must undergo mechanical-biological or thermal treatment prior to being dumped in landfill sites. **This avoids the formation of landfill gas** and reduces the volume of waste. The target for 2020 goes several steps further: [33] by then, there should be no urban waste ending up in landfill at all. It should all go through the process of complete energy or material recovery. Long term, there will therefore be no municipal landfill sites in Germany; 160 are still in operation in the country at the moment (category II landfill). [34]

The topic of soil protection plays a key role in a landfill context. In the past, the sealing of landfill sites often left a lot to be desired, with the result that pollutants contaminated the underlying layers of soil and the groundwater. Such problems can only be resolved with a great deal of effort and expense using **special soil decontamination methods**.

32 See Eurostat (2011), p. 146
33 "By 2020 at the latest, treatment technologies should have been developed and refined to such an extent that all urban waste in Germany can be completely recycled in an environmentally friendly manner" – according to the Federal Environment Ministry's objective dated 1999
34 See Bundesumweltministerium (2011e), p. 6

A combination of several methods was applied in the grounds of the University of Kassel, where a new Science Park Center and parking garage are being built. The ground and water there demonstrated a high level of pollution because coal, coke and petroleum trading activities had been carried out on that plot of land for decades. The incomplete combustion of organic matter like coal and wood left its mark – the topsoil in this region is heavily contaminated with polycyclical aromatic hydrocarbons. Rubble from the Second World War added greatly to the contamination. Several thousand cubic meters of topsoil had to be removed. Not only that, the subsoil was contaminated with petroleum hydrocarbons so it, too, had to be taken away and disposed of. And a ground water purification plant with five remediation wells is being used to rid the groundwater of toxic substances. [35]

There is another observable trend in the landfill market segment: the increased utilization of landfill gas. For several years now, processes to **recover the energy from methane gas** have been in use. Admittedly, this is only practicable when the methane content of the landfill gas is at least 50 percent. The decreasing volumes of waste going to landfill sites mean that the calorific value of landfill gas is falling. This development indicates that processes used to date for recovering the energy from landfill gas are likely to become ineffective.

A solution to this problem has been identified by the City of Freiburg's waste management and cleaning department (ASF), the energy service provider Badenova and the waste disposal company Remondis. Methane gas produced by fermentation of domestic waste at Freiburg's Eichelbuck landfill site has been used to supply power and heat since the early 1990s. The landfill gas is piped through to the district of Landwasser, where it supplies energy for a cogeneration plant that produces electricity and heat. Once no more domestic waste was being delivered to the site from 2005 onward, the methane content in the landfill gas fell – as did the calorific value, making it ineligible as a fuel for the cogeneration plant. The solution to this problem lies in **enriching the landfill gas with biogas from the biowaste fermentation plant**, where Remondis collects around 30,000 tons of organic waste per year from Freiburg and the administrative district of Breisgau-Hochschwarzwald. The mix of biogas and landfill gas achieves a methane content of at least 50 percent, thus ensuring that it can continue to be fed into the cogeneration plant. The parties involved in this Freiburg concept estimate that their approach for enriching lean landfill gas could serve as a model for around 45 landfill sites in Germany. [36]

FROM TOXIC LANDFILL TO ECO-POWER PLANT

If you had suggested, 30 years ago, that the hill in Hamburg's Georgswerder district would become an attraction for scientists and tourists alike, you would probably have been met with incredulous glances. The area of land in the northeast corner of Wilhelmsburg became a destination for rubble and domestic waste after the Second World War, later to be joined by toxic industrial waste, paints and varnishes. Following the closure of the dump in 1979, dioxin seeped into the groundwater in 1983. The landfill site was sealed and covered with topsoil to make it safe. A wind turbine was placed on top of the 40-meter hill.

The former "toxic factory" is now being reborn as an eco-power plant. To mark the International Building Exhibition (IBA) taking place locally, the former garbage mountain has been transformed into an energy mountain, set to supply around 4,000 households with power. There will be a number of other regenerative sources in addition to the wind turbine on the top: a photovoltaic plant covering 10,000 square meters will adorn the southern slope. When the grass is mowed it will be turned into biogas. The landfill gas formed inside the mountain as a result of the decomposition processes that are still active there contains a high proportion of methane - making it a good source of energy for Aurubis AG, a copper works situated not far from the Georgswerder hill.

Source: IBA Hamburg GmbH (2011)

35 See Universität Kassel (2011)
36 See unattributed (2011f)

Sustainable water management

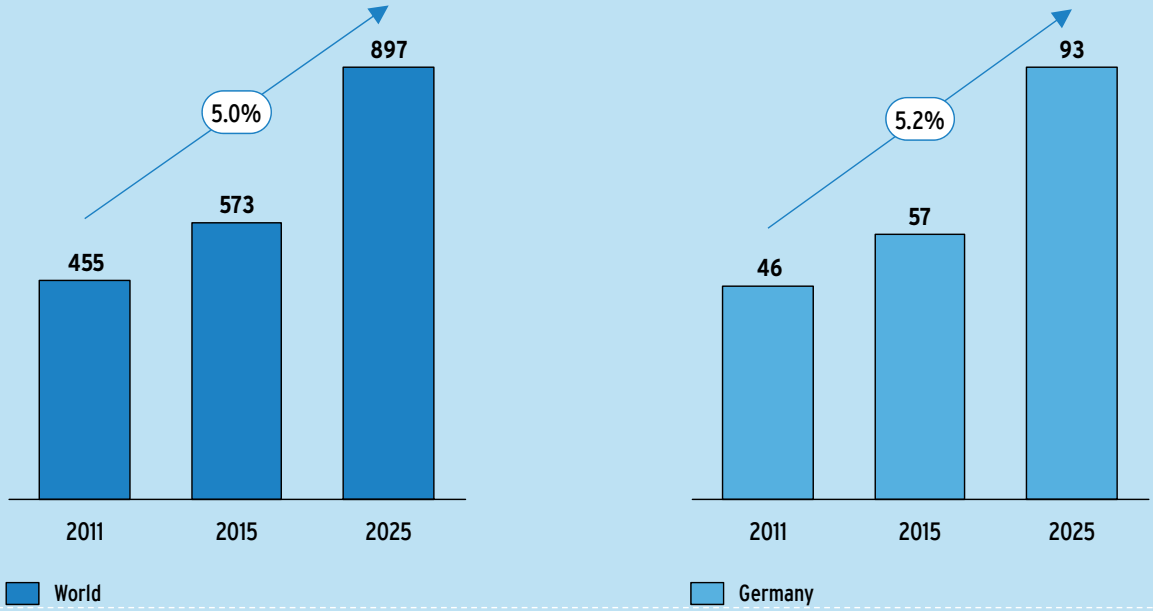
In July 2010, the General Assembly of the United Nations (UN) declared safe drinking water and sanitation a universal human right. [1] Yet this declaration has remained an unmet promise of a better future for one in ten of the world's population. **In many regions of the world, the amount of fresh water available to each person is below the minimum 20 to 50 liters per day that the UN definition describes as necessary to meet basic human needs.** By way of comparison, each person in Germany has a potential water ration of almost 2,300 cubic meters per year on average, more than 6,000 liters per day.

The efficient and sustainable husbanding of water resources is a must, not only in areas where they are in short supply, but also in (water-) rich industrialized nations: **the treatment of drinking water and disposal of waste water consumes enormous quantities of energy**.

Against the backdrop of rising demand for water worldwide, the big challenge for the coming decades is to **ensure the sustainable management of water resources**. In doing so, we must meet the basic needs of current generations without jeopardizing the basis of life for those that come after us. The only way we can achieve this is with the help of efficient environmental technology. Indeed, green tech already plays a key role in all stages of water production and consumption – from the source to the faucet, the sewers to the sewage works. Water management depends upon green high-tech methods and products to safely supply consumers and protect the environment. **Sustainable water management is therefore an important lead market of environmental technology. It is divided into market segments in accordance with the water cycle: water production and treatment, water distribution, efficiency of water usage, and waste water disposal.**

1 See Umweltbundesamt (2010e), p. 11

Figure 64: Market forecast for sustainable water management, 2011, 2015 and 2025 (in EUR billion, average annual change 2011-2025 in percent)



Source: Roland Berger market model

Water production and treatment

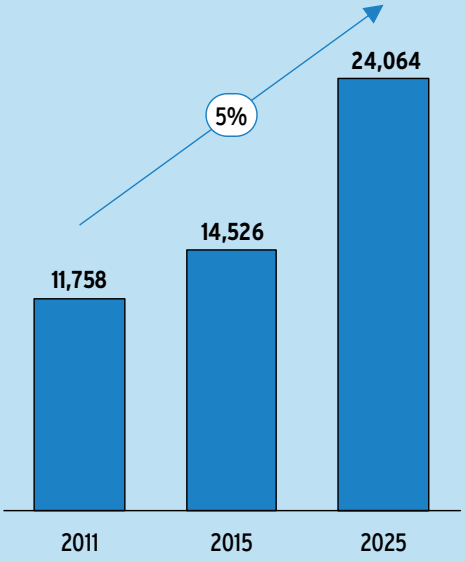
The first stage in the water cycle is **water production and treatment**. This **market segment incorporates a broad spectrum of products and services: development and extraction of fresh water resources (wells, pumps), groundwater monitoring and the necessary measurement techniques, and the planning, construction, operation and maintenance of systems for water treatment.** Such systems include conventional treatment methods, seawater desalination plants and systems for rainwater handling and storage.

There is no risk of the "blue gold" running out in water-rich Germany. The available water supply [2] amounts to 188 billion cubic meters, whereas the quantity of water removed totals 32 billion cubic meters. [3] The majority of this, almost 20 billion cubic meters, goes into the energy supply infrastructure, where it is used to cool thermal power plants. This in itself brings home the **relationship between energy supply and water supply**. About five billion cubic meters of water were supplied to households and small businesses.

Water can be obtained from groundwater or surface water. Surface water comes either direct from lakes and watercourses or is taken as bank filtrate from wells in the vicinity of bodies of water. The world covers about one-fifth of its entire water needs with groundwater, and almost 74 percent with surface water. In Germany the ratio is reversed: accounting for around 70 percent, groundwater from springs or wells is the main source of our drinking water supplies. The **quality of the groundwater is monitored** by a network of **around 800 measuring points**, evenly spread across the whole of Germany. Measurements are taken here of both the chemical content of the groundwater and the quantity. Each federal state is responsible for installing and operating its own measuring points. [4]

2 Definition: "The available water supply is a measure of the regional water cycle and is calculated on the basis of the amount of precipitation and evaporation as well as the balance of water inflows and outflows. It indicates the volume of water potentially available for use"; see Umweltbundesamt (2010e), p. 16
3 Ibid.
4 See Umweltbundesamt (2010f), p. 14f

Figure 65: Market forecast for water production and treatment, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

Monitoring the groundwater level is important not only from the point of view of water supplies, but it is also a crucial aspect of flood protection. Projects have therefore been initiated in some risk zones to ensure that groundwater levels can be monitored. In Dresden, for example, 61 measuring points automatically transmit the groundwater level to a server in the town hall. When there is a risk of flood, local citizens can get hold of information immediately, giving them more time to take the necessary measures to protect their buildings.[5]

Methods of water treatment

When ground and surface water is extracted, it passes through numerous process steps between the well and the consumer. Untreated water needs to be cleaned and prepared before it can come out of the faucet in drinking water quality (germ-free, colorless, clear, odor-free and with an untainted taste). There are a number of steps that are applied here, classified according to the effect they have:[6]

ORGANIC FARMING IN THE MANGFALL VALLEY

Nitrate contamination from agriculture puts drinking water supplies at risk. The salts in the nitric acids are used as fertilizer and are carried into the groundwater with the rain. In Germany and other EU states, the legal limit for nitrate concentration in drinking water is 50 milligrams of nitrate per liter. Eliminating nitrate from untreated water is very costly and as a result, groundwater with raised nitrate levels is no longer considered for use in our drinking water supplies. Some 15 percent of the 800 or so measuring points in Germany show raised nitrate levels. Nitrate contamination also caused trouble for Stadtwerke München, the Bavarian capital's municipal utility company, which meets around 80 percent of the city's water needs from the Mangfall Valley. When the nitrate concentration in the groundwater was at a raised level in the 1980s, the company encouraged local farmers to switch to organic farming. More than 100 farmers now participate in this water protection initiative, which has led to the Mangfall Valley becoming the biggest contiguous area of organic farming in Germany.

Source: Stadtwerke München (2011)

5 See Landeshauptstadt Dresden, Umweltamt (2007)
6 See Umweltbundesamt (2010e), p. 79

- Filtration and separation methods
- Precipitation and flocculation processes
- Biological processes
- Substance exchange at interfaces
- Precise metering of additives
- Irradiation methods

A number of innovative methods are described in detail below:
Water needs to be cleaned of pollutants on various scales (nanofiltration, ultrafiltration, microfiltration). Special and selectively permeable membrane filters remove microbiological contamination in the water, such as bacteria and viruses. **Membrane filter technology** is superior to conventional filter systems in that it does not require the use of additional chemicals and has a proven track record of application in large-scale sewage treatment plants. These advantages will ensure that the use of membrane filter technology increases by 20 percent per year worldwide in the years to come.

Trace elimination is currently a key issue in water treatment: traces are substances like pharmaceuticals, hormones, pesticides and basic industrial commodities that get into the water system through the waste water and in the form of particles from agriculture. These micropollutants can be toxic to aquatic systems even in low concentrations. By way of illustration, 500 nanograms per liter – just one drop of a cubic meter – of the active pharmaceutical ingredient diclofenac causes tissue changes in the kidneys, liver and gills of fish. Standard waste water cleaning is not capable of completely eliminating such traces. Special technologies are needed, such as **adding an ozone system to a membrane filtration plant**. Waldbröl district hospital (North Rhine-Westphalia), for example, uses this combined process to clean its waste water. There, the ozone system supplied by Stulz-Planaqua GmbH (Bremen) ensures that things like pharmaceutical and diagnostic residues are eliminated to a large extent.

Other methods of water treatment include activated charcoal filters, cleaning by high ozonation and treatment with UV radiation. The use of **activated charcoal filters** is primarily suitable for solutes that are difficult or impossible to remove with other biological methods of waste water cleaning. The substances targeted for removal from the waste water are made to adhere to the activated charcoal by adsorption; target substances include chlorinated hydrocarbons, dyestuffs and oil.

Ozonation (ozone oxidation) is used for sterilization and disinfection. The process is much more environmentally friendly than chlorination. Ozonation is also used for trace elimination (see above). Ozone is added to the waste water for filtration. The triatomic oxygen molecule (O_3) destroys the micropollutants.

UV radiation treatment is another method used to disinfect drinking water or swimming pools. It can also be used to disinfect waste water. It works by subjecting the microorganisms in the water to germ-killing ultraviolet rays. UV radiation causes a photochemical change in the nucleic acids of the microorganisms, which prevents their proliferation.

In practice, water treatment systems combine more than one method. Their application depends on the type and quality of the untreated water, and also the intended purpose of the treated water: process water for power plants or industry has different quality criteria to meet than drinking water.

Seawater desalination

Whereas Germany has more than sufficient quantities of groundwater available, water production and treatment represent a major difficulty in countries in arid zones. The challenge there is to develop other sources of water in addition to what scarce groundwater resources they have. One way of doing this is by desalinating seawater.

Various processes can be used for seawater desalination. Common methods of removing salts and minerals from water include distillation with a multiple-stage flash evaporator, reverse osmosis and the electrochemical process known as electrodialysis.

WARNING OF RISKS AND SIDE EFFECTS

Pharmaceuticals have been detected time and again in surface water in Germany. They get into rivers and lakes through the sewers because they are not eliminated by the conventional methods used in sewage treatment plants. Though these micropollutants are present only in the tiniest of quantities, the drug, hormone and diagnostic residues are believed to damage the ecosystem by affecting the sensitive hormonal balance of fish and bottom dwellers. Lab tests have shown that fish react with reduced reproduction to the active ingredient 17Đ-ethinyl estradiol, which is contained in some hormonal contraceptives and menopause drugs.

Source: Umweltbundesamt (2010e), p. 92

A plant employing **multiple-stage flash evaporation** technology has been operated by Siemens in the United Arab Emirates for several years now. A combined power and desalination plant in Abu Dhabi supplies residents of the emirate with power and water. The desalination plant consists of several chambers, through which the seawater passes in sequence. The waste heat from the power plant brings the chambers up to a temperature at which the water partially evaporates under reduced pressure. The resulting steam is cooled down, whereupon it turns back into water. This condensate (distilled water) is enriched with minerals to become drinking water.

In the process of **reverse osmosis**, seawater is forced at high pressure (60 to 80 bar) through a semipermeable membrane. Only certain ions and molecules can pass through this "filter" and the seawater is demineralized as a result. [7] The high pressure pumps needed to facilitate this process consume a great deal of energy.

Electrodialysis with ion exchange membranes uses electrical voltage to remove ions from the seawater. In this process, the energy expended is proportionate to the salt content. Electrodialysis is therefore currently uneconomical where salt concentrations are high. Siemens has had some success in solving this problem, however. In a pilot plant that went live in Singapore in 2010, they combined electrodialysis and electrodeionization and managed to cut the energy consumption of seawater desalination by more than 50 percent over other methods. The next step in getting the technology ready for market is to build a demonstration plant on the original scale, which should be ready by 2013. [8]

All of the conventional **methods of seawater desalination require considerable amounts of energy.** Reducing energy consumption is therefore an essential goal in the search for new processes for producing drinking water out of the sea. One way of doing this would be to ensure that the energy used to operate seawater desalination plants came from regenerative sources. Solar power plays a particularly important role here, given that many seawater desalination plants are operated in regions that enjoy strong sunlight. Osmosis represents another means of reducing the energy needed for demineralization: instead of forcing the saltwater against a membrane under pressure as in reverse osmosis, the **natural process of osmosis** can be used. A drawing solution containing a much higher concentration of ions than the surrounding water is used to draw the seawater through a membrane without any artificially generated pressure. The water molecules are able to pass through the membrane, whereas salt and debris are left on the other side of the filter. [9] The costs of this method are still high, so in order to reduce them, a team of scientists from Yale University has further refined the process by using ammonium bicarbonate, or baking powder, as the drawing solution.

Even though the energy footprint of fresh water production from **seawater is set to improve thanks to new technologies, seawater desalination plants still have their critics among environmentalists** because of the considerable impact they have on aquatic systems. After all, desalination returns copper, chlorine and other substances to the sea, thus raising the salt concentration and temperature in the surrounding waters over the long term.

Water distribution

This **market segment** includes **all elements in the water distribution system** that facilitate the transportation of drinking water from the sewage treatment plant to the faucet in the home: **pumps, valves, fittings, pipes and containers. Water distribution also includes the planning, construction, operation and maintenance of the water supply system.**

Water is distributed through a network of mostly underground pipes. Laying such pipes, maintaining them and servicing them is a costly business; around two-thirds of the money invested in the public water supply is spent on the **water distribution system**. Like the electricity grid, it is made up of **numerous levels**: long-distance pipes transport the water to the water tower. Feeder pipes bring the water from the water tower into the local system. And within the local system there are supply pipes and access pipes. [10]

7 See Enercon (2011)
8 See innovations-report (2011)
9 See Czycholl, H. (2010)
10 See Wasserwirtschaftsamt Ingolstadt (2010)

One of the main technological challenges in operating the water distribution system is ensuring **the right pressure**: it mustn't be too high – the maximum is six bar [11] – otherwise parts of the pipework would be overstrained and pipes and faucets would be damaged. But the pressure must not be too low, either; if it were, the customer would get no more than a trickle out of the faucet. A whole arsenal of pumps, valves and fittings is needed to keep the pressure at the right level for the water system to function. So-called booster stations are used to raise the pressure in water systems, for instance if it drops below a minimum level or peak levels of water consumption need to be supplied.

The materials used in **water pipes** have changed over time: pipes made of gray cast iron with dip-tar coating are the veterans in the water system. They were gradually replaced by ductile cast iron pipes, manufactured from the end of the 1950s onward. Steel is superior to all other materials in strength, fracture strain and toughness. There are also fiber cement pipes and reinforced concrete and prestressed concrete pipes. Even plastic is used for water pipes: PVC and hard and soft polyethylene are used for pressure pipes in particular.

The **condition of the piping** determines the efficiency of water distribution to a significant degree. The leakier the pipe, perhaps as a result of corrosion or damage at the joints, the more water gets lost between the source and the consumer. Germany is the best in Europe when it comes to water losses from leaks, losing just 6.8 percent. Central and Eastern European states lose a large proportion of their fresh water between the water treatment plant and the end consumer: losses from leaks total 50 percent in Bulgaria, 40 percent in Slovenia, 35 percent in Hungary and 32 percent in the Czech Republic. But Western Europe has room for improvement, too (28.5 percent in Italy; 26.4 percent in France; 22 percent in Spain). [12]

Leaks in water pipes can have many causes and are therefore difficult to identify. Systematic monitoring with a registration module attached to the water meter, on the other hand, enables consumption figures to be precisely ascertained – this is known as **smart metering**. This is an indication of the fact that many of the modern systems for controlling and monitoring water distribution in the future will be found in the virtual and so-called smart market.

DRY RUN IN THE WATER SYSTEM

Designing and operating a water system is one of the supreme disciplines in control and automation engineering. Control units and sensors need to be employed to guarantee the right water volume, pressure and rate of flow. Siemens has developed a method of simulation that can test water systems and their components in the planning phase. This virtual engineering cuts development times and increases energy efficiency: the simulation program can be used to help plan new water systems and modernize existing ones. What it does is precisely adjust the capacity (water volume, pump output, etc.) to the respective requirements – and this, in turn, enables the system to be produced to optimum dimensions.

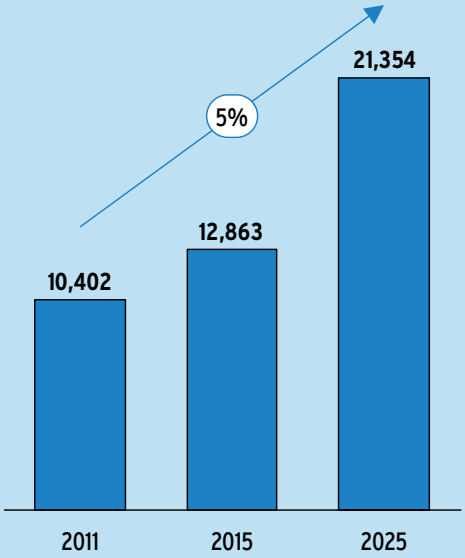
Source: Siemens AG (2010a)

Ultrasonic meters from Kamstrup, for example, are able to measure water consumption to a high degree of precision. Leaks would therefore be picked up immediately. Furthermore, these meters contain no moving parts: wear is reduced and these instruments are made to last.

The words precise and smart can also be used to describe the KNX Association's extensive range of electricity, gas, water and heat meters for consumers.[13] Integrated KNX interfaces provide the full range of required figures. And an integrated log function saves the meter readings every 15 minutes so they can be retrieved later. Customers are also able to view their consumption data across all areas and all manufacturers.

11 Ibid.
12 Umweltbundesamt (2010e), p. 80
13 KNX is the worldwide standard for home and building control. It covers heating, lighting, blinds and shutters, ventilation and security systems. The international KNX Association has more than 100 member companies. See KNX Deutschland (2011)

Figure 66: Market forecast for water distribution, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

Increasing the efficiency of water usage

The **market segment for water efficiency technologies** is very broad. It encompasses **instruments for water measurement and water efficiency technologies in the household, in industry and in commerce**. The success of water-saving technologies from this market segment is manifested in the fact that the amount of water taken out of the system in Germany has fallen dramatically in the last two decades. Water withdrawal has fallen 30 percent since 1991, totaling 32 billion cubic meters in 2007.[14] The Federal Environment Agency puts the more effective utilization of water down to "technology developments, multiple use and closed cycle systems". But the potential for savings in the husbanding of water resources is nowhere near exhausted. There are a number of areas in which action can be taken, concerning both the consumption of fresh water and the avoidance of waste water.

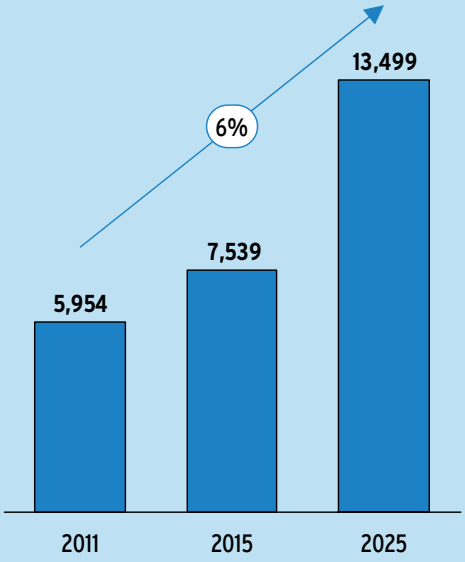
Of all consumers, industry has the greatest need for water, accounting for more than 80 percent of water withdrawal. This figure underscores the importance of actions to improve **water management in industrial enterprises**. And since the supply and disposal of water also carry weight as cost factors, the arguments in favor of optimizing water utilization are not just environmental but also economic.

As part of its group-wide strategy for environmental preservation, BMW minimizes its water consumption and waste water volumes. Between 2006 and 2012, these two parameters were reduced by one-third, says the automaker. The company has set itself the **target** of making its **production processes almost free of waste water**. Having closed cycles and avoiding fresh water consumption are important levers in achieving this. Biological water treatment in the car washing plant, for example, enables about 90 percent of the water to be used repeatedly. The paint shop, one of the biggest water consumers, is going to be completely free of waste water in the future. The company's Regensburg plant is currently working on systems to clean the water used in the paint shop and recirculate it back into production.

The car manufacturer is also pushing on with the development of processes that do not require the use of water as a resource. "Snow-cleaning" plants are one

14 See Umweltbundesamt (2010e), p. 75

Figure 67: Market forecast for increasing the efficiency of water usage, 2011, 2015 and 2025 in Germany (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

example. The Landshut plant does not use any water to clean the plastic exterior components; instead the dirt is cleaned off with CO_2 "snow". The carbon dioxide used here is a waste product of fertilizer manufacturing. It is measures like these that have enabled BMW to get a great deal closer to its water-saving targets: fresh water consumption in 2010 was 3.4 million cubic meters, some 7 percent lower than in 2008 – despite higher production volumes. Water consumption per vehicle was reduced by almost 10 percent in the same period, and process water volumes fell 6.5 percent. [15]

Another example of the resource-efficient use of water is provided by Neumarkter Lammsbräu (Bavaria). Reducing water consumption is instrumental in the organic brewery's system of environmental and sustainability management. A **rainwater collection system** is one element in this. The rainwater that falls over the company grounds does not go down the drain: it is used for the cooling condensers in the cooling system and for washing vehicles, cleaning the courtyard, etc. The materials to construct the rainwater collection system cost around EUR 5,000 and the amount of rainwater collected per year is 600 to 800 cubic meters, depending on the weather, so the company saves as much as EUR 3,000 in water costs. [16]

There are also numerous opportunities to cut water consumption in private households. That said, even the most sophisticated technology will be ineffective in the battle against water wastage if the behavior of end consumers does not change. Leaving the tap running while brushing your teeth wastes 5.2 liters of drinking water. On the other hand, using a cup to rinse your mouth out consumes as little as 0.2 liters. Taking a bath uses up 150 liters; a shower consumes just 50 liters of water.

Regulating the flow rate in washbasin faucets and shower heads can substantially reduce the demand for water – and with it the demand for energy to heat it. Water-saving shower heads, for example, can halve the amount of water needed. [17]

Household appliances have made enormous improvements in water efficiency in recent years. Washing machines and dishwashers now use much less water than their predecessors. The use of sensors, intelligent microprocessors and motors, for instance, have cut the water consumption of washing machines and dishwashers made by BSH Bosch und Siemens Hausgeräte GmbH by around two-thirds since the start of the 1990s. The efficiency champions among the washing machines made by manufacturers like BSH, Miele and AEG manage on just 8 to 12 liters of water per wash.

15 BMW AG (Hrsg.) (2010), p. 41
16 See Bayerisches Landesamt für Umwelt (Hrsg.) (2011); see also Neumarkter Lammsbräu: Nachhaltigkeitsbericht 2010
17 See Institut für Umweltverfahrenstechnik der Universität Bremen (2011)

NO DIGGING REQUIRED

Around 150,000 kilometers of the public sewer network in Germany are already more than 50 years old – making them potential renovation cases. Pipelining is enjoying increasing application in the rejuvenation of ancient sewer tunnels and pipes. This method of sewer rehabilitation premiered in London in 1971. It involves creating a hydrostatic head to enable a pipe dipped in synthetic resin to be pushed into the part of the sewer that needs renovation, where it sets. The sewer is then as good as new. In other words, its pipeline tightness, abrasion resistance, static load-bearing capacity and thermal and chemical resistance meet DIN standards. These stipulate that a renovated system must meet the same performance requirements as a new system. Nowadays, materials other than resin are used for the internal coating of the pipe lining; these include glass fiber and carbon fiber. Pipelining does not require any digging. Because the sewer pipes do not need to be excavated, this form of renovation is significantly quicker than conventional methods. The leading provider of this technology in Germany is insituform Rohrsanierungstechniken GmbH.

Source: Insituform Rohrsanierungstechniken GmbH (2011)

Sometimes, drinking water processed to the highest levels of quality with considerable energy consumption is not really necessary. For some areas of application, **process water** is absolutely sufficient. Rainwater, for example, can be used as process water in industry, in carwashes or to flush toilets at airports or soccer stadiums. [18]

The **use of gray water** can also help save water: water of drinking water quality flushes down toilet bowls, waters the lawn and washes the car. German households use more than 50 liters of water per capita per day for applications where gray water would do perfectly well. Gray water is slightly polluted waste water that contains no sewage; the kind of water you get after showering or washing your hands. After filtering and treatment, the quality of gray water is good enough for use in washing laundry, cleaning, watering the garden or flushing toilets. Using gray water to flush toilets would cut fresh water consumption by about half and waste water volumes would fall by around one-third.

Cruise ships and hotels have facilities for treating gray water. Huber SE (Berching) developed a **gray water recycling system** for the treatment of slightly polluted gray water. The modular standard system is available in six different sizes and can be installed in a building's cellar space. The manufacturer from the east of Bavaria has run calculations for a hypothetical four-star hotel with 215 beds in Berlin, which indicate that investing in equipment of this kind would pay off in about six years. The hotel owners would recoup the cost of buying the system in the form of savings on fresh water and waste water taxes. According to the model, the gray water recycling system would earn the hotel about EUR 38,000 after ten years. And if the price of drinking water were to rise, the payback period would be even shorter and the earnings higher.

Waste water disposal

There are many sides to this **segment of the market** for sustainable water management. Besides "traditional" waste water treatment involving **public sewage treatment plants**, it also encompasses the **utilization of sewage sludge as an energy carrier, energy-efficient sewage treatment plants**, the **use of waste water as a resource (for instance, for producing heat or recovering materials), and small-scale sewage treatment plants**. The **piping for waste water transportation** is also an important area of this market segment.

Waste water disposal plays a crucial role in environmental protection and the sustainable management of water resources: if we did not have the infrastructure for cleaning and treating waste water, the health of the population and our complex aquatic ecosystems would be endangered. Environmental technology presents a range of **new methods for the effective and efficient disposal of waste water**.

18 See Umweltbundesamt (2010e), p. 83

There are two stages to waste water disposal: the discharge of the waste water, or effluent, into the sewers and the treatment of the effluent in sewage treatment plants. The sewer network in Germany is around 480,000 kilometers long in total: if all of the waste water pipes were laid end to end in a straight line, they would reach further than the moon. Some ten billion cubic meters of waste water flowed through the sewers and into almost **10,000 publicly owned sewage treatment plants** in 2007. [19] They employ a **combination of mechanical, biological and sometimes chemical methods to clean the waste water from industry, commerce and households in a number of different stages**, before releasing it back into one of our bodies of water.

One promising new method involves **plasma treating the waste water**. [20] The process destroys organic pollutants in the water by triggering an electrical discharge into the water. This simultaneously releases so-called radicals, such as hydroxyl groups, and free electrons. These highly reactive molecules and particles react with the organic elements, thereby destroying them. UV light is emitted as well, which also kills germs. The fact that no chemicals are required is the big advantage of this method. It is most useful for treating waste water at contaminated point sources directly, such as municipal effluent, industrial waste water and hospital discharges. Fresh water treatment is another area of application for this plasma method, especially in the withdrawal of surface water, which is a much-used source of untreated water in Berlin and the Ruhr region.

About 1 percent of the German population is not connected to the public sewers. This includes remote properties, which could be integrated into the public sewer network only at considerable cost and effort. Owners of such properties are obligated by law to clean their waste water in **small-scale sewage treatment plants**. These **decentralized sewage systems** in miniature format need to meet the *requirements for general technical approval for the application of small-scale sewage treatment plants* as stipulated by the Deutsches Institut für Bautechnik (German institute for civil engineering, DIBt). The requirements define the effectiveness of small-scale sewage treatment plants on the basis of effluent categories. These range from C (basic cleaning with removal of carbon) through +H (removal of carbon and nitrogen and additional hygienization with germs filtered out). The authorities usually insist on this top egory only for karst regions and water protection areas. [21]

The small-scale sewage treatment plants in use today are technologically sophisticated products that are nothing like the cesspits of old. The main methods for decentralized waste water treatment are fixed-bed sewage treatment plants, the SBR method [22] and membrane technology. In the case of aerated fixed-bed sewage treatment in a three-chamber plant, the "fixed bed" is located in the central chamber, where waste water, which has already passed through the mechanical cleaning stage, flows around it. The microorganisms settle on the fixed bed and form a biofilm. This process is supported by the addition of oxygen in precise doses. Any bacteria left over are washed into chamber number three for subsequent purification, where they are deposited as sediment. An air-lift pump is then used to convey this back into chamber number one. [23]

SLOWING THINGS DOWN IN THE SEWERS

Heavy rain has often presented a problem for sewage treatment systems: great deluges of water are too much for many sewage treatment plants to cope with. In these cases, the effluent is not sufficiently cleaned and ends up contaminating our rivers and lakes. Numerous sewage works have built flood retention basins, but this is costly. An innovation by Güthler Ingenieurteam GmbH is set to make this expensive investment unnecessary. The company from Waldshut-Tiengen (Baden-Württemberg) has developed a "flow brake" for use in sewer systems. The no-maintenance, mechanically self-adjusting system makes use of the volume of retained water in the sewers and regulates the flow of effluent, thus preventing the sewage treatment plant from being overloaded. Not only can the "HydroStyx" effluent brakes be fitted in new tunnels, they are also suitable for retrofitting existing sewers. According to the manufacturer, the effluent brake also serves to put the brake on costs: using "HydroStyx" is 90 percent cheaper than storing water in a flood retention basin.

Source: Deutsche Bundesstiftung Umwelt (2009)

19 See Umweltbundesamt (2010e), p. 86
20 See Cluster Umwelttechnologien.NRW (2011b), p. 35
21 See Huber DeWaTec GmbH (2011a)
22 Sequential Biological Reactor
23 See Huber DeWaTec GmbH (2011b)

In the **SBR method**, the waste water is cleaned in two chambers. The first chamber pre-cleans the effluent mechanically, and the second chamber is where the biological purification takes place. Here, oxygen is added to aerate and activate the sludge to make it easier for the microorganisms to clean. The water separates from the sewage sludge during the "rest phase". The purified waste water is drained off and some of the activated sludge is pumped back into chamber number one. [24]

Small-scale sewage treatment plants with membrane filter technology are capable of achieving the top category of effluent treatment, +H. They work based on the following principle: first the waste water is mechanically pre-cleaned; then it is passed into a membrane bioreactor, where oxygen is added to activate the microorganisms into breaking the effluent down. Once biologically cleaned in this way, the waste water flows through membrane filter plates with microscopic pores. The germs get stuck in these mini-sieves, whereupon the water is left perfectly hygienic. Ultrafiltration can then be applied to enable the purified waste water to be reused in the household without additional chemical treatment, for instance to flush toilets. [25]

Sewage sludge treatment

According to the Federal Statistical Office, in 2009 Germany had to deal with just under two million tons of sewage sludge [26, 27] from municipal sewage works. **Dumping sewage sludge in landfills has been banned since 2005**, which is why alternatives for "final disposal" have grown in importance. Approximately one-third of sewage sludge in Germany is used as fertilizer in agriculture. There are applicable limits in place regulating the amount of heavy metals and organic pollutants that can be present in the effluent sludge; this ensures that farmland is not contaminated. **52 percent of sewage sludge in Germany is incinerated (thermal recycling).**

Given that the properties of coal and sewage sludge are similar with respect to drying and incineration, **sewage sludge is often used as an "admixture" in coal-fired power plants** to produce electricity or, in combined heat and power generation plants, both electricity and thermal energy for heat supply. The Lippendorf power plant in Saxony is an example of sewage sludge co-incineration. This steam power plant near Leipzig is operated on the basis of brown coal and consists of two block units, each with a gross nominal capacity of 933 megawatts. The Lippendorf plant is certified for the thermal disposal of sewage sludge; this is mixed with the raw brown coal in a proportion not exceeding 5 percent. Up to 385,000 tons of sewage sludge per year can be incinerated in this way – saving more than 40,000 tons of brown coal. [28]

Energy-efficient technology in sewage treatment plants

Sewage works have a very high demand for energy: the 10,000 or so sewage plants in Germany consume some 4,400 gigawatt-hours of power a year and emit around three million tons of CO_2.[29] So energy efficiency is an issue of immense importance. Correspondingly high **saving potential** can be realized for instance through **more efficient aeration**, the **use of motors and pumps featuring the highest levels of energy efficiency** and **improved equipment controls**. If German sewage works applied the full range of possible actions, one-fifth of the electricity currently needed could be saved on average – equivalent to a 600,000 ton reduction in CO_2. [30]

The **high-load digestion** process developed at the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB represents an energy-efficient method of converting sewage sludge into biogas faster and more cheaply. With high-load digestion, a net energy gain is achieved as the sewage sludge is stabilized. The biogas produced during the process can be used as a regenerative source of energy to cover the sewage plant's need for thermal energy; and the combined heat and power generation brings an increase in energy efficiency. [31]

Like other sewage treatment plants in Germany, the group sewage works at Schozachtal (Baden-Württemberg) is counting on the benefits of high-load digestion. When the project was initiated, the objective was to largely eliminate organic substances in the sewage sludge, to minimize the quantity of sewage sludge and to increase the "yield" of biogas so as to

24 See Huber DeWaTec GmbH (2011c)
25 See Huber DeWaTec GmbH (2011d)
26 Dry weight in tons; as of 2009
27 "Name given to digested or otherwise stabilized sludge from sewage treatment plants. Sewage sludge from domestic waste waters contains a great deal of nutrient and humus matter and can be used as a fertilizer under certain conditions. Depending on the type of waste water and the treatment applied, sewage sludge may contain substances that can be damaging to the environment or human health"; definition according to Umweltbundesamt (2010e), p. 141
28 See BHKL Schlammentwässerungs-OHG (2011)
29 See Umweltbundesamt (2010e), p. 91
30 Ibid.
31 See Fraunhofer-Institut für Grenzflächen- und Bioverfahrenstechnik IGB (n.d.), p. 3

ultimately cut energy costs. The operators have every right to be pleased with the results. Not only is the sewage sludge turned into biogas more quickly and effectively, but the volume of digester required for this process is also lower. The energy extracted from the biogas in the digestion process is used to cover the power plant's energy demand. The results in figures: 400,000 kilowatt-hours "from in-house production" cuts the electricity bill by around EUR 50,000. [32]

Waste water as a resource

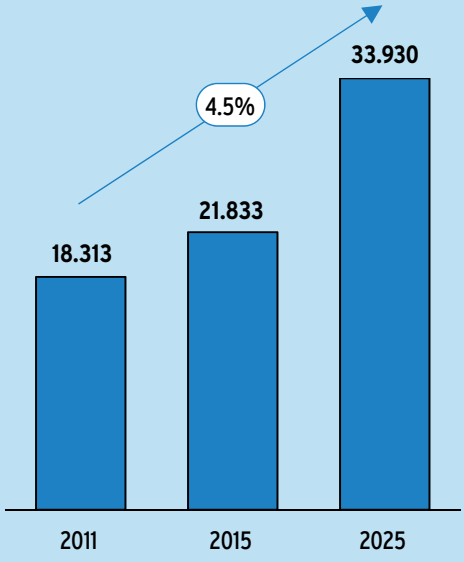
There has been a paradigm shift: **waste water** is no longer seen as nothing more than the "residual waste" of supplying water. It is actually seen **as a usable resource**. This is clearly shown by the methods available for the recovery of materials in waste water treatment and in the concepts for utilizing the heat from waste water.

Metals and phosphates are among the substances that can be recovered from waste water. Phosphates, the salts in phosphoric acid, are needed to produce detergents and fertilizers, for instance. If phosphorous compounds get into the water, they cause the excessive growth of water plants, which ultimately leads to a reduction in the oxygen content. In the worst case scenario, this can cause a body of water to eutrophicate. To avoid eutrophication, phosphorous pollution must be reduced by means of suitable waste water treatment.

But ecological concerns are not the only reason why we need to thoroughly address the issue of phosphorous in waste water. There are also economic considerations to take into account: phosphorous is a scarce, non-substitutable resource, and one for which we are heavily dependent on imports. The quantity of this chemical element that can be found in waste water and sewage sludge equals half of our mineral imports of phosphorous. Wet chemical processes could be applied to recover around 40 percent of this total in the form of magnesium ammonium phosphate, which can be used as a chemical fertilizer. [33] The **recovery of phosphorous from sewage sludge mono-incineration ashes** promises an even higher yield – 90 percent.

Waste water can also be used as a source of heat. The temperature of waste water from households and commerce is 10 to 15 degrees Celsius, even in winter. Pilot projects in Germany are currently using the waste water in large sewers as a source of heat for residential and factory buildings, a swimming pool and a sports hall. And the concept could be expanded: with adjustments to building services, the heating energy from the sewers could emit up to two-thirds less CO_2 than conventional heating technology. [34]

Figure 68: Market forecast for waste water disposal in Germany, 2011, 2015 and 2025 (in EUR million, average annual change 2011-2025 in percent)



Source: Roland Berger market model

32 See Nickel, N. (2009)
33 See Umweltbundesamt (2010e), p. 90
34 Ibid.

How environmental technology and resource efficiency are driving the modernization of traditional economic sectors – Transformation in four dimensions

Five megatrends – demographic development, urbanization, globalization, the scarcity of resources and climate change – will shape social, political and economic conditions around the world in the decades to come. In light of this inescapable fact, there is in the long term no alternative to making economies sustainable. Essentially, this means striking the right balance between successful business performance, social cohesion, protecting the natural basis that supports human life and shouldering international responsibility. These main tenets of sustainable development show the direction we must take in mastering the transformation to a green economy.

The green economy will rest on two pillars. One consists of companies in traditional industries that pursue a sustainability strategy. The other is a strong green tech industry. Seen from this angle, environmental technology and resource efficiency is a key driver of development toward a green economy. The sections *The dawn of the green economy, Distributed power supply structure, Smart cities and Environmental technology services – New challenges, new business models* describe how this process is unfolding. Drawing on strategies and product innovations that are already emerging, they illustrate how environmental technology and resource efficiency presents hand-on solutions to pressing ecological and social challenges.

Each of the four sections that follows describes one dimension of transformation; and each dimension constitutes an important step along the road to sustainable economic and social development. One major criterion behind the choice of topics was the following pivotal question: To what extent does the dimension in question have the potential to resolve the challenges confronting humankind in the form of the five specified megatrends? The first section in this chapter, *The dawn of the green economy*, stakes out the context within which transformation in the other three dimensions is to be understood.

The dawn of the green economy

As the world's population continues to grow, it is vital to master the challenges of climate change and scarce resources. Since these megatrends will shape and mold social and economic conditions in the future, there is **no long-term alternative to making economies sustainable**. At the World Economic Summit in Davos, Ban Ki-moon urgently appealed to those in attendance to cast off the illusion of unlimited quantitative growth. "We believed in consumption without consequences," he admitted. But: "Those days are gone. In the twenty-first century, supplies are running short and the global thermostat is running high. Climate change is also showing us that the old model is more than obsolete. It has rendered it extremely dangerous. Over time, that model is a recipe for national disaster. It is a global suicide pact." [1] The General Secretary of the United Nations went on to stress that it is high time to usher in a new era: "We need a revolution. Revolutionary thinking. Revolutionary action. A free market revolution for global sustainability." [2]

Pursued in a market-economic context, sustainable development, to quote the German government's definition, "at once targets successful business performance, social cohesion, the protection of the natural basis that supports human life and the acceptance of international responsibility. These goals must be brought into a robust and long-term equilibrium in order to increase macroeconomic prosperity." [3] These key tenets of sustainability broadly map out the development path that leads to a green economy.

As yet, however, there is no clear definition of the term **green economy** or what it involves. Well-known approaches have been formulated by the **United Nations Environment Programme (UNEP)** and the **International Chamber of Commerce (ICC)**, for example. Individual elements of a definition of the green economy are also touched on in the European Commission's "Europe 2020" strategy. [4] The understanding that economic growth, social responsibility and ecological concerns are equally valid goals is a common thread in these definitions. The efficient use of resources, safeguarding biodiversity, protecting the environment and pursuing decarbonization are cited as essential attributes of a green economy. [5] [6]

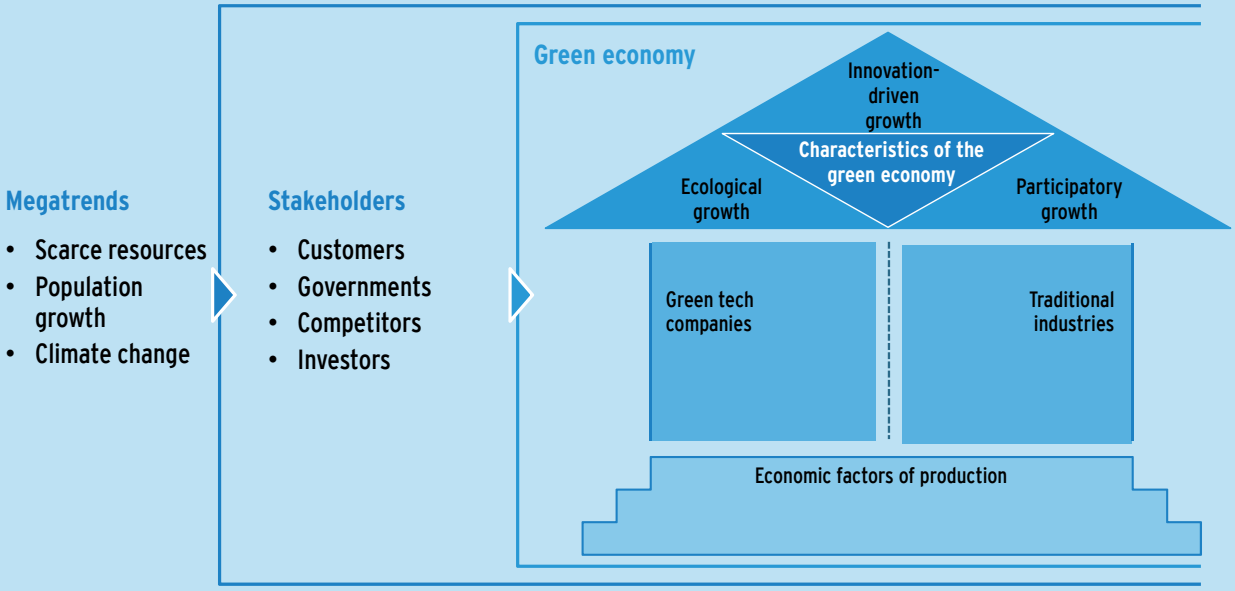
In its 2011 environment report, the German Ministry for the Environment identified the following characteristic traits of a green economy: [7]

- Continual reduction of harmful emissions and pollutants in all environmental media [8]
- Waste management and recycling practices in which material cycles are as closed as possible
- Absolute reduction in resource consumption through the more efficient use of energy, raw materials and other natural resources, and through substitution of renewable resources for non-renewable resources
- Protection of the climate
- Power supplies that, in the long term, are based exclusively on renewable energy sources
- Preservation of biodiversity and restoration of natural habitats

In light of these approaches and based on interviews, surveys and intensive discussion processes with players in the business community, it is reasonable to draw up the following **frame of reference for and broad definition of the green economy** (see figure 69): The green economy is a form of economy distinctively characterized by innovation-driven, ecological and participatory growth. It rests on two pillars: a strong environmental technology industry on the one hand and, on the other, companies in traditional industries that pursue sustainability strategies which are integrated in all levels of their management system ("sustainable business"). [9] The development of the green economy is influenced primarily by four groups of stakeholders: governments, customers, companies and investors. The expectations and demands of these stakeholders are in turn largely shaped by three global megatrends: climate change, the scarcity of resources and population growth.

1 UN (2011)
2 Ibid.
3 Bundesumweltministerium/Umweltbundesamt (2012), p. 67
4 See the following statement on the EU Commission's website: "Europe 2020 is the EU's growth strategy for the coming decade. In a changing world, we want the EU to become a smart, sustainable and inclusive economy. These three mutually reinforcing priorities should help the EU and the Member States deliver high levels of employment, productivity and social cohesion."
5 UNEP (2011)
6 International Chamber of Commerce (2011)
7 See Bundesumweltministerium/Umweltbundesamt (2012), p. 68f
8 Namely soil, air and water
9 For a definition of sustainable business, see Henzelmann, T. (2010), p. 21: "Sustainable business is the guiding principle behind a holistic approach to management that integrates the three dimensions ecology, social responsibility and economics in a company's strategy and in all its processes."

Figure 69: Frame of reference for and characteristics of the green economy



Source: Roland Berger, based on UNEP, EU, ICC

The **three characteristic traits of the green economy (innovation-driven growth, ecological growth and participatory growth)** each subsume different areas that require action (see figure 70). Aspects such as innovative capabilities, knowledge, education and the digital society are subsumed under the heading "innovation-driven growth". "Ecological growth" is understood to mean advances in areas such as energy and resource efficiency, the reduction of emissions, the preservation of biodiversity and sustainable mobility. Areas such as employment, involvement in green growth, equitable wages and social diversity are assigned to the heading "participatory growth". All three characteristics of the green economy and their constituent parts can be measured and verified in many different ways (see figure 70).

Figure 70: The green economy – Dimensions and metrics

Innovation-driven growth

Education
- Number of university graduates in environmental technology-related subjects
- Penetration of trade shows that relate to environmental technology themes

Research and development
- Number of patent applications in traditional industries that relate to environmental technology (products, processes and services)

Government subsidies
- Number and scope of government-initiated green subsidy programs
- Number of environmental clusters and transfer hubs

Ecological growth

Efficiency gains through green technology
- Energy productivity
- Material productivity

Degree of green technology penetration
- Renewable energy's share of energy mix
- Volume of investment in green technology
- Traditional industries' share of sales in lead markets

Quality of life
- Damage to the environment (through chemicals, greenhouse gases)
- Renewable natural resources (forests, fish, etc.) and non-renewable natural resources (e.g. raw materials)
- Quality of drinking water

Participatory growth

Macroeconomic significance
- Environmental technology's share of GDP
- Proportional/absolute number of employees in environmental technology

Consumers' perception
- Per capita income
- Sickness and disease due to pollution
- Growing awareness of the green transformation in society

Source: Roland Berger, based on UNEP, EU

In Germany, **the structural transition to a green economy** has already begun. Proactive environmental policy has played a seminal role in this development: "German environmental policy is a bona fide success story. We have achieved a lot for the environment, climate protection and the conservation of nature." [10] Major milestones include the German government's ambitious goals for reducing CO_2 emissions, improving energy efficiency and having 80 percent of the power supply covered by renewable energy resources by 2050.

When it comes to protecting the environment and the Earth's climate, these targets make Germany a pioneer in the international community. Without the environmental awareness that has been cultivated in German society over many decades, adopting such a pioneering role would have been inconceivable. For Udo Kuckartz, Professor of Empirical Education at Philipps University in Marburg, one thing is clear: [11] Environmental issues "have deep roots at a fundamental level in the population, and also in the echelons of leadership. They have reached the very heart of society," the specialist for environmental awareness and education notes. [12]

The phrase that they have "reached the very heart of society" implies motion from the outside toward the center. This kinetic energy is driven by a growing environmental consciousness that has now permeated all areas of society. In our present context, it is not possible to trace every aspect of the "secret genesis" [13] of this phenomenon. Nonetheless, it is worthwhile **briefly looking back** to the era in which the opening chapter of Germany's environmental policy success story was written.

The **"ecological revolution"** took place in the late 1960s and early 1970s. [14] Around the globe, more and more people protested against the ruthless exploitation of ecosystems. Germany too was the scene of large demonstrations and rallies. The building of nuclear power plants mobilized numerous opponents of this technology, who used protest campaigns to voice their rejection of nuclear energy.

Five decades ago, abusing nature – with all the significant risks to human health that this entailed – was the order of the day. A few examples from a lengthy list of ecological sins suffice to underscore the point: In the US, farmland was sprayed from the air with DDT; industrial waste and dilute acid were dumped into the oceans; Japanese children died of the consequences of photochemical smog and mercury poisoning; and some of Germany's rivers were so heavily polluted that the Rhine was derided as a "cesspit".

It was against this backdrop that resistance to the wanton pillaging of nature grew. The protest movement resonated with political institutions. The Council of Europe ratified the "Water Charter" and the "European Clean Air Charter" in 1968, before declaring 1970 to be the "Year of Nature Conservation". In 1972, **Stockholm** hosted the **first UN Environment Conference**, which ultimately led to the founding of the United Nations Environment Programme (UNEP). At the same time, a number of citizens' action groups advocating the protection of the environment sprang up in Germany. This grassroots movement was an important factor in firmly anchoring environmental policy in German society right from the outset. [15] It also impacted the political arena. In July 1974, the Federal Environment Agency was founded as a separate supreme authority within the remit of the Federal Minister of the Interior.

Environmental policy issues remained high on the political and social agenda in the 1980s too. The **Chernobyl reactor disaster in April 1986** once again focused social attention on environmental policy. The founding of Germany's Federal Ministry of the Environment on June 6, 1986, was an indication of the growing importance of environmental protection. In the early 1990s, in the wake of reunification, ecology may not always have been a prime-time political theme. But it never dropped off political agendas altogether; nor did the public eye ever completely lose sight of it. On the contrary: The exit from nuclear power, the embrace of renewable energy and the challenge of climate change were and still are issues of central political importance in Germany.

10 See Umwelt spezial (2011), p. 3
11 See Umwelt spezial (2011), p. 21
12 The implications that growing environmental awareness has for the corporate community are discussed in detail in the section on "Key players in the green transformation" on p. 140
13 See Radkau, J. (2011), p. 161
14 According to Radkau (2011), p. 124ff
15 See the opinion aired, for example, by Hubert Weinzierl, who presided over Bavaria's Nature Conservation Association from 1969 through 2002: "It was only the shift in the sociopolitical mood at the end of the 1960s that created fertile soil for new movements and, hence, a robust ecology movement. The European Year of Nature Conservation in 1970 then achieved the breakthrough for a holistic view of nature conservation. The Earth was recognized as a home shared by all living beings." Quoted by Radkau (2011), p. 135

Key players in the green transformation

This, then, is the foundation on which German environmental policy was built. One of its unique aspects is the many "authors" who have penned this success story. Germany's progress to date along the road to a green economy has been possible only because different players stood up for ecological concerns and, in so doing, established a social **consensus about the importance of environmental policy**. In particular, interaction among citizens, companies, research organizations and the political establishment served as the catalyst that, in recent decades, has brought environmental policy out of its bit-part role in Germany and moved it center stage. The section that follows takes a panoramic look at all the different stakeholders, showing how and what the government, consumers, the finance industry, business and the scientific community are contributing to the "green transformation".

The government – A source of stimulus for innovation and investment

For decades, the government has played a leading role in Germany's environmental policy. Why? Because when it comes to resources such as clean water and pure air, there is no self-regulating market in which Adam Smith's "invisible hand" acts in concert with the laws of supply and demand. In the absence of such intervention, it is left to the legislator to wield its **armory of regulatory actions and market-economic incentives**. Environmental policy also needs an institutional framework. In Germany, the key anchor points for this framework were the launch of the Advisory Council on the Environment in 1971, the creation of the Federal Environment Agency in 1974 and the founding of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety in 1986.

The government has thus had a large hand in preparing the success of environmental protection in Germany. As far back as the 1970s, the then government set the standard for other industrialized European nations in terms of **environmental legislation**. The Lead-in-Petrol Act, for example, was ratified in 1971, as was the first nationwide waste law a year later. The Federal Immission Control Act and the Environmental Statistics Act followed in 1974. [16]

Numerous environmental laws were passed in the 1980s too. One example is the Ordinance on Large Combustion Plants, ratified in 1983 with a view to limiting emissions of dust, sulfur dioxide and nitrogen oxide. Together with the Technical Instructions on Air Quality Control (TA Luft, 1986), this ordinance drove the retrofitting of new and old plants alike, curbing emissions and setting an example for the Large Combustion Plants Directive issued by the European Community in 1988. An amended version of the Detergents and Cleansing Agents Act in 1987 put an end to the mountains of foam in Germany's rivers. The environmental impact of road traffic was improved by the ban on regular leaded gasoline in 1987 and the imposition of stricter standards for car emissions in 1988.

Even at this early stage, it became apparent that **regulatory and environmental policy conditions would have an impact on innovations and the emergence of new markets**. Government-imposed regulations raised the requirement for the development of new technologies. To begin with, this mechanism manifested itself in traditional end-of-pipe technologies: New thresholds for air purity necessitated more powerful filters. New water purity laws demanded new purification methods capable of significantly reducing water pollution. In this way, domestic legislative activity gave a major boost to investment.

Earlier than in other countries, ambitious environmental laws confronted German companies with the challenge of advancing sustainable innovation and using ecofriendly products and processes. This necessity was instrumental in giving environmental technology made in Germany an **edge in international competition** – an advantage from which the industry still benefits to this day.

The German government did not only use prescriptions and prohibitions to stake out the road to environmental protection, however. It also **actively supported green growth industries**. The upswing in renewable energy would not have been possible without the support envisaged by the Renewable Energy Sources Act , for example. With the wind at their backs, German companies were thus able to take the lead in the international market segment for renewable energy. If renewable energy had not been promoted in this way, it is also fair to say that the technologies in existence today would probably

16 See Radkau, J. (2011), p. 128

neither be mature enough nor sufficiently inexpensive to facilitate the government's "new energy policy" and enable the power supply industry to be largely hooked up to renewable sources. The Renewable Energy Sources Act was a pivotal factor in allowing Germany to assume a pioneering role, showing other industrialized countries the way forward to a sustainable, decarbonized power supply constellation.

Consumers – Sustainability as a key criteria in how companies and their products are judged

A magazine asked the PR manager of a natural cosmetics brand whether the "green lifestyle is a passing fashion fad". Her reply was unequivocal: "People are more critical nowadays. And I think they'll stay that way. Climate change, allergies and food scandals are doing their bit too. Organic is here to stay." [17]

TV advertising confirms this assessment. Energy efficiency is the subject of numerous ads. The German private channel ProSieben runs a "Green Day" campaign covering climate protection and energy-saving themes. There are therefore clear indications that ecological issues are no longer a special-interest feature: They have **arrived in the mainstream**. More and more consumers look long and hard at companies' compliance with social and environmental standards. Sustainability is becoming an important criterion when people judge businesses and their products.

Various long-term studies of consumer behavior patterns attest that **consumers' discovery of sustainability** is far more than just a passing fad. The Otto Group, for instance, has published a trend study on ethical consumption every two years since 2007. Its 2011 trend study concentrated primarily on consumer confidence. Its findings were abundantly clear: "Ethical principles have gained crucial importance for today's culture of consumption." [18] Nearly three quarters (72 percent) of the people interviewed in the course of the study stated that "ethical criteria have become a regular component in their purchase decisions". [19] In the preceding study in 2009, only 26 percent of respondents said they frequently buy "ethically sound products". By 2011, the proportion had risen to 41 percent. [20] Consumer goods manufacturers and retailers would do well to heed these numbers – and to draw appropriate **conclusions for their management practice**, as the Otto trend study points out: "Companies' values are becoming more important than brand values, because people are more willing to trust what a firm does in practice than the promise of its brand. The other side of this coin is that business ethics cannot be left to CSR departments alone, nor is it just a job for marketing. It is a matter of corporate culture." [21] And corporate culture has to be built on more than mere "greenwashing" and glossy PR brochures. Today's enlightened consumers and their organizations are quick to spot attempts at "cosmetic greening". In the age of Web 2.0, sustainability promises that are not honored can quickly become an ugly stain on a company's image. Networked media are stepping up the pressure on companies to go beyond mere statements of intent and genuinely – and verifiably – live out the content of their CSR policies.

This transparency makes the Internet a vital platform in spreading the idea of sustainable consumption, first among like-minded communities on the World Wide Web, and then across the reality of purchasing behavior. That is the goal to which utopia.de, one of Germany's larger online platforms for sustainable consumption, subscribes: "Every one of us can make an important contribution. But together we have more leverage." [22]

The "changemakers" and other companies that accept sustainability as part of their strategy have understood that this whole issue is about much more than simply responding to the expectations of the public. Growing **consumer awareness** also creates opportunities for ethical management practices to give a company competitive advantages. A sustainable profile stands out from the crowd.

There is no question that an understanding of the need for sustainable action is much more widespread today than it was just a few years ago. Yet this is another situation in which "better is the enemy of good". Scientist Udo Kuckartz wishes that people were more aware of the consequences of their own behavior: "They limit themselves to symbolic, low-impact gestures such as separating waste, buying energy-saving lamps and taking day trips out on bicycles. And then they jump aboard a low-cost airline

17 Sabine Kästner, press spokeswoman for "Lavera", in an interview with *Brigitte* (issue 22/2011)
18 Otto Group (eds.) (2011), p. 4
19 Ibid., p. 12
20 Ibid., p. 5
21 Ibid.
22 Utopia (2011a)

which – in terms of carbon emissions and other pollutants – wipes out all the good they have done. People need to think more coherently, understanding the link between the big steps and the small ones, which we obviously need too." [23]

Finance industry – Sustainability criteria growing in importance

The first tender shoots of a transition to the green economy are beginning to appear in the finance industry too. As a criterion by which to judge financial investment, sustainability has long since emerged from the shadows to become an important consideration for private individuals and professional fund managers alike. And precisely because this trend will grow stronger in the years ahead, it is important to clarify exactly what we are talking about. How do investments earn the right to be called "sustainable"? Since the "green wave" began sweeping over the financial markets, the relevant criteria have at times been defined extremely generously. Some practices have bordered on greenwashing; others have not even stopped there. In accordance with the "Darmstadt definition", **sustainable investments** [24] contribute to sustainable development: "They enable [such development] by analyzing every aspect of investment objects, including economic and social performance, ecological footprint and social developments." [25]

However, such "comprehensive analysis of investment objects" requires the existence of sustainable management criteria that are both identifiable and lend themselves to operational practice. The sustainability indices, systems of ratios and reporting frameworks briefly described below provide valuable assistance.

In recent years, a plentiful supply of **sustainability indices** has sprung up all over the world, with portfolios that supposedly reflect the sustainability of listed corporations. Essentially, there are two ways to determine which companies are included in an index and which are not: the best-in-class principle and defined sets of positive and negative criteria.

The **MSCI World ESG Index** (launched in 2010) and the **Dow Jones Sustainability Index** (launched in 1999) apply the **best-in-class principle**. The analysts at the Swiss-based Sustainable Asset Management Group pick candidates for the DJSI World – probably the world's best-known family of sustainable indices – from the 2,500 biggest global stocks listed on the Dow Jones Global Total Stock Market Index. Selection is based on an exceptionally promising outlook in terms of economic, ecological and social considerations. Companies admitted to the index must also be among the top 10 percent in their chosen industry with regard to sustainability criteria. [26] Since the best-in-class principle essentially knows no *a priori* exclusion criteria, even companies in the oil industry, operators of nuclear power plants and tobacco groups can be included in the sustainability index. This perhaps explains why increasing numbers of skeptics warn against regarding inclusion in the DJSI as a kind of quality seal for sustainability. BP, for example, used to be listed as top of the class in the oil industry. After the explosion of the Deepwater Horizon oil rig in April 2010, however, the group had to be taken off the index in July of the same year. [27]

Other sustainability indices choose companies on the basis of negative and positive criteria. **FTSE4Good** and Germany's **Natur-Aktien-Index** (NAI) are two examples of this approach. Launched in 1997 by Hamburg-based financial services provider Securvita, the latter index comprises 30 companies of different sizes from various countries and industries. The condition of entry to the index is that companies must "make a global contribution to the development of sustainable ecological and social styles of business". [28] A five-person committee whose members are recruited from scientific institutions and environmental organizations decide on the acceptance of a company in the NAI. Candidates must satisfy at least two out of four positive criteria. They must: (1) be providers of products and services "that make a material contribution to the sustainable ecological and social resolution of key problems facing humanity"; and/or they must play a pioneering role (2) in product design within their industry, (3) "in the technical design of the production and sales process", and (4) "in the social design of the production and sales process". [29]

Yet indices alone are not enough to assess a company's sustainability. For one thing, only publicly traded stock corporations can be admitted. For another, indices do not model all information that is of relevance to financial analysts and investors. The latter demand data that provides a transparent view of

23 Umwelt spezial (2011), p. 21
24 In some instances, "green investment" is used here as a synonym for "sustainable investment". To some extent, this equivalence has become common parlance, although the term sustainability addresses both the social and economic dimensions in addition to ecological considerations, and therefore – strictly speaking – requires a broader definition than merely "green"
25 Hoffmann, J./Scherhorn, G./Busch, T. (eds.) (2004), p. 6
26 See Dow Jones Sustainability Index (2012)
27 Dow Jones Sustainability Index (2010)
28 See Natur-Aktien-Index (2012a)
29 Natur-Aktien-Index (2012b)

opportunities and risks with regard to environmental, social and governance (ESG) contexts, and that makes companies readily comparable with each other. This requirement is met by special **key performance indicators (KPIs)** that express the degree of compliance with ESG criteria. Though there is still no binding standard for the uniform, numbers-based presentation of sustainability criteria, KPI models have taken shape in practice. One of these is **KPI for ESG 3.0**, a model devised by the DVFA Society of Investment Professionals in Germany to accommodate the growing need for sustainability reporting. [30]

On behalf of the Federal Ministry for the Environment and the consulting and auditing company Deloitte, Axel Hesse came up with an alternative: **the Sustainable Development – Key Performance Indicators (SD-KPI)** concept. For each of ten different industries, this concept identifies the two or three SD-KPIs that are regarded as the most important non-financial performance indicators for sustainable business development. [31]

For the **Eco-Management and Audit Scheme (EMAS)**, EU-Regulation 1221/2009 introduced the following binding core indicators: energy and material efficiency, water, waste, biodiversity and emissions.

Global Reporting Initiative (GRI) guidelines have become the **accepted de facto international standard for sustainability reporting**. [32] An offshoot of collaboration among non-government organizations, the United Nations Environment Programme (UNEP) and various stakeholder organizations at the end of the 1990s, the GRI has since grown to become an international network whose activities span more than 70 countries. The organization published its first set of sustainability reporting guidelines in 2000. The third edition of this reporting framework ("GRI 3.1 Guidelines") is now in print. The guidelines comprise 56 "core indicators" covering the following categories: [33] the company's profile (including its strategy, organizational profile, governance, management approach and performance indicators) and indicators of economic, ecological and social performance (human rights, social responsibility, product responsibility and working conditions). Industry-specific performance indicators complement these core indicators.

The **Carbon Disclosure Project (CDP)** plays a key role in attempts to base reporting on greenhouse gas emissions on a uniform standard. Founded in 2000, the CDP represents over 550 institutional investors with a total investment volume of USD 71 trillion. This independent, non-profit organization has set itself the goal of "materially contributing to solution strategies with regard to climate change by providing private enterprise, governments and the financial industry with relevant information". [34] The CDP claims to maintain the world's biggest database for climate information that is relevant to the corporate sector.

These developments and initiatives show that, for investors, sustainability considerations have risen to far greater prominence than in the past. Nonetheless, the **volume of sustainable investments** still remains modest in absolute terms. On June 30, 2011, a total of 363 sustainable mutual funds with a combined volume of roughly EUR 34 billion were licensed for distribution in Germany, Austria and Switzerland. Two other numbers add a sense of proportion to this figure: Germany alone has 6,600 mutual funds in which EUR 695 billion is currently invested. [35] In 1999, however, a mere 17 sustainable mutual funds with a combined volume of EUR 650 million were listed in German-speaking Europe. [36]

The **alternative banking sector**, which invests primarily in ecological and social projects and aligns its financing business policy with strict sustainability principles, has gained significant ground in recent years. Even so, banks such as UmweltBank, Ethik Bank, GLS Bank and Triodos Bank only manage total assets of around EUR 20 billion. From a quantitative perspective, they thus remain so many Davids alongside the banking industry's ranks of Goliaths. [37]

On the other hand, there are two ways to interpret these figures. If one measures what are known as socially responsible investments (SRIs) in absolute terms, it is easy to gain the impression that sustainable investment is little more than a footnote to the activities of the financial markets. However, if one traces the emergence of SRIs in German-speaking and other European countries, it becomes clear that green investments have long since left the ecological peripheries and penetrated the heart of the financial markets.

30 See DVFA/EFFAS (2010)
31 See Bundesumweltministerium (2009e), p. 8
32 See Carbon Disclosure Project (2011a), p. 63
33 List taken from the Sustainability Reporting Guidelines (Global Reporting Initiative (2011), p. 1)
34 See Carbon Disclosure Project (2011a), p. 73
35 According to data from the Sustainable Business Institute (2011)
36 See Heintze, A. (2011), p. 87
37 Ibid., p. 88

"These days, if you represent a sustainable fund you are no longer regarded as an oddity. Increasingly, people will listen to what you have to say," notes Ingo Speich, speaking from his experience as the person in charge of sustainable investments at Union Investment. [38]

Browse around the established financial institutions and it becomes clear that the subject of sustainability has gained a very firm foothold. Alongside hard financial data, the managers of sizeable funds are attaching growing importance to ecological and social criteria and good corporate governance when picking stocks for their portfolios. A study commissioned by Union Investment led to a European first: the compilation of an index **"of sustainable investments by German institutional investors"**. The mood in this segment is clearly upbeat. On a scale from -100 to +100, the index scores +22, which equates with a "positive attitude" on the part of large German investors. Tellingly, the study respondents represent a high-caliber mix of pension funds, insurance companies, foundations, banks and large companies with combined total assets of EUR 1,030 billion. [39]

Corporate boardrooms would do well to pay particular attention to the following detailed finding of the Union Investment study: More than 40 percent of respondents stated that they support the notion of sustainability and want to do so in their capacity as active investors. In other words, they plan to consciously influence compliance with ecological, social and ethical principles in the context of corporate management. Even before the Fukushima disaster in 2011, energy group RWE experienced at first hand – at its 2009 annual general meeting – what "active investors" are capable of in practice. Fund manager Speich and other investors criticized the group's plans to build two nuclear power plants in Bulgaria and Romania, both regions that are prone to earthquakes. Neither project got off the drawing board. [40]

Companies cannot close their eyes to the trend toward greater **sustainability in large investors' strategies**, as evidenced by a study published jointly by the Sustainable Business Institute and the Deutsches Aktieninstitut in September 2011. According to the study, more than two thirds of listed companies claim that the topic of sustainability "is of considerable importance to the future development of the company". To put that figure in its historical context: Only around 40 percent of companies were prepared to make the same statement in 2003. [41]

Companies seeking to stump up capital on the stock markets are not the only ones having to contend with higher expectations placed on the sustainability of their business strategies, however. The banks – traditionally a mainstay of corporate finance in Germany, especially for small and medium-sized enterprises – are likewise raising the bar for compliance with a list of ecological, social and ethical criteria. **Risk management** is by no means their least reason for doing so. As raw materials grow ever more scarce and expensive and the climate continues to change, the issue of whether or not a company succeeds in designing an energy-efficient and sustainable value chain is crucial to its medium- to long-term positioning. "For key industries such as power generation, automotive engineering, transportation and insurance, as well as agriculture, climate change is becoming just as important as exchange rate and interest rate risks." This view, formulated as far back as 2007, has lost none of its validity in the meantime. [42]

Companies – In the black thanks to green concepts

Conservative political forces in some countries still hold doggedly to the claim that the gulf between economics and ecology is unbridgeable. In Germany, however, this friend-or-foe dualism, built on the fiction of antagonistic and inherent contradictions between business interests and those of the environment, has long since proven to be obsolete. True, the ecology movement of the 1970s had few close allies in the boardrooms of German companies. As early as the 1980s, however, more and more companies began to concern themselves constructively with protecting the environment – a fact documented by the beginnings of corporate environmental reporting and the precursors of today's ecological audits. After Chernobyl at the latest, it was clear to everyone that the issue had become a long-term trend that would powerfully affect both the supply and the demand sides of markets.

The megatrends scarcity of resources and climate change have since become even more firmly embedded in social consciousness, as has the need to protect the environment. Slowly but surely, more and more

38 See Schönwitz, D. (2011), p. 40
39 See Union Investment (2011)
40 See Schönwitz, D. (2011), p. 40
41 See Sustainable Business Institute/Deutsches Aktieninstitut (2011)
42 See Berenberg Bank (2007)

businesses are understanding that, **in the decades ahead, climate change and the scarcity of resources will not only redraw the lines of the political and social arena, but will change the rules of the economic game too**. All industries – from heavy industry to financial services to retail – will feel the impact sooner or later.

The scarcity of resources and climate change are thus rewriting the demands placed on corporate strategies. They are doing so by changing the expectations and demands of social players. From the perspective of corporate stakeholders, they are thus significantly influencing the context within which companies operate. As a result, **companies are coming under increasing pressure from customers, investors and the government to align their business strategy with the dictates of a resource-efficient, low-carbon economy**. The mood described in the section on the finance industry has already shown how stakeholders can forcefully express their heightened demand for sustainability.

It therefore becomes clear that the transition to a green economy changes an economy's entire corporate landscape. Its impact is not restricted solely to green tech firms. The **definition of the green economy** used in this volume (see page 137f) explicitly mentions two key pillars: a strong environmental technology industry and companies in traditional branches of industry that also pursue sustainable business strategies.

To master the challenges of climate change and scarce resources, companies must, depending on their industry affiliation, **define strategies** that anchor the principles of sustainable development on an operational level. **"Sustainable business"** is the name given to this approach, and is the guiding principle for a holistic approach to management that integrates the three dimensions ecology, social responsibility and economics in a company's strategy and all its processes. [43] This concept is instrumental in translating the green economy into reality. In the way it confronts climate change and the scarcity of resources, it goes far beyond mere risk management. It also tackles the issues of how far companies can put these megatrends and their implications for the various markets to good use for their own competitive positioning. The path to sustainable business can be described as a **green transformation**. At the core of this far-reaching change process is the need for every company to evaluate the risks and opportunities that the megatrends will present to their business model at every link in the value chain. Having performed this analysis, they must then make the necessary changes on all levels and in all processes.

Environmental technology – A growth industry

Growing environmental awareness has triggered the development of environmental technology and resource efficiency as a whole new branch of industry. This new branch has grown out of the core competencies and innovative capabilities of "traditional" industries such as mechanical, plant, automotive and electrical engineering as well as chemicals, all of which are areas where Germany has proven strengths. Accordingly, it did not take long for German firms to shine on the world's markets as providers of typical environment protection technologies such as waste processing, recycling and water conservation. Now that the scarcity of resources and climate change are developing into ever more pressing megatrends, German companies are reaping rich rewards from growing global demand in the lead markets for energy efficiency and material efficiency, in the renewable energy and energy storage segments, and in alternative propulsion technologies. In these segments, many **German green tech firms play in the equivalent of the Champions League** on international markets.

All the signs indicate that the markets for environmental technology and resource efficiency will continue to grow in the years ahead. They are already worth a total of over EUR 2,000 billion, which is set to rise to more than EUR 4,400 billion by 2025. **Positive stimulus for Germany** is to be expected from this expansion – a view shared by acatech, Germany's National Academy of Science and Engineering, which sees the country playing a lead role in the markets for resource efficiency and sustainable power supply.

Science – Research and higher education as the idea forge of the green economy

Science too has made a huge contribution to the success of environmental policy and to the "green structural transition" in Germany. The scientific community has been a **powerful voice in political and social discourse**; it has also delivered **momentous achievements in research and development**.

43 See Henzelmann (2010), p. 21

"Green tech made in Germany" has been and will continue to be successful largely because of the innovative strengths of Germany's environmental technology sector. Yet for all their vast potential, companies remain dependent on cooperation with research organizations, especially in basic research and during the translation of new knowledge into practical applications. The sheer diversity of Germany's research landscape is in itself a success factor for many companies in the lead markets that make up the environmental technology and resource efficiency industry. Left to their own devices, many market players – especially those in young disciplines such as renewable energy – would never have been able to complete the arduous journey from basic research to market-ready products. There is no room in this publication for more than a few examples of the colorful variety in Germany's green tech research landscape. The accounts that follow therefore make no claims of completeness. Their purpose is solely to give an impression of the diversity of scientific activities that are currently underway in environmental and sustainability research.

In recent decades, Germany has established itself as a hive of **dynamic research and development activity in the green tech sector**. Research organizations are playing a large part in advances in this industry. Many of the 80 research institutes that belong to the **Fraunhofer-Gesellschaft applied research organisation** devote themselves to issues such as energy and housing or production and the environment. Among the Fraunhofer's green flagships are Oberhausen-based UMSICHT (the Fraunhofer Institute for Environmental, Safety and Energy Technology), the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, whose 1,100 or so staff make it the largest solar research institute in Europe, and the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), which operates two sites in Bremerhaven and Kassel.

Öko-Institut e.V. (the Institute for Applied Ecology) and the Wuppertal Institute are two of many organizations whose research into various aspects of sustainable development is held in high regard both in Germany and abroad. The former was founded in Freiburg in 1977 and now has satellite facilities in Darmstadt and Berlin. Spread across these three sites, over 130 staff conduct research on chemicals management and technology assessment, energy and the climate, emission control, ambient pollution control and radiation protection, and sustainable consumption, mobility and resource management, to name a few. [44] The scientists at the Öko-Institut advise political institutions at the regional, federal and European Union levels.

The **Wuppertal Institute for Climate, Environment and Energy** was launched in 1991 under the guidance of Professor Ernst Ulrich von Weizsäcker. This research institute adopts an interdisciplinary approach and concentrates primarily on applied sustainability research. This approach is reflected in collaboration with numerous universities and institutes both in Germany and on an international level. [45]

The list of Germany-based research institutes of national and international standing could be continued almost indefinitely. In the interests of brevity, however, we shall – pars pro toto – mention only two further institutes at this point. The **IFEU Institute for Energy and Environmental Research Heidelberg** was established in 1978 by scientists at the University of Heidelberg as an independent ecological research institute. Its more than 50 staff represent a variety of scientific and engineering disciplines and engage in a large number of projects to realize the vision of their founding father, who sought to create a "space for independent research on issues of relevance to the environment". [46]

Headquartered in Duisburg, the **IUTA Institute of Energy and Environmental Technology** employs around 150 people and is one of the largest institutes in Germany in the field of energy and environmental engineering. [47] The IUTA focuses on research and development projects in which scientific knowledge is translated into innovative products and processes in collaboration with partners. It attaches great importance to cooperation with universities and other institutions of higher education. Collaboration is especially close with the University of Duisburg-Essen.

Alongside the rich diversity of the country's research landscape, patent statistics provide a further expression of Germany's potency in environmental technology R&D. Patents are an important indicator of an industry's research performance and innovative strength. On this score too, environmental technology is clearly a **powerful driver of innovation**. Between 2004 and 2007, for example, the number of German patent applications in this sector rose by around 19 percent per annum to 1,044. German companies are among the front-runners in international patent statistics as well. In 2007, the European Patent Office granted about 23

44 See Öko-Institut e.V. (2011)
45 See Wuppertal Institut für Klima, Umwelt, Energie GmbH (2012)
46 See Institut für Energie- und Umweltforschung Heidelberg (2011)
47 See IUTA e.V. (2011)

percent of all new environmental technology patents to German firms. The US (with 22 percent) and Japan (19 percent) followed in second and third place respectively. German environmental technology firms are especially innovative in the disciplines of solar thermal energy and wind power, where they account for roughly a third of all patent applications.

Above and beyond the scope of research and development, science is a powerful engine to accelerate the transition to a green economy in the context of higher education as well. German universities have in recent years brought forth a **sizeable crop of chairs and institutes** that concern themselves intensively with various disciplines and aspects of environmental technology and sustainable development. [48] Graduates from these courses in turn become key multipliers whose knowledge helps drive the green structural transition in industry and business.

Aside from higher education, corporate development and education also offers promising ways to integrate resource efficiency in day-to-day operations. Examples include courses leading to **qualification as a European Energy Manager (EUREM)** that were introduced under the auspices of the Energy Manager training program by the Nuremberg Chamber of Industry and Commerce in 1999. This qualification model for specialists and managers was initially adopted by other Chambers of Industry and Commerce in Germany, and then also by 15 European partners. Headed by the Nuremberg chamber, the initiative has now grown into the EUREM.NET project that is backed by the European Union and has so far trained more than 2,500 European Energy Managers. Every action initiated by these energy-saving experts has saved an average of 750 megawatt-hours of energy, EUR 30,000 and 200 tons of carbon emissions per year. [49]

Outlook

There is no alternative to embracing the dawn of the green economy. Simply "carrying on as you were" is simply not a viable solution given the urgency of megatrends such as climate change and the scarcity of resources. A society that eats into the substance of its natural resources and destroys what future generations need to live on has no future. Society and the economy must cultivate a sustainable focus to break the link between growth and ever greater resource consumption and, hence, to accept that there are limits to how far our ecosystems can be strained.

In Germany, the dawn of this "green structural transition" is already breaking. And just in the nick of time, to quote Jeremy Rifkin: "The entire industrial infrastructure built on the back of fossil fuels is aging and in disrepair. It is becoming increasingly clear that we need a new economic narrative that can take us into a more equitable and sustainable future." [50] Rifkin, a respected scientist, trend researcher and advisor to numerous governments, is convinced that humanity has reached a **turning point in economic history**, because the new convergence of information and communication technology and renewable energy is birthing a new order in the energy sector. Germany's new energy policy sketches an initial **outline of what this new energy order might look like**. It is immensely important to the scope and speed of the green structural transition.

48 Here are some examples of institutes of higher education that have developed courses of study in ecology and sustainability: The Eberswalde University for Sustainable Development, the IEEM Institute of Environmental Engineering and Management at the University of Witten/Herdecke; the artec Sustainability Research Center at the University of Bremen; the Institute of Environmental and Biotechnology at Bremen University of Applied Sciences; the Energy and Environmental Engineering course at the Technical University of Hamburg-Harburg; the Technical University of Dortmund; the Chair of Environmental Technology at the Technical University of Dortmund; the Chair of Thermal Process Engineering and Environmental Technology at the Technical University of Dresden; the Chair of Urban Water Management and Environmental Technology at the Ruhr University in Bochum; the Birkenfeld Environmental Campus at the Trier University of Applied Sciences

49 See Industrie- und Handelskammer Nürnberg für Mittelfranken (2011)

50 Rifkin, J. (2011)

Distributed power supply structure

In light of the scarcity of resources, climate change, the world's growing population and rising demand for energy, safeguarding the world's supply of energy and power will be one of the major challenges in the decades ahead. That is why the subject of a distributed power supply structure ranks as a key dimension of transformation along the path to the green economy. In Germany, the political framework was put in place in June 2011 when the Bundestag approved the new direction in the government's energy policy with a sizeable majority. Referred to in German more literally as the "energy turnaround", the new policy envisages a fundamental change in Germany's power supply system. The package of laws passed in June 2011 links a clearly defined timeframe for phasing out the commercial use of nuclear power to a concept for **improving energy efficiency** and **expanding the use of renewable energy**. The latter is to raise its share of the national power supply from around 20 percent today to at least 35 percent by 2020. By 2050, the figure should be 80 percent according to the government's energy concept. [1] In the decades to come, distributed power generation systems will therefore cover an increasingly large proportion of Germany's demand for electricity.

The plans are not only quantitative in nature. They will also precipitate a **transformation of the power supply structure in a number of ways**. Central aspects include the integration of renewable energy into markets and the overall system, flexible power plants, optimizing load management and expanding both power grids and storage capacity. The real challenge in the government's new energy policy is to link all these complex elements together. And that task may safely be termed "revolutionary", since it has to bring about a fundamental change in the energy structure, with renewables as the main source, distributed operator structures, intelligent networks and storage technologies, and a genuinely European power grid so that power from renewable sources can flow freely and smoothly across the continent.

"Revolutionary" means questioning and realigning inherited customs and practices. The revolutionary – and hence historic – nature of the new energy policy becomes even clearer when comparing the concept with existing power supply structures. The **full scope and consequences of the necessary changes** can be grasped only in contrast to the current situation.

1 Bundesministerium für Wirtschaft und Technologie/Bundesumweltministerium (2010), p. 5.

For this reason, this section begins by retracing developments over the past few decades. Only then does it describe the technological possibilities and challenges that lie ahead as Germany's power supply structure changes direction.

Looking back: How Germany's power supply structure became what it is today

Like most energy experts and politicians in the 1970s, Dixy Lee Ray, President of the US Atomic Energy Commission in 1973, was not impressed by the idea of a distributed power supply. She famously said that in terms of technical implementation, using solar energy was about as difficult as harnessing the energy of ten million fleas by teaching them to all jump in the same direction at the same time. [2] The whole idea seemed diametrically opposed to the spirit of an age in which Big Technology was mainstream.

The **structure of the power supply system** in Germany and other industrialized countries was initially shaped by medium-sized to large fossil-fuel-burning power plants. These historic nodes in the power grid had sprung up in cities and industrial conurbations and were linked to each other by power utility companies. West German nuclear plants fed power into the grid for the first time in 1972. Over time, an integrated network emerged that carried the electricity produced by medium-sized and large fossil-fuel and nuclear power plants via regional and local distribution grids (see figure 71). Within this cascade structure, the flow of power was a one-way street from producer to consumer.

Buoyed by the growing ecology movement, sobered by a series of oil crises and shocked by the Chernobyl disaster, scientists began looking for alternative forms of power supply. Thus it was that 1989 went down in history not only as the year in which the Berlin Wall came down, but also as the beginning of a **turnaround in Germany's energy policy**. At the time, it was "recognized as the state of the art that power generated by distributed consumers can be fed into the grid." [3]

Origins and drivers of distributed power supply structures

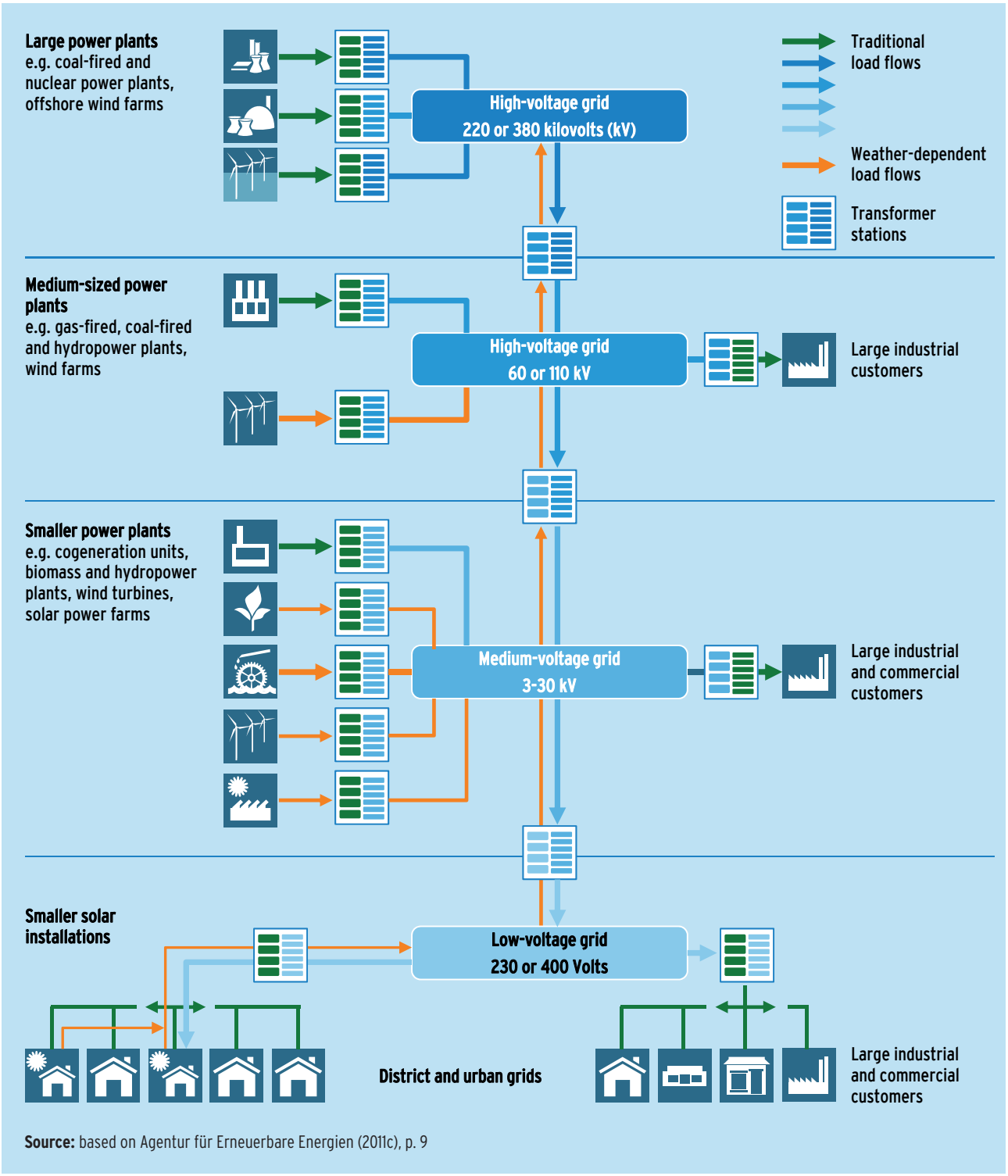
At the start of the 1990s, renewable energy accounted for a paltry 3.1 percent [4] of power generation in Germany. By July 2011, it had passed the 20 percent mark. These numbers highlight the speed at which renewable energy has flourished and grown in Germany. Inevitably, this development has accelerated the **decentralization of power generation** – renewable energy sources such as the sun, wind and biomass can normally be tapped only on a local scale. Moreover, pioneers in renewable energy have mostly begun by focusing on self-sufficiency based on autonomous systems. Almost by definition, the early days of the renewable energy era were "distributed".

Political backing likewise played a part in making renewable energy such a success. Development was kick-started by the "1,000 roofs program" launched in 1990 "to assess the current state of the art and identify what still needs to be done to develop small-scale photovoltaic systems that are hooked up to the grid." [5] Between 1991 and 1995, this field test analyzed the solar yield from 2,000 photovoltaic installations on the roofs of single-family houses and duplexes. Although the PV systems were subsidized to the tune of 70 percent, homeowners still had to contribute about EUR 10,000 per installation. In 1991, the government passed the **Act on the Sale of Electricity to the Grid**. In the future, compensation was to be paid for electricity generated from renewable sources by private providers. In adopting this model, German policy backed the demand side to promote renewables. This in turn acted as a catalyst to the decentralization of power generation. By comparison, the US was streets ahead of Germany on solar technology in the 1970s. Yet the US government opted to subsidize power utility companies to encourage further development in photovoltaics. [6] Today, Germany is the technology leader here.

The decisive boost to power generation from renewable sources came with the **Renewable Energy Sources Act**, which took effect in 2000 and has since been amended several times. This law and its predecessor, the Act on the Sale of Electricity to the Grid, gave small, distributed producers of green electricity guaranteed access to the grids of the major energy groups. The latter found themselves obliged to feed green electricity into their grids in return for a minimum charge.

2 See Radkau, J. (2011), p. 479
3 Ibid., p. 482
4 I.e. 3.1 percent of gross power consumption; see Bundesumweltministerium (2011d), p. 13
5 Launched by the Federal Ministry for Research and Technology, the 1,000 roofs program was officially called the "Federal/Regional 1,000 Roof Photovoltaics Program". See Hoffmann, V. (2008)
6 See Radkau, J. (2011), p. 479f

Figure 71: Power grid levels



Source: based on Agentur für Erneuerbare Energien (2011c), p. 9

By promoting the distributed generation of power from renewable sources in this way, Germany was quick to lay the foundation for the new direction in energy policy – a direction that was ultimately rendered unavoidable by climate change and the growing scarcity of fossil resources. Three factors in particular were, and still are, the primary motives for this **paradigm shift in energy policy**. First, as around 80 percent of all greenhouse gas emissions are energy related [7], it is imperative to substitute renewable energy sources for the fossil fuels coal, oil and gas to the greatest extent possible. The fight against global warming cannot be won if power generation is not decarbonized. Second, price trends and signs of the scarcity of fossil fuels – especially oil – are powerful arguments for the search for alternatives. And third, ramping up renewable energy can make Germany less dependent on energy imports.

The government's attempts to promote a distributed power supply from renewable sources would nevertheless have failed, had it not been for the strong positive response from users. Private consumers grew increasingly fond of renewables. Besides wanting to play an **active part in protecting the environment and the climate**, the majority of users also saw rising oil and electricity prices as key reasons to invest in distributed power supply systems. The hope was that they would be able to break out of the anticipated upward spiral in prices.

The decentralization of the power supply in recent years has also been expedited by **technological progress**. It took innovations in all segments of renewable energy to help this discipline make the leap from niche to mass market. And it took quantum leaps in information and communication technology (ICT) to create the conditions needed to integrate distributed sources into the power grid.

The **trend toward distributed power generation** is gaining further impetus from the interplay between growing demand, technological progress and declining prices for generating green power. Photovoltaics is a good example: Since 2006, the price of photovoltaic systems has dropped by more than half to just under EUR 2,200/kWp [8]. This plunge in prices is essentially attributable to the significant improvement in the efficiency of solar modules achieved by innovation. At the same time, larger sales volumes are generating economies of scale.

Skeptics argue that distributed and fragmented power generation is inefficient and therefore too expensive. Yet departing from the centralized model clearly delivers **a series of economic benefits**. Generating power near to where it is consumed helps avoid line losses, for instance. It also eases the burden on transmission grids, thereby cutting demand for interregional infrastructures. In the medium to long term, this reduces systemic costs. In addition, distributed power generation structures reinforce value creation on a regional level. Profits for local companies and jobs for local regions can help avoid or at least narrow any urban/rural divide in terms of economic strength.

Power consumers as power producers – Power plants in the basement, on the roof and in the front yard

The decentralization of power generation has caused demand-side roles to shift. Yesterday's power consumers have now become potential power producers too. More and more of them are also seizing the opportunity to install their own systems and guarantee a steady supply of power from solar energy, biomass and wind energy.

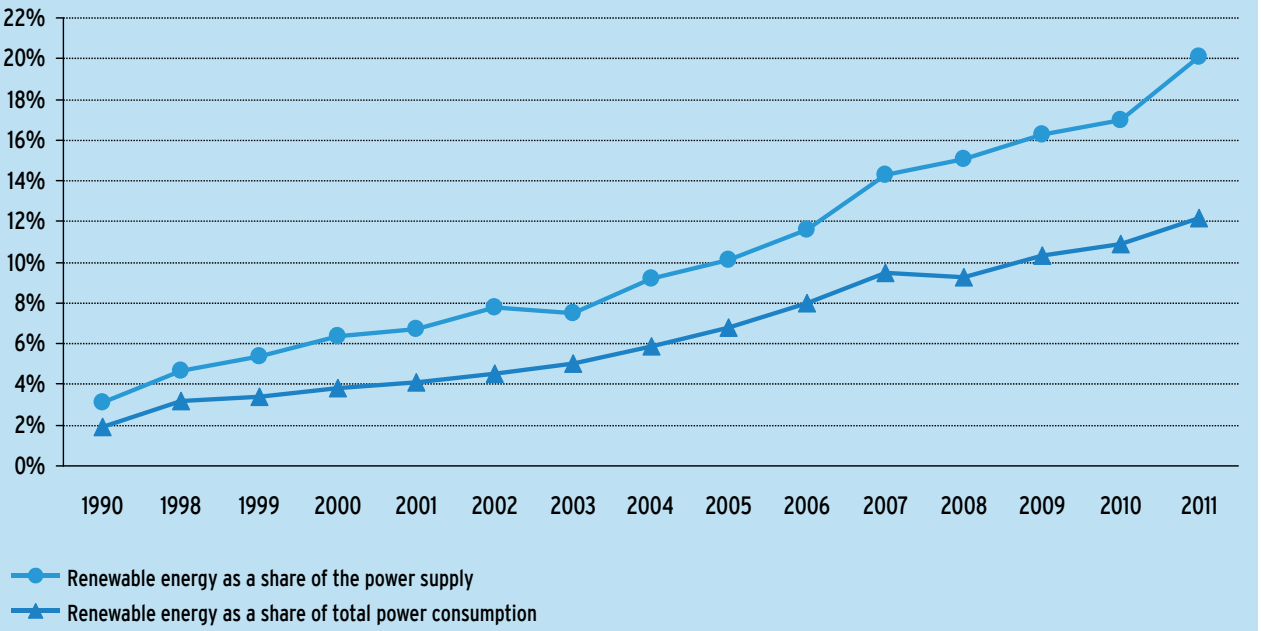
Photovoltaics and solar thermal energy

Around 2.3 million photovoltaics and solar thermal systems in Germany tap the inexhaustible energy of the sun to generate power and heat. In only a short space of time, solar power has thus emerged as a central pillar of distributed power supply constellations. The installed base of photovoltaic capacity shot up from 75 MWp in 2000 to 17,320 MWp at the end of 2010. **Power generation from photovoltaic systems** has plotted a similar trajectory, increasing from 64 gigawatt hours to 12,000 gigawatt hours in the same period. In 2010, the sun met the electricity needs of more than 3.4 million households in Germany, avoiding carbon emissions of around 6.2 million tons. [9] The aim now is for solar power to increase its share of gross power consumption from 2 percent to 10 percent by 2020. This trend is assisted by the declining cost of solar power. Between 2006 and 2011, the prices of turnkey rooftop photovoltaic installations were cut in half.

The German Solar Industry Association (BSW) believes that by as early as 2013, power produced on a building's own roof will be cheaper than most of

7 See Umweltbundesamt (2011c)
8 Average price to the end customer for turnkey rooftop installations of up to 100 kWp (excluding VAT); see Bundesverband Solarwirtschaft (2011b)
9 See Bundesverband Solarwirtschaft (2011b). The calculation is based on a three-person household with an annual power consumption of 3,500 kilowatt-hours

Figure 72: Renewable energy as a share of power supply and total power consumption



Source: Bundesumweltministerium (2011d), p. 13

the household rates charged for electricity by power utilities. By 2017, the association believes that rooftop photovoltaic systems whose output is used largely for the building's own consumption could be operated profitably with no financial subsidies. Driven by technological progress and mass production, the sustained **drop in prices** is increasing market penetration. A virtuous cycle will be set in motion: The more solar modules are sold, the sooner solar power will be able to compete without the need for subsidies.

Solar thermal energy – the generation of heat from sunlight – cannot boast the tremendous growth rates of photovoltaic systems. Yet it too has experienced remarkable development **in Germany**. At the turn of the millennium, the 350,000 installed systems added up to collectors covering just 2.9 million square meters. By 2010, the number of systems had risen to 1.5 million and the surface area of collectors to 14 million square meters. [10]

Biomass

Biomass has gradually attained a strong position in the distributed renewable energy mix, accounting for more than a third (33 percent) of all green electricity produced in Germany. A total of 33.5 billion kilowatt-hours of electricity was generated from biomass in 2010, a year-on-year increase of roughly 10 percent. **Biomass** is also undisputedly **top of the league in the generation of heat from renewable sources**, with a share of 92 percent. Of the various green energy sources in the mix, biomass is one of those that can best be controlled – an attribute that makes it a valuable complement to power generation that relies on the sun and wind.

Germany's first straw-fired cogeneration plant is currently being built in Emlichheim, near the Dutch border. Feeding on 75,000 tons of straw per year and subsidized by the Federal Ministry for the Environment, the Emsland bio-energy power plant generates a rated thermal input of 49.8 megawatts. [11] Electricity produced during the cogeneration cycle is channeled into the public power grid. Two customers benefit from the heat produced: The Emsland bio-energy power plant supplies process heat and high-temperature steam to the Emsland Group, which primarily manufactures potato starch and refined starch products. In addition, the hot water generated during power generation is pumped through a three-kilometer pipeline to a training center where it is used for heating purposes. Thanks to this efficient heating concept, the operators claim to achieve efficiency of up to 90 percent.

10 See Bundesverband Solarwirtschaft (2011a)
11 See Bioenergiekraftwerk Emsland (2011)

Wind power

As a renewable energy source, wind power plays a vital role in both large and small projects. Over the past 15 years, what are known as **citizens' wind turbines** have sprung up at many locations in Germany. This phenomenon illustrates how the idea of distributed power supply structures is increasingly gaining ground. The citizens' model usually involves shareholders from a particular village or region investing in one or more wind turbines. Small wind turbines constitute another option in the context of distributed power generation.

Photovoltaic installations on rooftops have long been a common sight, at least in rural areas in Germany. By contrast, wind turbines in people's front yards are still something of a rarity. In the future, however, there are to be more of these **small wind turbines** that currently account for only a small fraction of the 21,600 turbines in Germany. The rated output from small turbines ranges from 1.5 kilowatts ("micro-wind turbines") to 100 kilowatts ("medium-sized wind turbines"). In terms of wind yield, however, these Davids cannot keep up with the Goliaths that populate large onshore and offshore wind farms, boasting hub heights of 92 meters and rotor diameters of up to 126 meters. There are two reasons why this is so: First, wind speeds are much lower at a hub height of between 5 and 30 meters. Second, there is more turbulence closer to the ground. Where small wind turbines do score points, however, is in their ability to generate wind power for use by the operator on a decentralized basis. According to a study commissioned by the German Wind Power Association (BWE), small wind turbines are therefore likely to enjoy substantial market potential in the medium term. The number of small turbines that will be built in the years ahead is set to rise sharply, the study indicates. [12]

A mix of renewable energy systems

As every good cook knows, the secret is getting the right mix of ingredients. That is also a fairly succinct way to describe one of the most important trends in distributed power supply constellations: **Concepts and solutions that involve the interplay of different sources of renewable energy** – sources that complement each other ideally – are very much on the rise. The benefits of this strategy are particularly apparent in the context of **surplus ("plus") energy buildings**, in which different components ensure a positive energy balance. One example is the main administrative building at Werner & Mertz GmbH in Mainz. Thanks to a sophisticated energy concept, this building not only meets its own need for electricity – around 156 megawatt hours per year – but also produces an extra 21 megawatt hours on top. Inaugurated in fall 2010, this surplus energy building combines geothermal energy, wind power and photovoltaic systems. The seven-story building has nearly 6,000 square meters of net floor space. The 16 small wind turbines on the roof can generate 123 megawatt hours of electricity per year. Almost the entire 350 square meters surface area of the roof is taken up with a photovoltaic installation with an output of 45 megawatt hours. The geothermal use of groundwater takes care of passive cooling for the building. To keep heating needs to a minimum, the façade has a four-layered structure to maximize thermal insulation. The family-owned company, well-known in Germany for its emsal, erdal and Frosch brands, invested around EUR 14 million in this new, emission-neutral office building. [13]

Combined heat and power plants and cogeneration units

Improving energy efficiency is a key factor in the expansion of distributed power supply structures. Combined production of heat and power, which is exceptionally energy-efficient, thus plays an important role, and thus it is one of the main technological drivers of decentralization.

The beauty of combined heat and power is seen when contrasted with power production in **conventional power plants**. Most power generation in Germany takes place in what are known as condensing power plants, in which steam turbines are used to convert thermal energy to electricity. The **efficiency** of these plants is **rather modest**: Only about 30 to 40 percent of the primary energy fed into condensing plants actually passes through the metamorphosis and becomes electricity. The majority of the rest – around 50 percent – is written off as "condensation loss". In cogeneration units, this waste heat is put to good use increasing the energy yield. Large power plants often serve a district heating network, for example. Yet even in these plants a lot of energy is – quite literally – left by the wayside.

Not so **distributed cogeneration units**. These units apply the combined-cycle principle on a small scale. Power is generated in the immediate vicinity of the place where the heat given off during power generation is needed. Since the thermal energy only has to travel short distances, transmission losses are kept within reasonable limits. Small cogeneration units have efficiency levels as high as 90 percent.

12 See Bundesverband WindEnergie e.V. (2010b), p. 14
13 See Werner & Mertz GmbH (2011)

Manufacturers offer them with a choice of combustion engine or Stirling engine. While the combustion engines for most cogeneration units run on natural gas, other fuels such as biogas, rapeseed oil, coal, biomass and waste are also viable options.

Hot water storage tanks enable power to be generated and the resultant heat to be used at different times. That makes sense at times when power is much in demand but little heating is needed, for example. **Suitability for use as distributed energy storage units makes cogeneration units**, or rather the combined heat and power principle on which they are based, an important element in the integration of renewable energy in the power grid. Cogeneration units are very flexible and can be run up or down very quickly.

Cogeneration units come in a variety of sizes, with **rated output** ranging from 0.8 kilowatts to 20 megawatts. Plants with output of between 10 and 20 megawatts are referred to as small or medium-sized cogeneration units. Depending on their size, they can handle the supply of heat to industrial zones, hospitals or housing estates. One example of the commercial use of a cogeneration unit is the Solon SE plant that runs on biogas at the Adlershof science and technology park. In 2010, Solon SE was singled out as "Cogeneration Unit of the Year". [14] It has a gross efficiency of 89.7 percent and produces 386 kilowatts of electricity and 510 kilowatts of thermal energy. The unit supplies heat and cooling capacity to the headquarters of the photovoltaics company. The electricity generated is fed into the power grid. [15]

The cogeneration unit for a high-rise apartment building in Hanover likewise runs on bio-natural gas. Installed on the top floor, the unit supplies residents of the building in the urban district of Laatzen with carbon-neutral heat and electricity. The Martin Luther Hospital in Bochum **generates power and heat in its own basement**. The cogeneration unit has a rated annual output of over 2,800 megawatts and supplies the nearly 300-bed hospital with all the energy it needs. [16]

Micro- or mini-cogeneration units ("thermal plants that generate electricity") have a rated output of between 0.8 and 10 kilowatts. [17] Sales figures are still low: Only about 8,000 new units are installed every year. [18] However, providers are reporting **growing interest among consumers**. According to a survey conducted by opinion researcher TNS Emnid on behalf of Greenpeace Energy, around two-thirds of the German population want to become more independent with regard to the supply of energy. [19]

Meanwhile, green power utility Lichtblick is planning a sales offensive for its "home power plant", a gas heating system that also generates electricity. [20] Up to now, even the smallest cogeneration units have been too big for single-family homes. Now, a number of manufacturers have plugged this gap with micro-cogeneration units.

Cogeneration units already make a significant contribution to energy efficiency and climate protection in Germany. Technological progress is expected to drive the wider penetration of this type of distributed power supply system. A joint project by EnBW Energie Baden-Württemberg AG and the German Aerospace Center (DLR) is charting new territory regarding the drive systems for such units. The project involves research into **natural gas-based micro-turbine cogeneration units**. It is hoped that this technology will make distributed power supply systems up to 500 kilowatts more cost-effective. The turbine engine produces less harmful emissions and is easier to maintain than a combustion engine. [21]

Attempts to use fuel-cell heaters as combined heat and power plants in single-family homes and condominiums are still in the trial phase. These installations extract hydrogen from natural gas and then use an electrochemical reaction to transform it into electricity and heat. This method of distributed power generation is high on efficiency and very low on emissions. The use of fuel cells to supply power to owner-occupied dwellings is being tested in the project **"Callux"**, a practical trial that ranks as one of the lighthouse projects for the National Innovation Program for Hydrogen and Fuel Cell Technology (NIP). Power utilities EnBW, E.ON Ruhrgas, EWE, MVV Energie and VNG Verbundnetz Gas are all involved in this model project, as are equipment manufacturers Baxi Innotech, Hexis and Vaillant. The ZSW Center for Solar Energy and Hydrogen Research is coordinating the trial, which is slated to run from 2008 to 2015. [22]

14 The award was presented by a jury from the German Cogeneration Association
15 See Mühlstein, J. (2010)
16 See Buderus Thermotechnik GmbH (2011)
17 See Deutsche Energie-Agentur (2011c)
18 For comparison, a total of more than 420,000 new gas- and oil-fired condensing boilers were installed in Germany in 2009; see Diermann, R. (2010), p. 37
19 See Erneuerbare Energien (2011)
20 See also the section on *Environmental technology services – New challenges, new business models*
21 See EnBW (2010)
22 See NOW GmbH (2011), p. 60f

The aim of Callux is to **develop fuel-cell heaters** into systems that are mature enough for everyday use – and hence for the marketplace. More than 100 prototypes are currently being put through their paces in the boiler rooms of owner-occupied properties. Geographically, this field trial is concentrated in the southwest and northwest of Germany, in and around Berlin and in the Ruhrgebiet conurbation. In 2012, as many as 800 fuel-cell heaters are to be subjected to practical trials, bringing the technology a big step closer to market launch.

Decentralized and centralized energy systems on the same grid: Enmity, coexistence or fruitful collaboration?

In the decades ahead, the biggest challenge to the power supply industry will be to link up the different distributed power generation systems and plug them into the power grid. To **keep the grid stable** and ensure a reliable supply of power, the power fed into the grid and the power drawn from it must be in equilibrium at all times – otherwise the threat of a blackout looms. Since the grid itself cannot store energy, other mechanisms are needed to balance production and demand at peak and off-peak times. The frequency of alternating current, which must be maintained at 50 Hertz (subject to narrow tolerances), is the mechanism of choice. In the integrated power grid, this frequency is regulated at the high-voltage level and at the link nodes to the distribution networks. If the frequency declines, i.e. if consumption increases, power generation is stoked up by adding what is known as control energy – from pumped storage or gas-fired power plants, for example. These types of power plant can be run up quickly and are thus ideally suited for use as flexible reserves.

By contrast, coal-fired and nuclear power plants are much slower to respond. For economic and technical reasons, their output cannot be scaled up and down at will. These power plants therefore primarily cater to the **base load**, which stands at between 35 and 40 gigawatts in Germany. Peak loads, which occur principally in the mornings, around lunchtime and in the early evening, can rise as high as 80 gigawatts. Since base load power plants have to keep running all the time, however, a phenomenon known as "negative electricity prices" has been known to occur during off-peak times when a lot of power was being fed in from renewable sources – during high winds, for example. In such circumstances, an excess supply of electricity can lead to the paradoxical situation where power users receive money from power producers.

Greater complexity

In centralized and heavily fossil fuel-dominated structures, adjusting power generation in line with the power load profile – the volume of power needed in the course of the day – is relatively easy. Now that more power from renewable sources is being fed into the grid, making such adjustments is far more challenging for the **grid infrastructure** and **grid management**. Green electricity can be scaled up and down only to a limited degree: You cannot simply put the sun and wind on line and then take them off line again. There are thus two key problems when incorporating a growing proportion of renewable energy into the power mix. One is the issue of **reserve power** if the flow of renewable energy declines as the wind drops or the sky clouds over. The other is that the grid can become unstable if glorious sunshine or a particularly stiff breeze cause photovoltaic systems and wind turbines to feed more power into the grid than is currently needed.

Initially, then, **renewable energy makes the energy system more complex**, because the power fed in from wind turbines and photovoltaic systems fluctuates. Solar power goes off line at night and the power yield from wind energy varies depending on the weather. Logically, the feed-in volumes from photovoltaic systems peak in the summer and in transitional seasons, while wind turbines tend to run at full tilt in the winter.

Added to these considerations is the fact that the **power transmission and distribution structure** is still tailored to yesterday's power supply concept. An illustration: The centers of industry in Germany and other countries generally emerged in places where the energy resources needed for production could be

found. It is no coincidence that the smoking chimney stacks of steel mills in the Ruhrgebiet conurbation punctuate the skyline right next to large coal mines. Today, by contrast, the places where renewable energy is generated and the places where it is needed can be a considerable distance apart. Thus while the largest volumes of wind power are generated in northern and eastern Germany, the largest centers of consumption are in the south and west of the country.

Existing distribution networks were originally intended for one-way traffic, carrying power over the "last mile" to the consumer. Now the traffic runs both ways, with the growth of distributed feed-ins creating the need to master **bidirectional load flows**.

Intelligent solutions

These challenges can be mastered, provided the right course is charted to convert and expand the infrastructure. In the decades to come, the crucial solution strategies will involve combining centralized and decentralized power generation. **Power load management is needed on the demand side** to strike the right balance in the grid between supply and demand for power. This can only be achieved by integrating power consumers in an intelligent fashion. Another component of the energy system of tomorrow will be the expansion of centralized and decentralized storage capacity to help maintain the right balance as power generation and demand fluctuate.

It takes an **intelligent or "smart" grid** – a grid that makes optimal use of all currently available information and communication technology – to satisfy these requirements. The term "smart grid" embraces all aspects of the sophisticated coordination and control of the various components hooked up to the power grid. Essentially, this involves energy management, grid stabilization and automation, intelligent power transmission and distribution, power consumption management and the provision of storage capacity.

Smart Grid I: Four-wheeled storage

If the federal government has its way, a million electric vehicles will be found on German roads by 2020. Ten years later, the plan is for this figure to rise to six million. [23] An important role has been assigned to these cars in the power grid of the future. Doubling up as distributed storage units on four wheels, the batteries used by e-vehicles can play a part in balancing out spikes and troughs on the power grid. If fluctuations in renewable energy feed-ins lead to a surplus of power on the grid (because of high winds or the searing midday sun, say), electric cars will be able to absorb this excess supply. Conversely, they will be able to give it back when heavy demands are placed on the grid. The catch is that **using car batteries to buffer power reserves** presupposes a technology that enables e-cars to communicate with the power grid. Suitable software and hardware is needed to manage the give and take across so many distributed storage units. Needless to say, the industry is already hard at work on such **vehicle-to-grid solutions**.

Solutions that do not involve filling electric cars with power out of the wall socket in the garage are also conceivable. One alternative would be to charge batteries with renewable energy from the car owner's "home power plant". This is an option currently being tested in practice by the Federal Ministry of Transport, Building and Urban Development. [24]

"My house – my filling station": This was the heading under which the Ministry of Transport launched a competition to **integrate surplus energy buildings and electromobility**. The basic idea behind such **"real e-state"** is as follows: A sustainably built, energy-efficient home should produce enough power from renewable sources to meet not only its inhabitants' need for electricity and heat but also to supply an electric vehicle fleet consisting of two cars and a motor scooter.

Institutions of higher education were invited to participate in the competition in collaboration with engineering companies. The winning entry was a design submitted by Professor Werner Sobek in conjunction with the ILEK Institute for Lightweight Structures and Conceptual Design at the University of Stuttgart. Under the ILEK Institute's leadership, the LBP Chair of Construction Physics, the IGE Institute for Building Energetics and the IAT Institute for Industrial Engineering and Technology Management all took part in the resulting "Efficient Surplus Energy Building with Electromobility" project. [25]

Together the Stuttgart-based research team crafted a high-tech building that maximizes both energy efficiency and home comforts for the people who live in it. A buffer store comprising reusable vehicle batteries gives the building an independent power supply.

23 See Regierungsprogramm Elektromobilität (2011), p. 10
24 See Bundesministerium für Verkehr, Bau und Stadtentwicklung (2011b)
25 See Erneuerbare Energien (2010)

This vision of residential life in the future is not just a nice idea. The house really exists – live and in full color at Fasanenstrasse 87 in Berlin's Charlottenburg district. In 2012, a family of four will move in to test whether this piece of choice 130 square meters real estate is genuinely suitable for everyday living. Scheduled to run for 15 months, the test phase is receiving scientific support from the Fraunhofer Society and the Berlin Institute for Social Research.

Smart Grid II: Intelligent meters

Reading the meter once a year has long been an established custom among electricity users. Smart meters will gradually render this ritual obsolete. Intelligent meters are one of the most important components of the smart grid. They should help to maintain a balance between power generation and power load. The aim is to reduce consumption and, wherever possible, swap it from peak to off-peak times. **Smart meters** focus primarily on the demand side. Each meter measures consumption data and transmits it to a computer screen or smartphone. These intelligent devices can do more than capture a household's aggregate data: They can also determine how much electricity is used by the refrigerator, TV and espresso machine. Power-hungry appliances thus have no chance to remain undetected. Acting as the communication link between power consumers and power producers, smart meters report consumption data to the power utility at short intervals. In return, utilities supply the **intelligent meters** with information about tariffs, which vary as a function of timing and load. Thanks to this exchange of data, high-tech smart meters can not only document consumption but also control it – telling you the cheapest time to start your washing machine or dishwasher, say.

Ideally, smart meters could then even instruct appliances to start. If household appliances are to hear these instructions, though, they too need a controller that can communicate with the smart meter. And only when this dialog takes place can intelligent meters actually handle **power load management on the demand side**. White goods manufacturers are currently in the process of designing suitable appliances. Miele has developed its own "SG Ready" label, meaning "ready for the smart grid". Washing machines, clothes dryers and dishwashers will then start their programs when electricity is cheapest. The command to start is issued via the Miele@home gateway, which in turn is connected to a router. The electricity company's tariff options are either fed to the gateway in real time or stored there. [26]

At the IFA consumer electronics and home appliances trade show in September 2011, Miele also unveiled a new kind of smart-grid-ready technology: appliances that start automatically when the solar modules on the roof supply enough power. For this to work, an **"energy manager" is needed as the interface between the photovoltaic system and the appliances**. Via an Internet connection, the energy manager acts as a kind of high-tech weather forecaster, predicting when it will be sunny and so when the necessary output from the solar cells can be expected. Serving as a "virtual spokesman" for the appliances themselves, the Miele gateway tells the energy manager which appliances are ready to run which programs at any given time. Naturally, users retain ultimate control over all these devices – they decide when what jobs need to be done by. If they specify that the dishwasher program should be finished by 7 p.m., the energy manager will execute the command even if the sky is full of black clouds: If there is not enough solar power to get the job done, it simply switches to regular grid mode.

This example of the interplay between white goods, controllers and home-based power generation provides an illustration of how smart micro-grids work. Nor are intelligent **micro-power grids** restricted merely to single-family homes: They can just as well be dimensioned to serve a school, office building or factory, or even a whole village. Moreover, they can operate either in isolation or based on a seamless, synchronized link to the (superordinate) power grid.

Since the start of 2010, installing intelligent meters has been mandatory in new buildings and complete refurbishment projects. Yet it will still take a very long time before all 42 million electricity meters in Germany are replaced by their smart successors. Intelligent meters have nevertheless been put to the test in numerous projects and the effects have already been evaluated. One example is E.ON's "10,000 Smart Meters" program, in which participating households were able to reduce their energy consumption by as much as 10 percent over the course of 18 months. [27]

In the "Intelliekon" project, 2,000 households in Germany and Austria have been experiencing how intelligent metering, communication and tariff systems can contribute to sustainable household energy consumption. Supervised by organizations including the Fraunhofer Institute for Solar Energy Systems (ISE) and the Fraunhofer Institute for Systems and

26 See smartmeter (2011)
27 See E.ON AG (2010)

Innovation Research (ISE), the field trial phase of this project likewise lasted 18 months. Analysis of the results shows that intelligent meters can help private households shave an average of 3.7 percent off their power consumption. Extrapolated for Germany as a whole, that means a saving of around five terawatt hours of electricity – or a billion euros. [28]

Smart Grid III: Virtual power plants

The whole can be more than the sum of its parts. Small and medium-sized distributed power producers such as wind and solar farms, hydropower plants and biogas plants are now joining forces to form virtual power plants. Teaming up in this way transforms many small players into one large one that has sufficient muscle to make its presence felt on the market. Together, distributed power producers can sell their capacity on electricity exchanges or offer it to regular grid providers as a control reserve.

Progress in information and communication technology has been an essential prerequisite for the kind of **networking** that underlies **virtual power plants**. Sophisticated control system software ensures that data on distributed producers' capacity and utilization levels comes together in the control center – the brain of the virtual power plant that controls the various units. The individual players that make up the virtual power plant do not necessarily have to be in the same area. Interregional partnerships can bring an array of distributed and geographically disparate producers together under one roof.

Version 2.0 of the virtual power plant idea is no longer restricted to the management and marketing of power generation. The new generation of virtual power plants also involves the consumer side, and that goes a long way toward keeping supply and demand in equilibrium within the power grid. Vattenfall's virtual power plant network in Berlin is a good example of how this balancing act can work in practice. [29]

In the Vattenfall plant, **combined heat and power units and heat pumps are linked together as distributed power producers**. The resultant network balances out fluctuations in the power provided by the individual contributors and supports the integration of wind power into the grid. The core of the virtual power plant is what Vattenfall calls the Control Room, which communicates via radio link with the combined heat and power units and the heat pumps. The instructions issued vary depending on prevailing wind conditions. When little wind power is being fed into the grid, the Control Room activates those buildings with combined heat and power units that can continue to produce electric power and heat. The electric power can be fed into the grid, while the heat can be parked in a heat storage system. This arrangement makes up for the lack of wind power. Conversely, when a stiff breeze gets the rotor blades of wind turbines working at full tilt, the Control Room passes on this information to the heat pumps. The heat pumps use surplus wind power to generate heat for use in heating and hot water systems. Heat that is not needed immediately can be deposited in heat storage systems for later. Vattenfall plans to connect around 100,000 homes to the virtual power plant in the course of 2012.

Smart Grid XXL: The super grid

An energy system that is fed predominantly from renewable sources cannot get by with no central elements at all. In spite of the decentralization trend, it will **still** be **necessary to expand the transmission network**. This need is driven not only by the increase in the share of green electricity, however. The goal of creating a single European electricity market also demands the construction of new high-voltage power lines and investment in cross-border infrastructure.

Improvements in the European power grid will also benefit the development of renewable energy. The resulting "super grid" could, for example, be better able to deal with regional bottlenecks or surpluses due to fluctuating power feeds. In addition, regional power generation systems will have to be complemented by major projects such as offshore wind farms and solar power plants. The power generated by offshore wind farms can only be transported to onshore centers of consumption if **high-performance cable routes** are put in place. Along the south-north axis, too, adequate transmission capacity is needed to distribute the solar power that is so plentiful in Southern Europe. The same goes for the Desertec project, which is to meet a quarter of Europe's need for electricity with power from solar thermal power plants in the deserts of North Africa by 2050. This will be possible only if high-voltage direct current transmission lines can bring all this power to Europe with few losses.

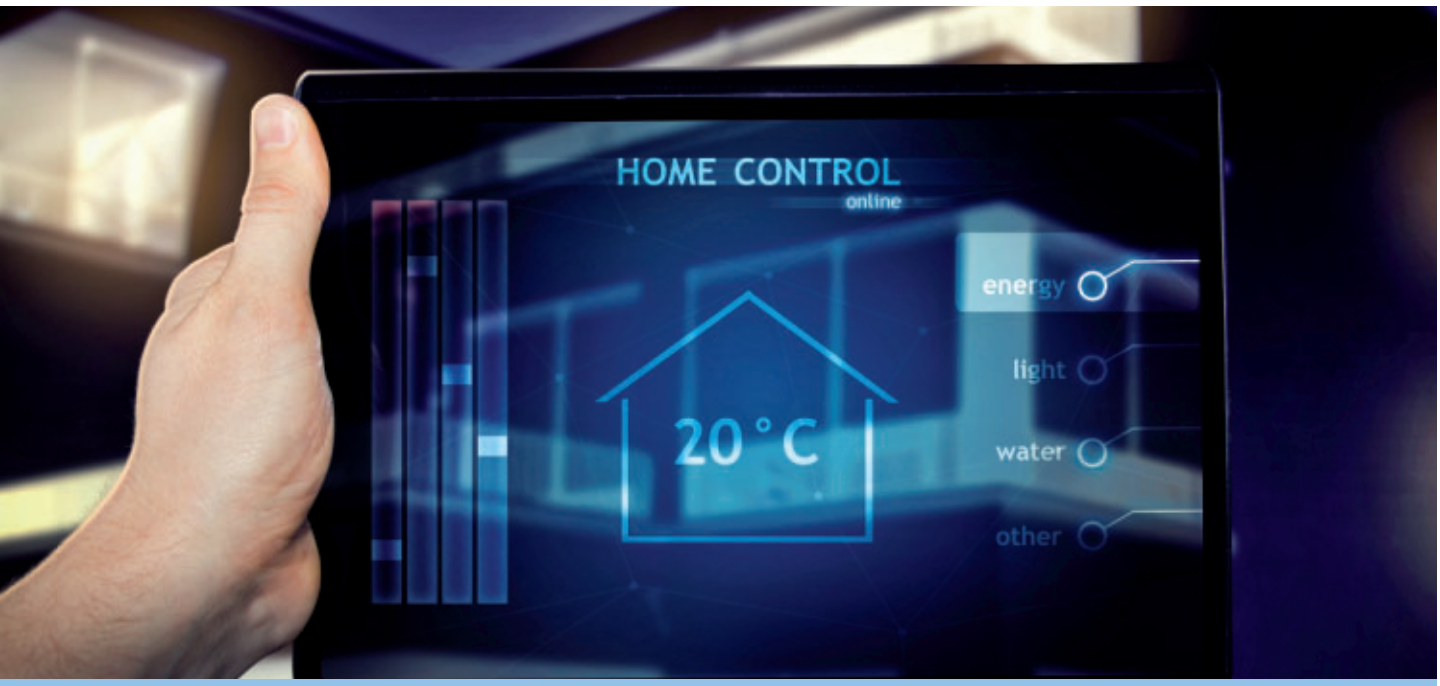
28 See Fraunhofer-Institut für System- und Innovationsforschung ISI (2011)
29 See Vattenfall Europe AG (2011c)

Toward the energy system of tomorrow

The German government's energy strategy leaves no room for doubt that the new direction in energy policy – focusing on power generation from distributed and renewable energy sources – is a truly Herculean task: "Existing power supply structures will have to be thoroughly overhauled in the medium to long term so that we can achieve a reliable supply, guarantee value for money and hit our climate protection policy targets." Until this overhaul is completed, the energy system finds itself in a **hybrid phase** [30] in which decentralized and centralized elements must work together to deliver a reliable supply of power to Germany. **The transition phase to a decarbonized energy sector** confronts all the parties involved – power utilities, network operators and commercial and private power consumers alike – with a completely new set of challenges. Integrating distributed, renewable energy types makes the energy system more complex. Ultimately, however, the specter of climate change and the scarcity of resources means there is no alternative but to move into this uncharted territory.

Germany is up among the front-runners in this journey of discovery. In the medium term, other countries will also have to go the way of carbon-free or low-carbon power supply structures. This can be seen as a source of **great potential**: If German research organizations and companies can show that a complex system involving the distributed generation, storage and distribution of power from renewable sources really works, the country will have a tremendous opportunity to **market** this **knowledge as a coveted export good**.

30 See Bundesministerium für Wirtschaft und Technologie/Bundesumweltministerium (2010), p. 3



Smart cities

The "millennium of cities" has begun. [1] By 2050, more than six billion people – around 70 percent of the world's population – will inhabit cities. But where exactly will they live, work and spend their leisure time? What will they eat? Where will they get the energy they need for electricity and heat? The **megatrend toward urbanization** is inextricably intertwined with urgent questions and numerous challenges. One thing is for sure: Environmental technology and resource efficiency will be instrumental in maintaining (or improving) the **quality of life in cities** in the future. This section describes the transformations that will take place in "smart cities" – and shows what green technology can do in practice to help make urbanization ecologically and socially acceptable.

The subject of how everyday life will be organized in the metropolises of the future has always fascinated people. Architects, engineers, philosophers, writers and film-makers have all tried their hand at painting **pictures of the urban future**, be they idyllic or apocalyptic. New York, it seems, was predestined to set the scene. In 1960, architect and designer Richard Buckminster Fuller [2] unveiled his model of the "dome over Manhattan": a transparent dome with a two-mile diameter arching over Manhattan. [3] This cocoon-like shell was to protect the people inside it from a hostile environment while also reducing energy consumption: "From the inside, contact with the outside will be undisturbed. The sun and the moon will shine on the landscape. The sky will be fully visible. But the unpleasant effects of the climate – heat, dust, pests, glaring light, etc. – will be modulated by the shell to create a Garden of Eden within." [4]

Belgian architect Vincent Callebaut likewise envisaged a Garden of Eden in his futuristic "Dragonfly" project. Vertical landscapes whose form was inspired by the outer skeleton of a dragonfly were to operate as **autonomous ecosystems**, supplying urban residents with renewable energy and food. Callebaut's Dragonfly has space for plants and animals within its upraised glass wings. [5] Ultimately, however, whether or not the future of the blue planet can really be transformed into such

1 The phrase was coined by the then UN Secretary General at the Urban 21 conference in Berlin in June 2000. See Eberl, U. (2000)
2 Richard Buckminster Fuller (1895-1983), architect and designer; inventor of the geodesic dome; coined the phrase "Spaceship Earth". See Borries, F. (2010)
3 See Design Museum (2011)
4 Quoted by Borries, F. (2010), p. 92
5 See Allianz (2011)

an idyll – or turned into a nightmare – will essentially be determined in the world's cities. Cities play an ambivalent role as economic powerhouses on the one hand and ecological danger zones on the other. Approximately 85 percent of Europe's GDP is generated in cities. Worldwide, cities are responsible for four fifths of greenhouse gas emissions – a fact that makes them a material factor in ongoing climate change.

Urban centers are at once the **perpetrators and the victims of global warming**. Their substantial share of global carbon emissions singles cities out as the biggest source of greenhouse gases. Conversely, however, urban residents still suffer hugely from the fallout from global warming, such as droughts, flooding and the other consequences of extreme weather situations: "In this new urban age, the megacities therefore loom as giant flood and disaster traps." [6] The rising sea level – another consequence of climate change – will pose a threat to coastal cities such as Buenos Aires, New York, Mumbai, Dhaka and Shanghai. On the upside, the dense populations that inhabit conurbations open up new possibilities for the efficient allocation of resources, as goods and services can be provided with relatively little effort and at relatively low per-capita costs.

The **megatrend toward urbanization** will be driven first and foremost by developments in Africa and Asia. By 2050, Africa's population will probably double to 2.2 billion. More than five billion people will live in Asia by then – a billion more than today. This contrasts with Europe, which will likely have 19 million fewer inhabitants in 2050.

Future demographic developments in emerging and developing countries will differ sharply from those in industrialized nations. Similarly, **urbanization** itself **will plot a completely different course** in these different settings. Cities and communities in advanced economies will face a very different set of challenges to those that confront agglomerations in emerging and developing countries.

In the latter, the pressure on ecosystems will increase immensely as infrastructures that are rudimentary at best are unable to cope with the flood of new arrivals. Few urban districts in these agglomerations are connected to the water supply or to the wastewater disposal system. Consequently, around 80 percent of **wastewater** in developing countries flows untreated into rivers or the sea or seeps into the ground. Organized waste disposal is virtually non-existent. Waste is deposited anywhere and everywhere. **Illegal dumps** and outdoor incineration are commonplace. The consequences – pollution of the air, soil and groundwater – give rise to considerable health risks. **Air pollution** from traffic and industrial exhaust emissions is another problem in conurbations. The increase in motorization in emerging countries in particular threatens to bring traffic in large cities grinding to a complete halt.

The challenge in most large cities in emerging and developing countries is therefore to build a robust infrastructure where none has existed up to now. Not so the industrialized nations, which must overcome entirely different hurdles. In these countries, the primary challenge is to "retrofit" existing infrastructures in line with the **need for sustainability and climate protection**, thereby improving the quality of life and work in major conurbations. Even in highly developed countries, water management – to take just one example – is still far from efficient. Nor can the allocation of this precious resource be described as anything like sustainable. In Europe, roughly a third of all water runs off into the soil due to leaky pipes. In the US, around 26.5 million cubic meters of water is lost (15 percent of the total volume). [7] In many places, the increase in private transport likewise poses a threat to urban dwellers' quality of life by polluting the environment. The building industry too remains one of the largest sources of CO_2 emissions.

Although different regions of the world are starting out from such starkly different points, **intelligent concepts** – known as smart city concepts – hold out the promise of solutions to the pressing problems of urban areas in the industrialized world and in emerging and developing countries alike. These concepts are smart because solutions are tailored individually to the specific circumstances and needs of each city, though the need to act is acutest in the cities in emerging and developing countries. Current growth patterns in these agglomerations are placing too heavy a burden on local ecosystems and threatening to destroy what future generations need in order to survive. To arrest this development, strategies are needed that will make it possible to break the link between rising populations and increasing resource consumption. The **smart cities concept**, in which information and communication technology (ICT) plays the vital role of enabler, opens up the possibility of a genuinely livable urban future.

6 UN-Habitat (2006)
7 See Deutsche Bank Research (2010), p. 14

Information and communication technology – The navigator and helmsman in complex urban networks

The dictionary defines "smart" as "shrewd" or "clever" – attributes one would not normally associate with a city. So what exactly does the term "smart city" mean? A definition proposed by acatech, Germany's National Academy of Science and Engineering, gives us a clue: "Smart technologies can provide innovative solutions to the current and future challenges facing cities and communities in various areas of life and work. From a technological perspective, a smart city is intelligent, integrated and networked." [8] **Networking within and between different urban subsystems** – such as traffic, power supply, buildings, production facilities, healthcare, and so on – is, then, a characteristic trait of smart cities. The sheer multiplicity of areas in which action must be taken in smart city concepts is evident from the length of the list below: [9]

- Population development – Arrivals and departures, nationalities, age groups
- Mobility – Traffic infrastructure, modes of transport, logistics
- Energy – The integration and networking of different sources in distributed power supply structures, coupled with central feed-in systems
- Environment – Energy-efficient and climate-friendly solutions
- Safety – A better quality of life as residents feel safe and secure; data protection and data security for infrastructure facilities
- Communication – Improved products, systems and services thanks to intelligent networks
- Healthcare – High quality healthcare services, better prevention and more individualized healthcare delivery concepts
- Administration – Simplified communication and interaction between authorities on the one hand and both citizens and companies on the other through the cultivation of e-Government
- Education – The networking of educational institutions and the creation of education platforms

Information and communication technology (ITC) is the enabler for the individual aspects of this complex urban system. Intelligent technologies lay the foundation for **efficient and networked infrastructures.** To inject more smartness into everyday city life, a whole raft of intelligent technologies is therefore needed. [10] Of these, the key ones are: high-performance data networks based on broadband technology; smart grids to control the power supply; networks of sensors as a precondition to the networking of machines and equipment; a highly scalable, extremely powerful IT infrastructure (the "city data cloud"); and the integration of all local authority infrastructure systems.

In the view of acatech, Germany has the potential to position itself in the international arena as the lead provider of and **lead market for these key technologies for intelligent urban infrastructures**. German companies' skills in systems integration in particular are a significant advantage in international competition. [11] Situated in the state of North Rhine-Westphalia, Bottrop is one of a number of cities that can reasonably claim to be a lead market for high technology in the smart city context. The city in the Ruhrgebiet conurbation recently won a competition launched by the Ruhr Initiative Group and now officially bears the title "InnovationCity". In a pilot region that includes the city center and areas of the southern part of town covering a total of 67,000 inhabitants, Bottrop has, over the next ten years, been chosen to showcase how innovative technology and projects can create a model city that sets an example for other local authorities to follow. The focus of the InnovationCity project is on energy efficiency and renewable energy.

Ideally, smart cities should use the key technologies listed above to slot all the individual topics and actions together and form a coherent overall concept. In reality, however, no city in the world is successfully realizing every aspect of this vision. Having said that, developments are taking place in isolated areas that visibly sketch at least an outline of the smart city concept and the opportunities it harbors. Precisely these quantum leaps forward are presented in the section below, focusing above all on smart mobility and smart buildings. The choice of these focal areas is legitimate because the building industry and mobility are both major sources of carbon emissions and are, as such, crucial to the fight against global warming. Getting a firm grip on greenhouse gases and reducing them in these areas plays an indispensable role in protecting the climate. A further argument for this **focus on smart mobility and smart buildings** is that these segments in particular make it abundantly clear how immensely important environmental technology is in practice as a cross-sectoral industry. Analyzing mobility and building construction clearly reveals how the green products and processes presented for the lead markets play a part in solutions that make big cities both livable and environmentally compatible.

8 Deutsche Akademie der Technikwissenschaften (eds.) (2011), p. 9
9 This list is based on areas for action defined by Germany's National Academy of Science and Engineering (2011), p. 13ff
10 Ibid., p. 15f
11 Ibid., p. 10

Smart mobility – Flexible, intelligent and fit for the future

The world's roads were traveled by something like 700 million cars at the turn of the millennium. By 2030, the number is likely to be 1.3 billion. And in 2050, mobility experts reckon that 2.5 billion cars will be in use around the globe. Yet the **traffic infrastructures in many cities are already on the verge of collapsing**. "100 kilometers of traffic congestion outside the gates of Beijing": In summer 2010, such headlines put the spotlight on the traffic situation in the Chinese capital. In the rush hour, cars crawl around the city at speeds of only seven kilometers per hour in some cases. In 2010, a record 700,000 new cars were licensed in Beijing. The city is in danger of being buried under what the Germans fittingly call a "metal avalanche". Since then, local government has pulled on the handbrake, imposing a ceiling of 240,000 new car licenses at most in 2011. The right to obtain a new number plate is drawn in a kind of lottery. Other actions taken to keep the traffic infrastructure from collapsing include mandatory traffic-free days: Every car in Beijing has to stay home for one day each week. The number plate determines which day this is. Moreover, local government is investing to expand local public transport, making it easier for current and future car owners in Beijing to switch to public transport. Five new subway lines were opened at the end of 2010, for instance.

The threat of utter traffic gridlock hangs over other cities around the world too. Congestion and stop-and-go traffic are par for the course on Moscow's main four-lane traffic highways. In São Paulo, vehicles sometimes stand bumper to bumper for an astonishing 300 kilometers.

These extreme examples show that, in its current form, motorized private traffic is anything but smart in the sense of intelligent and fit for the future. The aim is therefore to focus inner-city mobility on **ecofriendly alternatives to the automobile**. "Multimode transport" and "patchwork mobility" are two of the magic words. Both point the way to systems that will enable urban dwellers to use different modes of transport very flexibly. This kind of concept is made possible by the interplay of sustainable urban development and networking on the basis of both information and communication technology and other new technologies.

What is known as the "environmental alliance" of local public transport operators, bicycles and travel on foot – backed by urban planning – plays a key role in patchwork mobility. Urban districts used to be divided up into places to work, places to live and places to unwind. Now, the idea is to shorten the distances between all these different functions. If this is done consistently, the car's importance as a way to get around will experience natural erosion. The trend is already taking shape in the urban centers of Western Europe, with rising gasoline prices and increasing environmental awareness doing their bit to help. For "digital natives", the idea of owning a car has lost its sheen as a status symbol. This up-and-coming generation takes a more **functional view of mobility**. If it has to be a car, the important thing is being able to use one rather than owning one. Changing values are putting attributes such as innovation, sustainability, exercise and dynamism at a premium. Preferences in the choice of means of transport are shifting accordingly: Electromobility and cycling are thus poised to overtake big cars on the popularity scale.

To continue to foster a willingness to change routine mobility practices in the city, and to encourage other age groups and swathes of the population to follow suit, attractive alternatives to motorized private transport are needed. **Local public transport** is one vital part of the puzzle. German cities have shown that good public transport offerings can lower the volume of traffic on the roads. In Berlin, for example, private cars' share of passenger transport dropped from 38 percent in 1998 to 32 percent in 2010.

Developing and expanding public transport networks is a central factor in making this mode of transport more attractive. Improving integration with other modes of transport can likewise make this option more popular. **Park and ride concepts**, for example, ease the burden of commuter traffic on city centers. To create incentives for people to leave their cars outside the city and travel in on local transport, it is also conceivable to link discounts on parking fees to the use of public transport.

Work is currently in progress to tear down the barriers that keep people from changing their preferred mode of transport. The (((Germany e-ticket, for example, specifically addresses occasional users of public transport and target groups that travel by public transport in different regions. The basic idea behind the **(((Germany e-ticket** is to introduce a pay-as-you-go concept based on automated ticket price calcula-

tion. The distance covered is recorded for each journey. This can be done either using a check-in/check-out arrangement in which passengers insert their e-ticket in a terminal when they get in and out, or by establishing a wireless link to automatically capture ticket data. [12] Some local transport utilities in Germany, such as the one in Berlin, the one for the Berlin-Brandenburg region and the Rhine-Ruhr regional operator, have already signed up for the (((e-ticket system and are eager to press ahead in developing this electronic ticketing standard.

Alongside public transport, increasing the share of environmentally friendly two-wheeled traffic is another area in which action is needed to drive smart mobility. Many passengers who travel by public transport are all too familiar with the dilemma: The entire journey from A to B is too far to travel by bicycle, but getting from the last public transport stop to work or home, say, is a long walk. Innovative **bicycle hire systems** are therefore being tested in a model trial by the Federal Ministry of Transport as an attempt to solve this problem. The cities of Mainz, Nuremberg, Saarbrücken, Dresden and Kassel, the Ostvorpommern district and the Stuttgart and Ruhr metropolitan regions have received subsidies totaling over EUR 10 million to develop a public bicycle hire system linked to existing public transport offerings from 2009 through 2012. For its part, national rail carrier Deutsche Bahn (DB) has launched the Call a Bike service that is open not only to its own customers. Bicycles can be hired from DB in seven large German cities and at more than 50 ICE stations. Customers can register on the Internet or by phone, hop on a CallBike and get around spontaneously.

For everyone who would like to cycle but is less keen on overexertion or arriving at their destination bathed in sweat, e-bikes are an alternative to traditional pedal power. An electric hub motor fitted to the back wheel puts the wind permanently at the cyclist's back. Sales figures for **e-bikes**, or **pedelecs** (pedal electric cycles) as they are also known, have been growing constantly since 2007. While only 70,000 units were sold in Germany in 2007, the figure had already jumped to 200,000 by 2010. ZIV, Germany's two-wheeled industry association, predicts rapid market development with as many as a million e-bikes out on the streets by 2018. If this prophecy comes true, a niche segment with a five percent share of the German bicycle market in 2010 would have evolved into a veritable heavyweight on the market for two-wheelers.

E-bikes are going down particularly well in Germany and the Netherlands. The two countries together account for more than 50 percent of the market and thus constitute the foremost pedelec markets in Europe. [13] Indeed, the e-bike boom has exceeded manufacturers' and dealers' expectations: In some cases, customers are having to wait up to three months for delivery. [14]

Less noise, less pollution, no carbon emissions during travel... These are the attributes that score points for electric cars and fuel-cell cars, especially in busy conurbations that are groaning under the burden of ever more vehicular traffic. In the operating phase, electric cars are **zero-emission vehicles**. A current range of around 120 kilometers makes cars fitted with lithium-ion batteries particularly well suited to urban travel. Alternative engine technologies should not, however, be misunderstood as a general-purpose weapon to wage war on traffic problems in conurbations. "Smart mobility is not, as many people tend to think, a synonym for e-mobility, which is the electrified continuation of private transport." [15] Electromobility can do nothing to curb explosive growth in road traffic in many cities. Emission-free snarl-ups are still snarl-ups, however you look at them.

Alternative engine technologies do nevertheless have an important part to play in the context of smart mobility. In its white paper entitled "Roadmap to a Single European Transport Area", the European Commission recently formulated a specific goal: By 2030, it wants to have only half as many cars with combustion engines on the roads in EU cities as there are today. By 2050, cars driven by conventional engines should have disappeared from our cities altogether. Electric cars also play an important part in the long-term outworking of Germany's new energy policy. In a smart power grid, the **batteries used by electric vehicles** can serve as **mobile energy storage units**, making a significant contribution to development of a distributed "vehicle-to-grid" power supply system. [16]

Alternative engine technologies have already found their way into local public transport fleets. The Federal Ministry for the Environment has set aside a budget of EUR 10 million to promote the widespread market launch of hybrid buses in public transport. Thanks to these funds, twelve transport utilities in Germany have already put 50 **hybrid buses** into regular operation.

12 See VDV-Kernapplikations GmbH & Co. KG (2011)
13 See Zweirad-Industrie-Verband e.V. (2011)
14 See Velobiz (2010)
15 BITKOM (2011c), p. 13
16 See the section on *Distributed power supply structure*, p. 156, for more details

The various models produced by MAN, Carosserie Hess and Solaris had to comply with strict criteria: Efficiency gains of at least 20 percent compared to conventional diesel buses had to be proven. Compliance with stringent noise and air pollution standards is also prescriptive, as is a closed particulate matter filter system. [17]

Traffic flow management is pivotal to the realization of smart mobility concepts that rely on information and communication technology. Israel has already shown what intelligent traffic systems can achieve. Since February 2011, highway 1 from Jerusalem to Tel Aviv has had a "fast lane" controlled by dynamic tolls. The purpose of this special lane is to ease the burden on the main road into the Tel Aviv conurbation and avoid congestion and stop-and-go traffic. The fast lane concept is underpinned by an intelligent traffic control system from Siemens that guarantees a minimum travel speed at all times. In real time, the system captures the traffic situation on the road network, records the utilization of freeway capacity and the special lane and thus calculates anticipated demand. Based on these parameters, an algorithm dynamically calculates toll charges to the minute and displays these on variable traffic signs. Fast-lane users are registered by the video-based capture of number plates. To encourage car pooling, cars with more than three occupants are exempted from the toll. [18]

Smart buildings – Intelligent buildings that double up as nodes in the power-saving grid

Buildings consume 41 percent of primary energy in Germany. Of this amount, heating and cooling account for 35 percent, while electricity devours the remaining six percent. These numbers make the scale of **potential savings in the property sector** abundantly clear. In the medium to long term, however, it will be possible to tap this potential only if buildings become smarter. The smart building concept is not confined merely to structural alterations that improve energy efficiency in new and renovated buildings. In particular, it seeks to use **intelligent control** to enhance efficiency. Accordingly, a smart building is defined as a building "that is fitted with building automation systems and is also part of a smart grid" [19]

Figure 73 lists the relevant issues addressed by the concept of a smart building.

When buildings plug into a smart grid, they are expected to meet their own energy needs in the areas of heating, air-conditioning and electric power consumption. Geothermal energy and solar power are promising sources for these purposes. **Solar modules** open up completely new design options **for building integration**. Roofs and façades alike are transformed into energy providers, without the esthetic drawbacks of conventional solar panels. Solar glazing on façades can actually enrich the architectural design – and certainly look more appealing than floor-to-ceiling concrete. Useful technical qualities only add to the esthetic benefits: Solar glass façades have low overall energy transmittance, which does away with the need for exterior shading fixtures.

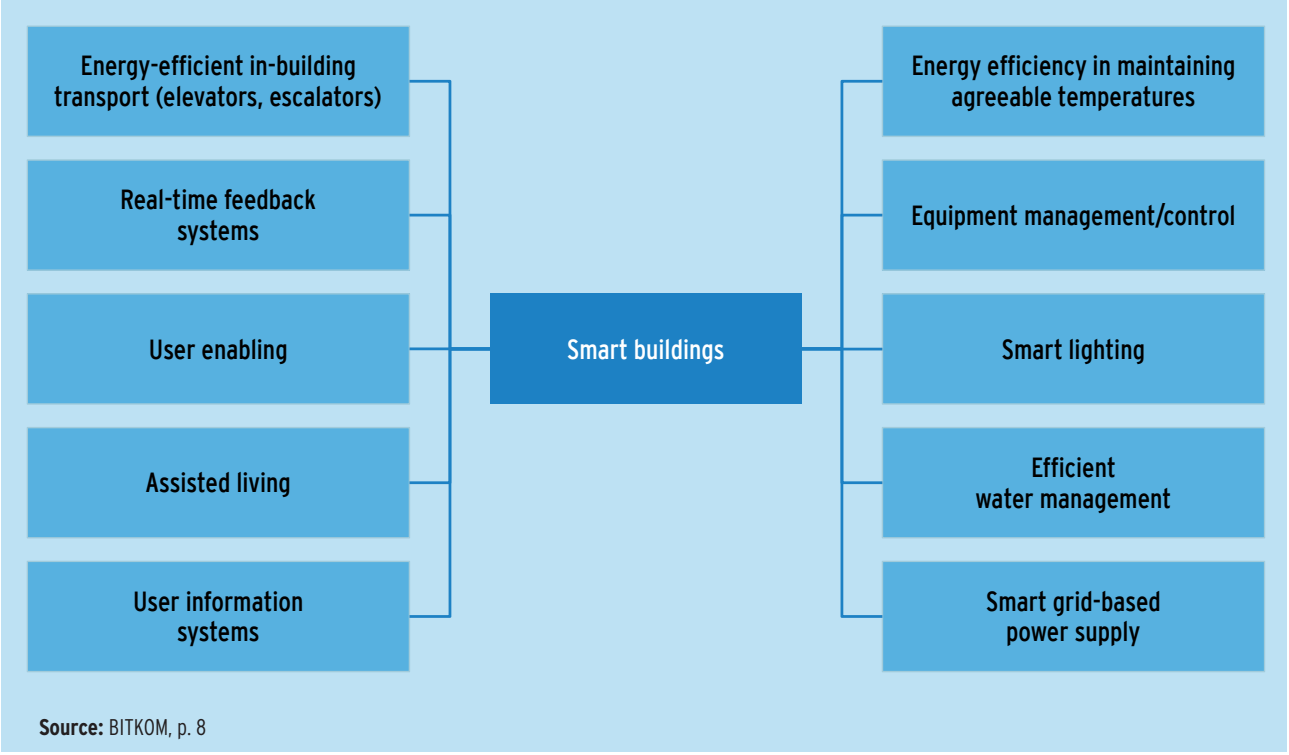
The idea of using the **shell of a building as a power plant** can be realized for new buildings and existing ones alike. When a military barracks in the German town of Wolfhagen was converted to a training center, for example, more than 7,000 semi-transparent photovoltaic modules from Schott Solar were installed on the roof of the former armored vehicle depot. A small town in the state of Hesse thus became home to one of the largest semi-transparent solar roofs in Germany.

Example of green renovation: Deutsche Bank's tower blocks in Frankfurt

To improve energy efficiency in buildings, it is vital to modernize existing structures. New buildings account for barely one percent of total building space every year. And legacy properties consume substantially more energy on average than the standard levels prescribed for new buildings. In many cases, **retrofit-**

17 See Bundesumweltministerium (2011a)
18 See Siemens AG (2011e)
19 BITKOM (2011c), p. 8. See also the following definition: "Smart buildings are buildings that are designed, built or operated using ICT-based technologies. The aim of smart buildings is to improve energy efficiency in all phases of building lifecycles." (SMART 2020 Addendum Deutschland, p. 33)

Figure 73: Relevant issues in smart buildings



Source: BITKOM, p. 8

ting efficient technology is enough to put an existing building on an energy diet. One spectacular example of how successful this can be is the metamorphosis of Deutsche Bank's tower blocks in Frankfurt to the "green towers" they are today. The project furnishes evidence that the principles of sustainable and smart construction can successfully be applied to legacy buildings too.

In line with its sustainability strategy, Deutsche Bank wants to significantly reduce its environmental footprint. By 2013 at the latest, the financial institution aims to run climate-neutral operations. In the meantime, carbon emissions are to be shrunk by 20 percent per annum relative to the defined base year. Two levers in particular – **energy efficiency** and the use of **energy from renewable sources** – are being activated to achieve this goal. Modernizing the headquarters in Frankfurt/Main was an important milestone in the overall process. Originally completed in 1984, the Deutsche Bank towers hosted the biggest building renovation project in Europe, which extended over three years. When they reopened in February 2011, the 155 meter-tall buildings in the west end of Frankfurt were two of the most ecofriendly skyscrapers in the world.

Milan-based architect Mario Bellini was responsible for the architectural design of the green towers, where as many as 3,000 people work. Bellini's concept is rooted in a holistic approach that embraces energy efficiency, user convenience and lifecycle costs.

Exhaustive renovation has left the green towers almost completely carbon-neutral. Lower energy requirements and the use of renewable energy have reduced carbon emissions by 89 percent per annum. The two buildings consume far less energy than they did ahead of the project. Demand for heating and cooling energy was slashed by 76 percent. Consumption of electric power too is down 55 percent. A new **water management system** has implemented internal water recycling and the use of rainwater, for example, to cut fresh water consumption by more than 70 percent. [20]

The green towers have been rewarded with the best possible certificates for sustainable building in honor of such exemplary resource and energy efficiency. The revamped headquarters were awarded the LEED platinum certificate – effectively a summa cum laude distinction from the US Green Building Council – as well as DGNB Gold, the highest rating granted by the German Sustainable Building Council.

20 See Deutsche Bank (2011)

Example of a new green building: the Unilever headquarters in Hamburg

An example of contemporary sustainable construction now proudly adorns Hamburg's HafenCity, where the Unilever offices are part of a spectacular ensemble with the Marco Polo Tower. Since summer 2009, the consumer goods group has had its head office for German-speaking Europe parked in an eye-catching location on the Strandkai overlooking the Elbe river. Gross floor space of 25,000 square meters provides workspace for nearly 1,200 people. Behnisch Architekten, a firm based in Stuttgart, shouldered the task of designing the Unilever headquarters and adhered rigorously to the principles of sustainable building. **Heating and air-conditioning technology** solutions were selected to minimize energy requirements. For example, heat-conductive reinforced concrete ceilings keep office space agreeably cool.

A lighting concept specially designed for this particular building also contributes to energy efficiency. An **SMD LED** system, with lights that use up to 70 percent less energy than conventional halogen lamps, illuminates communal areas and workspaces.

One of the highlights of the Unilever headquarters is the **transparent shell** that underscores the sense of lightness and openness exuded by the building. The polygonal folds in the curtain façade are more than just an attractive head-turner, however. Indeed, they are a masterpiece of technology. Radolfzell-based engineering consultant formTL designed a single-layer foil cover to protect the sun blinds on the façade from the wind. The ethylene tetrafluoroethylene (EFTE) foil used for this cover is lightweight, highly transparent and very durable. [21]

The ecofriendly high-tech office block on Hamburg's Strandkai has already been showered with architectural accolades. Pleasing to the eye and kind to nature, the design has won a **string of awards**, including the title "Best Office Building in the World" at the World Architecture Awards (Barcelona 2009), the Architecture Prize from the German Architects' Association (BDA) in Hamburg for buildings erected between 2008 and 2010, and the Schüco Green Building Award 2011. [22]

The future today – International examples of smart city development

In its purest form – as a holistic, integrated concept – no truly smart city exists as of yet. All over the world, however, promising beginnings are emerging that seek to apply the principles of intelligent and sustainable urban planning in practice. Let us therefore take a brief tour of three of these cities – Changchun, Stockholm and Masdar – to gain an insight into our urban future.

Latitude 43.81/longitude 125.32: The city of **Changchun in northeastern China** is slated to become the "Detroit of the east". The auto boom in the People's Republic is mirrored in this city's population figures, which have doubled to 3.4 million in the space of just 15 years. [23] Shortly after the turn of the millennium, the city authorities issued invitations to an international competition on urban expansion. The winner was Albert Speer & Partner (AS&P). The internationally respected architects and urban planners went on to design the Changchun International Automotive Development Area, the 120 square kilometers site of a satellite town to accommodate 300,000 residents. The meta-objective of their design activities was to **reduce land use and conserve resources**. To achieve this goal, the planners have sought to keep living and working spaces close together and make sure central amenities are easy to reach. Car factories and those of suppliers are based in the satellite town to keep distances between home and the workplace short. [24]

Vehicular traffic is to be kept to a minimum to reduce CO_2 emissions. To this end, a rail-based delivery and supply system will link up factories, suppliers and the university located in the development area. The satellite town also has a high-speed rail link to the center of Changchun. Plenty of open spaces are also planned to give the satellite "green lungs" that ensure a plentiful supply of fresh air, as well as inhibiting carbon emissions.

21 See Architekturzeitung (2011)
22 See Behnisch Architekten (2011)
23 These numbers refer not to the wider agglomeration, but to the city of Changchun proper.
24 See Albert Speer & Partner GmbH (2011)

Work on realizing the blueprints for the Changchun International Automotive Development Area has been in progress at an array of building sites since 2008. A further competition has now also been launched for development of the southern part of the city. The winner this time was Shanghai-based AS&P Architects Consulting. In this second Changchun project, which is to provide living space for some 400,000 people, **sustainability** once again **plays a prominent role**. The concept devised by Albert Speer & Partner follows the lead given by traditional Chinese urban development styles. Districts measuring 350 meters by 350 meters will allow residents to reach everything they need on a daily basis on foot.

Latitude 59.32/longitude 18.06: Stockholm's Hammarby Sjöstad district has long since gone beyond the planning phase. Thanks to sustainable urban planning, this district has, in just two decades, morphed from a contaminated former industrial zone to an ecological showcase. The goal of cutting carbon emissions in half was stated from the moment the revitalization project began. The local authority's master plan to develop this district in the southeast of Stockholm thus focused on closed cycles for the energy and water supplies and for waste disposal. Dimensioned to accommodate 11,000 homes, the district comes close to energy self-sufficiency, mostly using **solar power and biomass**. Heating and biogas are derived from Hammarby Sjöstad's wastewater. Waste is collected separately via subterranean pipelines and then reused. [25]

Urban planners in the Swedish capital also wanted to **keep the car density down** to an average of no more than 0.5 vehicles per housing unit. To achieve this goal, they had to offer residents viable alternatives to getting around on their own four wheels. Creating and expanding the district's connections to local public transport therefore figured very high on the list of priorities. Two new bus lines, a ferry link and a new streetcar line with a direct link to the center of Stockholm are at the core of the patchwork mobility concept that eases the"pain" of doing without a car. Moreover, residents who still need a vehicle from time to time can use the district's car-sharing system: 25 automobiles in Hammarby stand ready and waiting for their temporary drivers.

Latitude 24.42/longitude 54.61: Around 17 kilometers outside Abu Dhabi, the capital of the United Arab Emirates, the prototype of a sustainable city for 50,000 people is taking shape on a six square kilometer plot of desert land. Its name? **Masdar City.** Zero emissions and zero waste are the stated aims for this high tech enclave near Abu Dhabi's airport. Since the ecological footprint is to be no larger than a pinhead, conventional air-conditioning systems, cars and the use of fossil fuels have been banned from the urban planning strategy. The drafts prepared by British architect Norman Foster arrange the buildings in such a way that the shadows they cast will keep temperatures up to 20 degrees Celsius below those in the desert outside the city's boundaries. [26] Cars with combustion engines will have to stop outside Masdar City. Instead, the city's smart mobility concept will involve electric cars, a light rail transit system, taxis and a personal rapid transit system that will transport passengers to their destinations via a system of subterranean tunnels.

The **aim of carbon neutrality** can be realized only with the aid of sophisticated building services. Siemens has supplied a large chunk of the building technology, which is linked via a smart grid to the sustainable desert city's power supply system. Energy consumption can thus be managed and monitored for every single building.

Looking at the power generation concept, it is obvious why the city is often referred to as the "Silicon Valley of renewable energy". Masdar's **energy needs are to be met exclusively from renewable sources**. Solar thermal power plants will play the lead role, complemented by wind power and geothermal energy. A solar-powered sea water desalination plant will deliver drinking water to Masdar. To ensure that the precious "blue gold" is not wasted, the city has separated the supply of drinking water and gray water.

The "no waste" commandment also applies to the handling of refuse, which is collected and recycled via a central system. Biological waste is either transformed into fertilizers or used for power generation. Industrial waste and metals are to be used as secondary raw materials.

The planning for Masdar City began back in 2006. At a scheduled total cost of USD 22 billion, the project was launched and has been driven by the government of Abu Dhabi with a view to promoting **economic diversification** in the emirate. The project developers want 1,500 entrepreneurs to set up shop in Masdar. The high tech city in the desert also has a university: Students on the campus of the newly launched Masdar Institute for Science and Technology began the first round of courses in 2010. **IRENA, the International Renewable Energy Agency**, will likewise move its headquarters from Abu Dhabi City to Masdar – a symbolic gesture indeed. The oasis of sustainability

25 See Future Communities (2011)
26 See Industry Journal (2011)

will not be completed as quickly as was originally planned, however. Not even the United Arab Emirates emerged unscathed from the economic and financial crisis, which triggered a slump in the property market. Masdar too has felt the repercussions and is now due for completion in 2025.

Not everyone applauds the Masdar City project. Critics see the eco-city in the desert as the prototype of a "green gated community" with privileged living conditions on the inside but isolation from the outside. That would make Masdar little more than a rerun of the "dome over Manhattan" in the Arabian desert. It is a fact that ideal(ized) cities straight off the drawing board can never be a generally valid response to the challenges thrown out by urbanization. Different solutions are needed to shape the urban future as the climate changes and resources grow scarce, simply because different cities are starting from different situations and face differing conditions. There is, however, one common denominator that underpins all the available options: **Smart solutions** show the way forward to a sustainable urban future. "Green cities are not about [...] getting back to nature. They are about going forward to nature, armed with technology and creativity." [27]

27 Professor Hans Schellnhuber, Director of the Potsdam Institute for Climate Impact Research (PIK), quoted in *Die Zeit* on May 1, 2011

Environmental technology services – New challenges, new business models

Green services have proven to be a driver of growth in the global market for environmental technology and resource efficiency. [1] From 2007 to 2010 they expanded rapidly, raising their share of international green tech markets to 51 percent [2], and even 53 percent in Germany – here the market volume for environmental technology services rose from EUR 123 billion in 2008 to EUR 155 billion in 2010. Such dynamic growth has established green tech services as a powerful stimulus for the individual lead markets in the environmental technology and resource efficiency sector. Green services present solutions to the various issues and challenges that arise in the course of efforts to cope with today's megatrends. And it is precisely this link that makes development and progress in environmental technology services an important area of transformation on the road to a green economy.

A key factor in the expansion of **environmental technology services** is their **innovative strength.** New business models have emerged while existing ones have been adapted to the specific needs of green tech companies – also a form of business model innovation. To aid a systematic understanding of this wide-ranging topic, we distinguish below between fundamental environmental services, services to meet general industry needs and corporate services.

1 The role of environmental technology services as a driver of innovation and growth is described in detail in the publication *Umwelttechnik-Dienstleistungen. Treiber für ökologische Modernisierung und Beschäftigung* (Bundesumweltministerium, 2009d)

2 See p. 41f.

The structure of green services

Fundamental environmental technology services

Services that relate directly to environmental technology are considered fundamental environmental technology services. They originate in the environmental sector and have no equivalents in other industries. Fundamental environmental technology services are made possible – and in some cases necessary – by process or product innovations, or by shifts in demand. Examples include consulting in the various lead markets on issues such as energy efficiency, material efficiency, water supply/wastewater disposal, project development, energy contracting and innovative business models such as the sale of green electricity or ecotourism. A broad spectrum of customers ranging from private individuals and the corporate sector to public organizations make use of fundamental environmental technology services.

Environmental technology services to meet general industry needs

This category covers **services that support specific parts of the environmental technology industry's value chain.** Development services are provided in advance of production, production services during the manufacture of environmental technology products, and product services once the end product has been completed. Although these services do have equivalents in other industries, specialized knowledge in the relevant green technology segment is vital to their delivery. Examples of general industry services are research (both basic research and applied R&D), technical planning, consulting and validation, material management services (raw materials and supplies), sales, logistics, retail, and operating and maintaining technical facilities.

Corporate environmental technology services

Services that support production and service companies in the environmental technology industry are considered corporate environmental technology services. Unlike services to meet general industry needs, corporate environmental technology services are not restricted to specific parts of the value chain. Instead, they are made available to companies as a whole. This category of green services also has equivalents in other branches of industry. Once again, however, they presuppose a specialist knowledge of the green tech industry. Typical examples of corporate environmental technology services include financing provided by banks, private equity firms and venture capitalists, insurance, advice on strategy, human resources and IT issues provided by law practices, auditors and tax advisors, and company training and development programs. The environmental technology industry offers lucrative prospects for service providers that have hitherto operated in "traditional" industries, too. Those that move quickly to position themselves in this still relatively young discipline stand to gain a valuable competitive advantage.

The range of environmental technology services available is highly diverse, in keeping with the dynamism with which this segment is growing. The following examples of the many shades of green services that exist provide an **insight into the business models** that have evolved in and around the green tech industry.

Fundamental environmental technology services

In recent years, environmental legislation, growing cost pressure and a shift in customer awareness have encouraged the emergence of innovative business models in the area of fundamental environmental technology services. Rooted in such fertile soil, the providers of these services have gathered tremendous **momentum in the direction of a green structural transition.** Not only have they sold their services in response to existing demand, their portfolio has in turn fueled added demand for environmental technology. Power providers that specialize in the distribution of green electricity, for example, are deepening the market penetration of renewable energy. Similarly, energy consultants are stoking up demand for efficiency-enhancing technologies.

Emissions trading stimulates new business models

The trading of carbon certificates is an example of how a new market segment can emerge as a result of regulatory activity. The European Union Emission Trading Scheme (EU ETS) was introduced in June 2005. The cross-border system for trading in pollution rights – still the world's leading system of its kind – works on the **principle of cap and trade**. This principle is translated into reality by defining emission ceilings and allocating certificates. Certificates allocated to the power and industrial plants covered by the EU ETS (of which there were 1,630 in Germany in 2010) give these plants the right to produce a certain amount of carbon emissions. If their actual carbon emissions total is lower, they can sell off any certificates surplus to requirements. Conversely, if they exceed their "carbon credits" they must purchase additional certificates.

In Europe, certificates are bought and sold primarily on the European Climate Exchange in London and the EEX European Energy Exchange in Leipzig. In Leipzig, the German Emissions Trading Authority (DEHSt, a department of the Federal Ministry for the Environment) has weekly auctions held by the KfW banking group. **Around 40 million emission rights** are offered for sale every year. Between January and July 2011 alone, a total of 26,100,000 emission rights worth some EUR 400 million were auctioned off on the EEX. [3] The Carbix (EEX Carbon Index) is calculated every trading day as the reference price in Leipzig.

Beyond the EU ETS, carbon certificate trading also stimulates the growth of new business models. Companies and private individuals can help protect the climate by **voluntarily offsetting their carbon emissions**, for example. Almost all airlines nowadays give passengers the option of offsetting the carbon emissions caused by their flights. Lufthansa cooperates with myclimate here: Anyone wishing to make a voluntary contribution to climate protection can go to the Swiss non-profit organization's website and calculate the exact volume of CO_2 emissions caused by their flights. myclimate is one of the biggest providers of offsetting services. Spun off from the Swiss Federal Institute of Technology in 2002, the foundation works with numerous companies in tourism and other industries, as well as public institutions.

The principle of offsetting is rooted in the idea that carbon emissions generated in one place can be balanced out by saving the same volume of CO_2 elsewhere. Companies and private individuals who opt for voluntary carbon offsetting pay a certain amount of money per unit of emissions which myclimate.org then invests in selected climate protection projects. Quality standards comply with the Kyoto Protocol criteria (i.e. the Clean Development Mechanism). myclimate only supports activities that play a direct role in reducing emissions of greenhouse gases. Examples include renewable energy projects, improvements in energy efficiency and efforts to reduce methane emissions in combination with the use of methane to generate energy. In 2010 myclimate offset a total of 303,000 tons of carbon dioxide. [4]

Waste heat as a source of energy

Waste heat is given off during energy conversion in power plants and in many industrial processes. The term is misleading, however: This "waste" product has now been discovered to be a valuable source of energy for generating heat and power. A number of German states have already published maps of waste heat sources on the Internet. The "Energie-Atlas Bayern" ("Bavarian Energy Atlas"), for example, contains a waste heat land register that makes it easier for suppliers and customers to find each other. [5]

Waste heat cannot always be put to good use in the place where it is generated. This fact opens the door to **new business models that harness this useful resource**. One such model involves brokers specializing in waste heat. Waste heat contracting, for example, provides a "no-worries, all-inclusive" package. One of several start-ups operating in this young and lucrative line of business is e2-power GmbH. e2-power sells tailor-made solutions for the use of waste heat to industrial and commercial customers, as well as biogas plant operators. It focuses on organic Rankine cycle (ORC) technology for producing electricity. To guarantee one-stop shopping, the company handles everything from purchasing and configuring plants to connecting and maintaining them, as well as drawing up the contract between the customer and the power utility that wants to buy the electricity generated from the waste heat. [6]

LaTherm GmbH is another company that has come up with a business model based on the use of waste heat. The Dortmund-based company pursues a different strategy, however, actively trading in waste heat as a commodity that it then delivers to its customers. LaTherm exploits the fact that heat can be stored and/

3 See Deutsche Emissionshandelsstelle im Umweltbundesamt (DEHSt) (2011)
4 See myclimate (2011)
5 See Bayerisches Staatsministerium für Umwelt und Gesundheit (2011)
6 See Cluster Umwelttechnologien.NRW (2011a)

or released again extremely effectively during thermodynamic phase transitions. The company has developed a latent heat storage system that uses waste heat. A converted standard container serves as the heat storage unit. The storage medium is sodium acetate. The container can store around 2.5 megawatt hours of energy – about four times as much as a water storage tank of comparable size. That is enough to keep a single-family home heated and supplied with hot water for about three months. Heat exchangers are used to fill the heat storage containers with waste heat from industrial or biogas plants, for example. This method has advantages in terms of environmental impact as it reuses heat that has already been generated. LaTherm's containers are then shipped to the places where they are needed – schools, hospitals or residential buildings, say – and hooked up to the existing heating system. The building's hot water system channels cold water into the container, absorbs heat and gives this off again in the building's heating circuit. [7]

Sustainable mobility thanks to a smartphone

An average of 1.5 people sit in each car on Germany's roads. [8] In other words, 2.5 seats are normally empty. Filling these seats would be an important way to improve **resource efficiency in the traffic sector**: The better available capacity is used, the less fuel is consumed and carbon emitted per person kilometer. The magic word is "ridesharing". When the country's first ridesharing pools were opened in the 1970s, landline phones were the only technical tool available to support the professional placement of ridesharing opportunities. Thanks to the Internet, smartphones and GPS, the business model has now shaken off its image as a cheap and cheerful niche for students and low-budget travelers.

Every day some 32,000 ridesharing opportunities in Germany are successfully placed over the Internet. On average, drivers give rides to two to three other people, who pay part of the travel costs. **Car pooling for commuters** in particular pays off in a number of ways: On the one hand, it eases the burden on household budgets as travel costs are cut sharply. On the other hand, the volume of rush-hour traffic in particular is reduced. Several Internet sites have been set up to bring drivers and passengers together. One of the market leaders, mitfahrgelegenheit.de, has more than 3.5 million registered members. Founded in 2001, it also cooperates with other mobility providers. [9]

Indeed, the next phase in the placement of ridesharing opportunities has already begun. Its name? **Dynamic ride sharing (DRS)**. DRS uses mobile applications (on smartphones, using GPS data) to spontaneously arrange shared rides, especially for short distances. In New York, dynamic ride sharing is already being used to help people share taxi fees.

Dynamic ride sharing is now gaining a foothold in Germany, too. When flinc started up as the offshoot of a student project in July 2011, its claim said it all: "Ridesharing meets social network". flinc is an Internet-based system that runs in real time on PCs or via smartphone apps. It is integrated into a navigation system. More than 5,000 users took part in the project test phase from April to July 2011. flinc analyzes routes and brings drivers and potential passengers together in real time, making it the ideal exchange platform for all kinds of journeys – spontaneous or planned, short-distance or long-distance. [10]

General industry services

Providers of general services to the environmental technology industry do not normally have to specialize in green technology. Having said that, an increasing tendency in precisely this direction is nevertheless found throughout the value chain. Many development service companies in the private sector, for example, originally came from other industries such as automotive engineering. The desire to **diversify and participate in the growth prospects** for green technology are leading more and more companies to specialize in this industry. Some companies that provide technical planning and consulting services, for instance, started out in the energy sector and then gradually evolved in the direction of environmental technology. Today they deliver services in a variety of lead markets, including sustainable water management and waste management and recycling.

The importance of general industry services in all lead markets substantiates these findings. It is also a further indicator of how significant these services are

7 See LaTherm GmbH (2011)
8 See infas Institut für angewandte Sozialwissenschaft GmbH/ Deutsches Zentrum für Luft- und Raumfahrt e.V. (2010), p. 13
9 See mitfahrgelegenheit.de (2012)
10 See flinc AG (2012)

to ongoing development in the green tech industry. External service providers such as consulting engineers and research organizations drive the **innovation process** forward as they engage in highly specialized research and development activities on behalf of corporate customers. General industry services also play an important role in making the green tech industry **more international**. Manufacturers of products and providers of services assume a driver function in each other's markets: For instance, if a waste recycling plant is sold abroad, then planning, consulting and assembly services will be needed on site to get the project done. As a rule, the product-related services for such plants are provided by German specialists when the plants themselves are made in Germany ("service follows products"). Conversely, technical planning and consulting firms involved in projects abroad often use products supplied by German manufacturers ("products follow services").

Specialists for research and development

Development service providers support the R&D activities of green tech manufacturers across a broad spectrum, ranging from basic research to the adaptation of existing components. The networks forged between development service providers and manufacturing companies in the green technology industry are a powerful lever to activate the innovative capabilities of this industry. **Development service providers** come in all shapes and sizes: Both research institutions affiliated to universities and small engineering offices are active in this market. Many of them share common roots in other industries, such as automotive engineering or the aerospace sector. However, growing demand from environmental technology producers and the industry's growth prospects have made green tech an attractive proposition for development service providers.

Project developers as global players

Project developers who build renewable energy plants constitute an important segment of the general industry service category. In many cases, they also go on to operate the plants they have built. One classic example is the juwi Group. Launched as a two-man firm in 1996, the Wörrstadt-based company today employs around 1,000 people and turns over EUR 800 million a year. Around the globe, the juwi Group is engaged in projects to generate power from renewable sources: the sun, wind, bio-energy, hydropower and geothermal energy. Every service the customer needs – from planning, engineering and financing to operation – is provided from a single source. Plants built by the project developer from the German state of Rhineland-Palatinate are now installed in many countries. A few examples from the company's lengthy reference list suffice to make the point: in Costa Rica, the juwi Group set up one of the largest wind farms (49.5 megawatts) in Central America; in the US state of Nebraska, 40 turbines (60 megawatts) do their stuff on a wind farm created by juwi; the photovoltaic system on top of the soccer stadium in Verona is a juwi project; as is the 53-megawatt solar farm at a former military exercise facility in Cottbus, Germany. [11]

Germany has consulting engineers that take care of **every link in the value chain** – from development to management – for renewable energy plants, water supply and wastewater disposal plants, and waste recycling and disposal plants. This expertise is much in demand as an export good and German service providers frequently find themselves involved in projects abroad. One such service provider is the Dorsch Group, whose 1,800 or so employees provide planning and consulting services to industrial customers, private investors and public sector clients. The company provides an array of services in the fields of airports, transportation and infrastructure, architecture, water, the environment and plant engineering in 40 different countries. Environmental technology is an important part of its portfolio and one that is much in demand both at home and abroad. In the sustainable water management segment, for example, the Dorsch Group oversees projects in countries such as Albania, Egypt, the United Arab Emirates and Jordan. [12]

Packages sharpen suppliers' profiles

Green technology is one of many industries in which a clear **trend toward product and service packages** is observable. Matching services are built around the strengths of the core industrial product. These packages of capital goods and services – also referred to as hybrid products – are gaining in significance as they make it easier for companies to carve out a distinctive profile for themselves in hard-fought markets. Packages help a firm set itself apart from its competitors and cement customer loyalty. Due to their inherent complexity, they are also difficult for rivals to imitate. Increasing numbers of green tech producers are now leveraging the advantages of such packages of goods and services. Rostock-based Nordex SE, for example, develops and manufactures wind turbines.

11 See juwi Holding AG (2011)
12 See Dorsch Group (2011)

Nordex turbines are currently used in wind farms in 34 countries around the globe. The company offers turnkey projects: On request by the customer, Nordex will happily handle every aspect of planning, engineering, connection to the grid, operation and maintenance. [13]

Contracting models: Kind on resources – and on budgets

The more energy efficiency moves into the ascendancy, the better the outlook for contracting – an oversimplified but still fairly accurate way to describe the correlation between the need to deal sparingly with resources and the emergence of contracting as an operating and financing model. Although the beginnings of contracting in Germany date back to the early 1990s, it has only recently graduated from its long-standing niche status. The basic idea behind the business model is to **optimize power generation and distribution plants in buildings and real estate without the owner having to tie up capital**. On behalf of the owner, the contractor puts together a package containing the planning, financing, construction, operation and maintenance modules. Depending on the precise contract design, the contractor bears part or all of the responsibility – and the economic risk – for the supply of energy. [14]

The four basic forms of contracting are defined in DIN Standard 8930 Part 5 ("Contracting"). **Energy contracting** – also known as plant contracting – involves the contractee acquiring usable energy from the contractor in the form of heat, steam, refrigeration, electricity, compressed air or light, all in the required quantity and quality. **Finance contracting** (or plant leasing) normally involves the contractor handling the planning, financing and construction of a plant, while the contractee is responsible for operating the plant. With **technical plant management** (or operations contracting), the contractor is in charge of running the existing or newly built plant. In the case of **performance contracting** (or energy-saving contracting), the contractor sells its customer not only usable energy but also an efficiency concept that guarantees final energy savings in the form of electricity, gas, fuel oil, district heating and even water and wastewater. This last contracting variant is based on a mechanism in which the reduction in energy costs is sufficient to fund the contractor's investment in optimizing power generation and distribution over the term of the contract. Under normal circumstances, savings of 20 to 25 percent on previous energy costs are guaranteed. If these savings targets are not met, the contractor has to foot the bill.

Especially for properties in the public sector, performance contracting can be a sensible way to modernize energy systems despite tight budget constraints. The German Foreign Office was the first federal ministry to tread this path. As a result, its facility in Berlin-Mitte has reduced its energy costs by roughly a quarter – the equivalent of EUR 600,000 and 1,800 tons of carbon dioxide per year. A new cooling system, LED lamps and a solar air heating plant have been installed at the Foreign Office within the framework of this contracting model. [15]

Green electricity provider LichtBlick has developed a concept to apply the **contracting model to private households** too. The "home power plant" – a mini-cogeneration unit for single-family houses and duplexes – is gas-fired and produces both heat and electric power. Customers sign a heat delivery agreement with LichtBlick. In return, the company takes care of installation, connects the system to the power grid, handles feed-in and does all necessary maintenance. LichtBlick retains ownership of the mini-cogeneration unit. [16]

13 See Nordex SE (2011)
14 This account draws on an article on contracting published on the website of EnergieAgentur.NRW (2011)
15 See Deutsche Energie-Agentur (2011d)
16 See LichtBlick AG (2011)

Corporate services

Expansion is the order of the day for the environmental technology industry. Since the majority of green tech companies are growing quickly and constantly, their appetite for services is following suit. The providers of corporate services help **make the green tech industry more professional** by accelerating knowledge transfer. Their activities for customers in other industries have given them a thorough grasp of functional topics such as strategy, finance, organization, human resources management and financial analysis. Now the experience they have gained in established industries is being channeled into the still relatively young environmental technology sector.

Positive development in corporate services should not be understood merely as a dependent variable of green tech growth, however. The innovative skills of service providers are giving this segment **significant momentum of its own**. As they develop and specialize, service providers craft new services and business models by mapping products that have proved themselves in other industries onto the specific needs of environmental technology companies.

Made-to-measure insurance solutions for green technology

An example: Insurers involved in the renewable energy business do not have to reinvent the wheel. Instead, they can adapt their existing products to a changed set of requirements. Business interruption insurance is far from new. The innovative aspect is that this standard model is now being applied to private households' photovoltaic systems, for example. The development of renewable energy sources has given rise to completely new insurance solutions. **Productivity risk insurance** for geothermal power projects, as offered by companies such as Konsens KG, is one example. This policy covers the risk associated with the first (explorative) deep borehole. If the outcome turns out to be so bad that it would not make economic sense to proceed, the insurer covers the costs incurred in the boring. This approach lowers the investment risk barrier of the initial boring. [17]

HDI Gerling has come up with the KLIMArisk ("climate risk") product to protect clients against the whims of the weather. This policy targets companies in various industries that are keen to **cover weather-related risks**. Its offer is equally attractive to wind farms: If the projected wind force – and hence the planned volume of electricity – is not reached, wind turbine operators can now insure themselves against loss of revenue. [18]

Besides guarding individual companies and operators against assorted risks, the insurance business also fulfills another important function in the green tech industry: By modeling the risks associated with new technologies, it helps create transparency for investors.

Financing sustainable business ideas

Like all companies, players in the green tech industry have to come to terms with the issue of financing. They have to do so throughout their entire corporate lifecycle, from start-up through expansion to liquidation. Given the megatrends of climate change and growing scarcity of resources, investors' interest in environmental technology has increased noticeably in recent years. Yet even so, finding enough money for the launch and growth phases still presents a major challenge to many companies in this industry.

In principle, green technology companies can choose between various types of funding. A distinction is drawn between **internal and external sources of funds**. Internal sources include funding out of the company's own resources or the pockets of its shareholders. External sources include banks, venture capital firms, private equity firms, the capital market, and subsidies and grants from regional or federal governments or the European Union.

In the context of environmental technology, corporate finance remains a complex issue. Small and medium-sized enterprises (SMEs) give the industry its characteristic structure. However, SMEs tend to run into difficulties when they try to fund expansion using their own financial resources. Various aspects of green technology qualify for regional and federal subsidies and grants in Germany. [19] However, many of

17 See Konsens – Versicherungsmakler KG (2011)
18 See Talanx Deutschland AG (2011)
19 Examples include the Environment Innovations Program run by the Federal Ministry for the Environment and the Energy Storage Development Initiative. An exhaustive list of government support programs for environmental technology and resource efficiency is published on the website of the Federal Ministry for the Environment (http://www.bmu.de/foerderprogramme/aktuell/1762.php; in German only). An overview of funding programs backed by federal government, regional governments and the European Union, structured along thematic and cross-industry lines, is provided in the funding database of the Federal Ministry of Economics and Technology (www.foerderdatenbank.de; in German only)

these programs focus on research and development activities. It is much more difficult to secure **funds for young green tech companies**, above all in the market launch and expansion phases. For most SMEs, turning to the capital markets to solicit the necessary cash is not normally an option.

Which leaves them with the banks, the traditional external source of funding for small and medium-sized firms. According to the findings of an industry study in the German state of Saxony, many environmental technology companies are dissatisfied with the way banks behave when it comes to financing. Companies in the survey indicated that banks lack the skills needed to properly assess the **specific nature of the green tech industry**. Harsh as this judgment sounds, it is based on objective criteria. Assessing risks surrounding the granting of credit is much more complex in environmental technology than in other branches of industry. Why? Because factors beyond the scope of traditional banking and business administration doctrines can play a key role. Regulatory frameworks, subsidies and technological development all have a huge influence on the business prospects of green tech firms. Picking the right path through the labyrinth of rules and regulations when considering a company's financing needs requires special expertise that not all traditional commercial banks have at their disposal. Moreover, many banks divide their corporate finance business into conventional industry segments, with specialists in each sector. As a cross-sector industry, environmental technology is difficult to place within such structures.

Germany's UmweltBank approaches this challenge from a completely different angle. Headquartered in Nuremberg, the bank anchored the goal of promoting environmental protection in its charter from the moment of its inception in 1997. Customer deposits are channeled solely into environment projects, of which UmweltBank has so far supported more than 14,000 with a total credit volume of EUR 1.6 billion. Ecological construction projects and renewable energy are two main focus areas. The hybrid power plant in the state of Brandenburg that generates hydrogen from wind power received interim funding from UmweltBank. Numerous photovoltaic installations and biomass power plants have also been financed by green loans from the Nuremberg bank, as has an innovative hydropower plant. Years of experience in renewable energy have enabled the staff of UmweltBank to accumulate a wealth of **specialist knowledge about grants and subsidies**. As a result, borrowers benefit from expertise as well as cash injections. Incidentally, this distinctive profile has kept UmweltBank growing and profitable for years. In 2011, the bank saw its business volume break the EUR 2 billion barrier for the first time. [20]

Objective yardstick for sustainability reports

"If you ignore sustainability considerations, you are failing to discharge what have become essential management duties. That is negligence and exposes you to unnecessary risks." [21] Stefan Schaltegger, Professor of Business Administration and Chair of Sustainability Management at Leuphana University Lüneburg, is in no doubt whatsoever that **sustainability is a driver of long-term business performance**. In line with the three pillars model, sustainability combines environmental protection with both economic and social aspects. The three pillars of sustainability are also referred to as the "ESG criteria" (environmental, social, governance; in a management context, governance is synonymous with good corporate management). This three-dimensional understanding, embracing ecology, economics and society, lays the foundation for sustainable business. Sustainability must, however, be carefully monitored in order to identify the mechanisms via which ESG criteria contribute to business performance. Relevant **key performance indicators (KPIs)** and guidelines for sustainability reporting (such as the Global Reporting Initiative) lend themselves as tools for applying sustainability criteria in practice. [22]

The concept of sustainable business, how it can best be enshrined in corporate strategy and how controlling should operate as a management subsystem has evolved into a significant **line of business for auditors and consulting firms**. Deloitte, PricewaterhouseCoopers (PwC), Ernst & Young and KPMG, the four biggest auditors and consultancies in Germany, all provide an extensive array of sustainability reporting and carbon footprint assessment services. Ernst & Young, for example, groups three distinct areas – Sustainability Performance Reporting, Greenhouse Gas Accounting & Reporting and Sustainability Reporting Assurance – together under the heading Climate Change and Sustainability Services (CCaSS). [23] In this area in particular, the extent to which core competencies in auditing are gravitating toward green applications is apparent. As part of Sustainability Reporting Assur-

20 See UmweltBank AG (2011)
21 haufe.de/controllerwissen (2010)
22 For a detailed account of these KPIs and guidelines, see pp. 143ff.
23 See Ernst & Young GmbH (2012)

ance, for example, companies are having their sustainability information tested against transparent standards such as the Global Reporting Initiative criteria to guard against any suspicion of "greenwashing".

PricewaterhouseCoopers and branded sports and lifestyle goods manufacturer Puma have together stepped out into uncharted territory, producing the world's first **environmental profit and loss account**. This enables Puma to identify the true cost of using natural resources and shape its business processes accordingly. The company uses the environmental profit and loss account to document water consumption and carbon emissions at every stage of the value chain. These two variables are then expressed in terms of monetary value. This approach gives the company valuable leads in finding the most effective levers to improve risk management and drive the sustainable transformation of its value creation processes. [24]

Outlook

This brief tour of the innovative world of environmental technology services gives an idea of just how dynamically the segment is developing. In all probability, this pattern will continue in the years ahead. Green tech services will uphold their seminal role as a driver of growth in the global market for environmental technology and resource efficiency. To a large extent, the transition to a green economy is driven by innovation-based growth. This assures environmental technology services a prominent part in the process, as research and development activities, alongside other knowledge-based services, are essential catalysts to innovation-driven growth.

Current estimates (see p. 42) expect the global market for green services to expand by 5.8 percent per annum on average between 2011 and 2025, reaching an overall volume of EUR 2,402 billion by the end of this period.

24 See PricewaterhouseCoopers (2011)

Environmental technology and resource efficiency in Germany – Structure of the industry

Basis of the analysis

This portrait of the environmental technology industry in Germany was compiled from a number of different sources. The core of the present analysis of this young and dynamic sector of the economy is the evaluation of the company database compiled for this study on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. It contains around 2,000 data sets on green tech companies. The analysis also draws on other databases that contain information and assessments given by industry players. All this material has been further enhanced by numerous interviews with industry experts and by relevant findings from studies and publications produced by Roland Berger Strategy Consultants. Despite drawing on a wealth of source material, the analysis does not claim to be empirically exhaustive or offer a complete description of Germany's environmental technology industry. However, the following account does set out key structural data and trace current trends in the German green tech industry. We start by analyzing the industry from the perspective of Germany as a whole and then at the level of federal states.

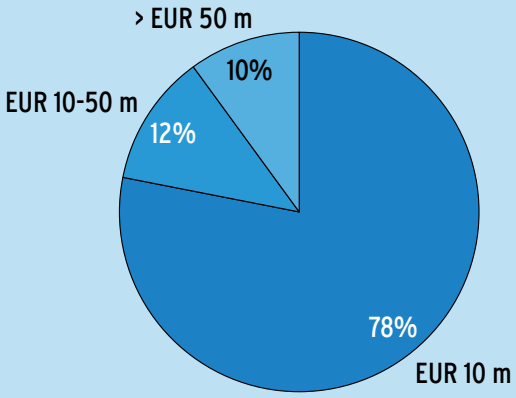
Selected indicators: Company sales, workforce, profitability and age

The results of this analysis reflect the already familiar **small-scale bias in the structure of Germany's environmental technology industry.** No less than 90 percent of companies generate annual sales of less than EUR 50 million (see figure 74). Compared to other industries, green tech is characterized overall by a relatively low revenue-per-employee ratio, currently standing at EUR 90,000. In electrical engineering, for example, this industry indicator comes to around EUR 220,000, and in the automotive sector to approx. EUR 470,000. The (so far) **low figure for per capita revenue** in environmental technology can be interpreted as a typical **feature of a young and dynamic** industry. After all, green tech embraces large numbers of start-ups and young businesses. And, as a rule, companies in the early stages of their lifecycle generate lower sales than companies that have been active in their markets for decades.

Just like the breakdown of companies by sales volume, a breakdown of companies by size of workforce (headcount) also reveals the small-scale structure of the industry. **Around three out of every four companies employ fewer than 50 people** (see figure 75). On average, a green tech business generates annual sales of almost EUR 27 million and employs around 300 people.

The key data on the industry structure clearly indicate how far small and medium-sized enterprises dominate the environmental technology and resource efficiency sector in Germany. In fact, small and medium-sized enterprises play a central role in all six lead markets (see figure 76). The highest level of penetration by small and medium-sized enterprises [1] (96 percent) is found in the waste management and recycling segment. This is largely explained by the relatively low degree of internationalization of this particular lead market. It is also explained by the strong focus on waste management, an area in which low-tech services are a major part of company portfolios. Sustainable water management is another lead market in Germany dominated by small and medium-sized enterprises. The 96 percent penetration in this segment is partly due to the presence of numerous service providers and retailers. It is also down to the fact that businesses operating in sustainable water management include many businesses that offer highly specialized solutions for specific problems. The market is therefore optimally served by smaller companies. The lowest level of small and medium-sized enterprise penetration (81 percent) is recorded in the lead market for sustainable mobility. This low figure points, conversely, to the greater role played by large-scale companies due to developments in this segment. Sustainable mobility concepts have acquired strategic importance for many automotive producers and their suppliers. Another factor here is the scale of research and development needed to compete. This demands considerable investment, and such commitments are often beyond the financial – and human – resources of even mid-sized businesses.

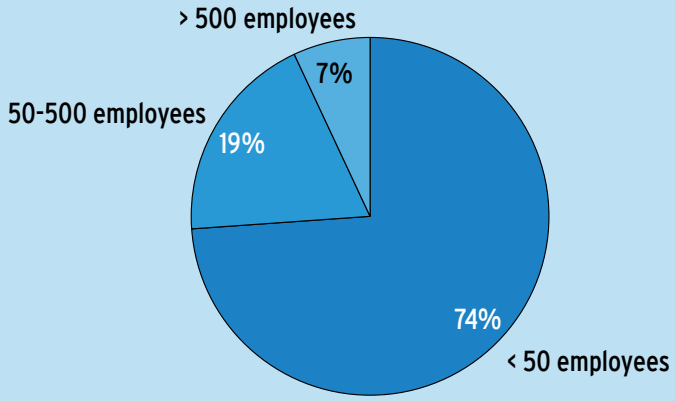
Figure 74: Companies by sales volume (percentage of mentions)



Source: Roland Berger

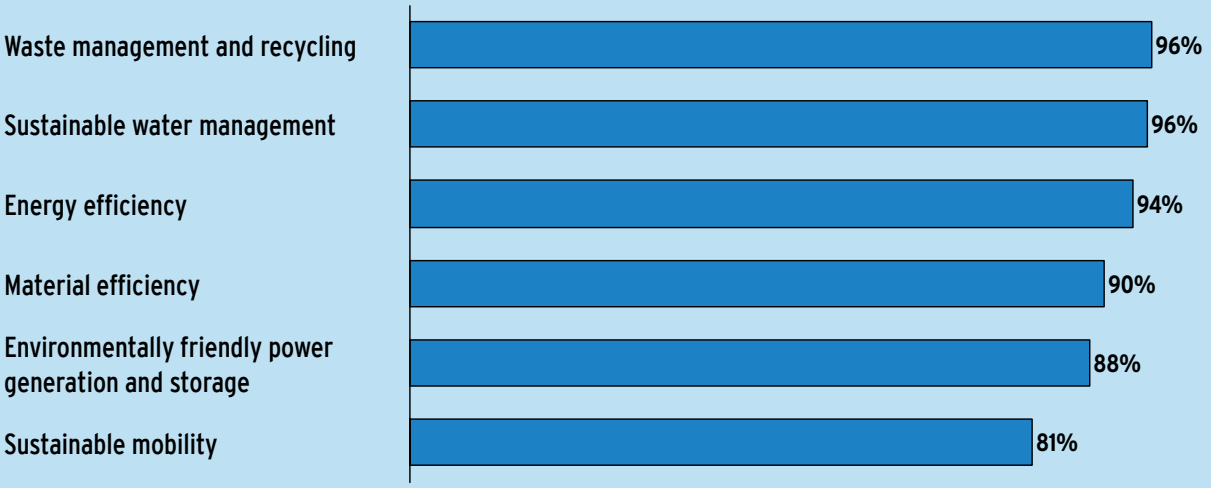
1 Small and medium-sized enterprises are defined as companies with annual revenues not exceeding EUR 50 million

Figure 75: Companies by size of workforce (percentage of mentions)



Source: Roland Berger

Figure 76: Small and medium-sized enterprises as a share of companies in the six lead markets in green tech



1) Small and medium-sized enterprises are defined as companies with an annual sales of no more than EUR 50 million

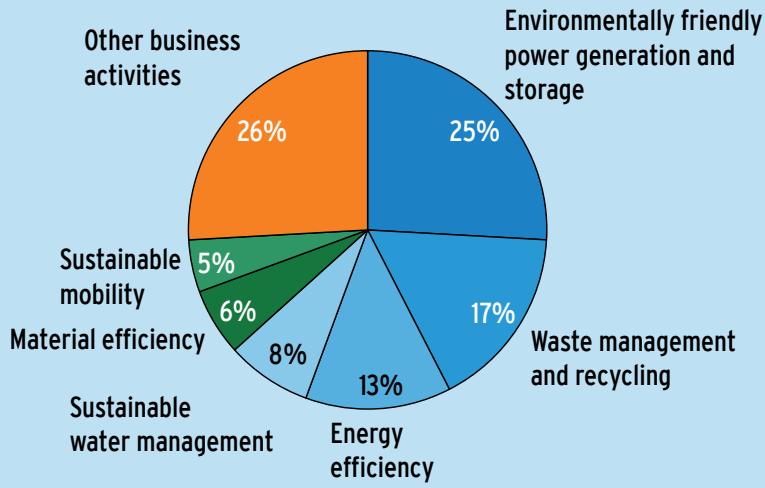
Source: Roland Berger

Looking at the **different shares of value created across the six lead markets** in environmental technology, we find that the lead market for **environmentally friendly power generation and storage**, with a **share of 26 percent**, is the highest volume lead market (see figure 77). This reflects the interest in renewable energy sources in Germany and the huge importance of renewables for the green tech corporate landscape as a whole. The lead market for material efficiency takes a revenue share of just 6 percent, although the outlook for this segment is highly promising in view of the megatrend toward resource scarcity. The global market potential of the material efficiency market is set to continue improving up through 2025, with average annual growth forecast at 7.6 percent.

As figure 77 demonstrates, green tech companies generate more than **a fourth of their sales outside the environmental technology sector** itself ("other corporate activities"). This finding clearly reflects green tech's character as an industry that cuts across and links to many other industries. Indeed, only a third of companies currently active in environmental technology were actually founded as green tech businesses. The majority came from other sectors, especially mechanical engineering, construction and chemicals, and later diversified into environmental technology activities.

As for employment, breaking it down into the individual lead markets gives us a **varied picture of company workforce sizes.** The lead market for

Figure 77: Combined company sales by lead market (weighted by absolute individual sales)



Source: Roland Berger

sustainable water management is dominated by small employers, with 85 percent of companies employing fewer than 50 people. By contrast, companies in the lead market for sustainable mobility have large workforces. Almost a fourth (23 percent) of businesses in this segment have headcounts of more than 500.

Looking at the structure of the environmental technology industry, we find from results of the current analysis that green tech has hardly changed since the publication of GreenTech made in Germany 2.0 in 2009. Small and medium-sized enterprises still constitute the overwhelming majority of environmental technology players and shape the corporate landscape of this industry.

Lead market focus

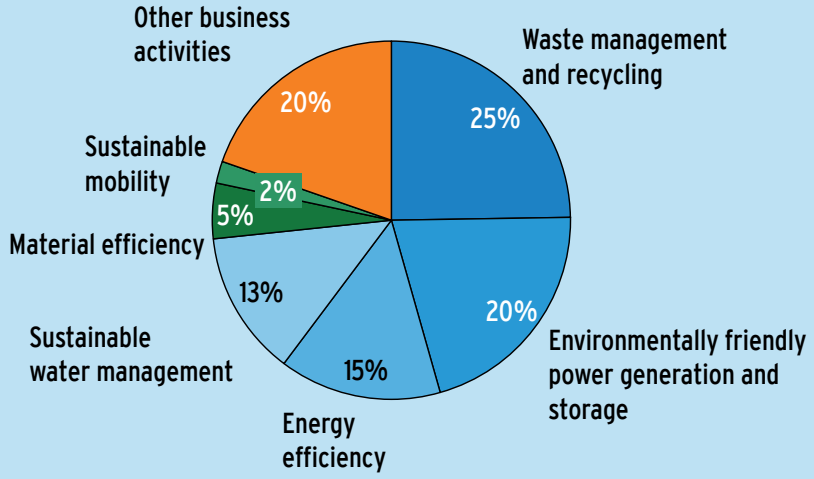
Another perspective on the relative importance of the individual lead markets within the environmental technology industry comes from analyzing the **lead market focus**.[2] The criterion here is each company's core business within green tech. Here, we asked about the lead market in which companies generate the largest share of their revenues (see figure 78). The lead market for **waste management and recycling** scores highest, with a **25 percent share** of all companies focusing on this segment.

Although **13 percent of companies** are found to have their **focus in the lead market for sustainable water management**, this segment constitutes only 8 percent of overall revenues in the environmental technology industry. The reason for the discrepancy lies in the size of companies operating in a market that encompasses large numbers of small and medium-sized enterprises. Of the companies reporting that their lead market focus is on sustainable water management, 91 percent generate annual sales of less than EUR 10 million.

The **lead market for sustainable mobility** is dominated by a few big companies with very high sales volumes. Although only 2 percent of all green tech companies regard this segment as their main business, almost a fifth of this subset (19 percent) have annual sales of more than EUR 50 million.

2 Lead market focus is defined as the lead market that accounts for the largest proportion of a company's sales

Figure 78: Number of companies (percentage of mentions) by lead market focus

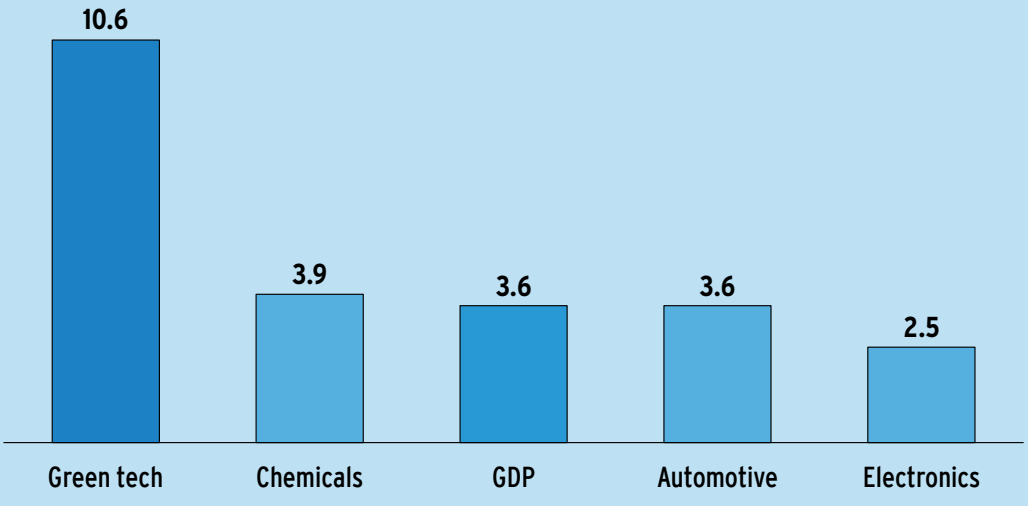


Source: Roland Berger

Growth prospects

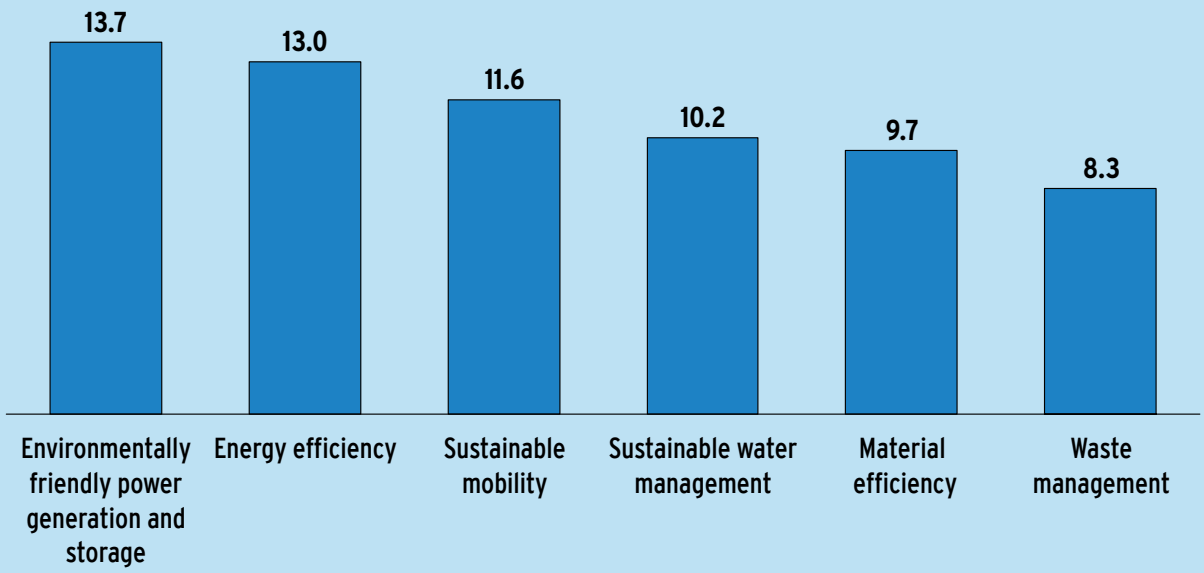
The **structure of the industry and the high proportion of young companies are factors that promise dynamic growth over the medium term. Green tech is expected to grow at an average of 10.6 percent per year over the next five years.** Under this scenario, environmental technology will not only outperform many other industries but also enjoy significantly faster growth than economy as a whole (see figure 79). In Germany, annual growth in GDP is forecast to average 3.6 percent through to 2016, so the **environmental technology industry** can look forward to a **far more dynamic trend**.

Figure 79: Expected annual sales growth of green tech through 2015 compared with other industries and the economy as a whole (average nominal growth of non-green tech industries and GDP in percent)



Source: IHS Global Insight WIS database, Roland Berger

Figure 80: Expected sales growth (percentage per year) until 2015 by lead market focus



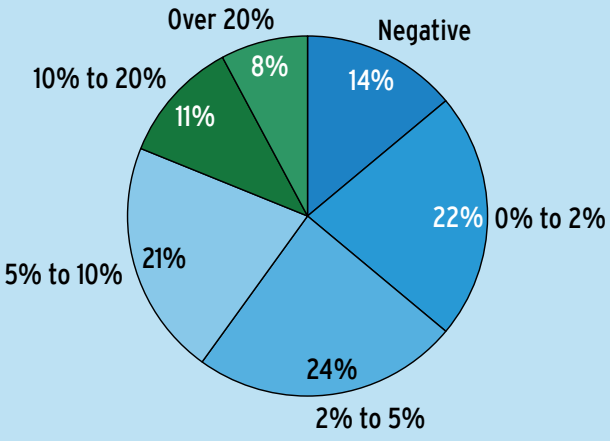
Source: Roland Berger

Breaking down these sales growth expectations by lead market focus, we find that the **companies concentrating on environmentally friendly power generation and storage** express the highest confidence levels when predicting their future sales (see figure 80). Players in this lead market expect annual sales to rise by almost 14 percent. More modest projections characterize firms focused on the lead market for waste management and recycling. On average, companies in this segment expect to see annual sales growing by 8.3 percent.

Reflecting their positive sales projections, companies across the industry are generally confident about future **employment trends**. With **workforces expected to grow on average by 8.4 percent** a year, green tech companies are making a major contribution to job creation in Germany.

The estimates given by companies show that the environmental technology industry has come through the recession triggered by the financial crisis of 2008/2009 largely unscathed. **The great majority of firms (86 percent) succeeded in making an annual net profit in 2010** (see figure 81). Only 14 percent of companies report that they finished the 2010 financial year in the red. Green tech has proven to be extremely crisis-proof.

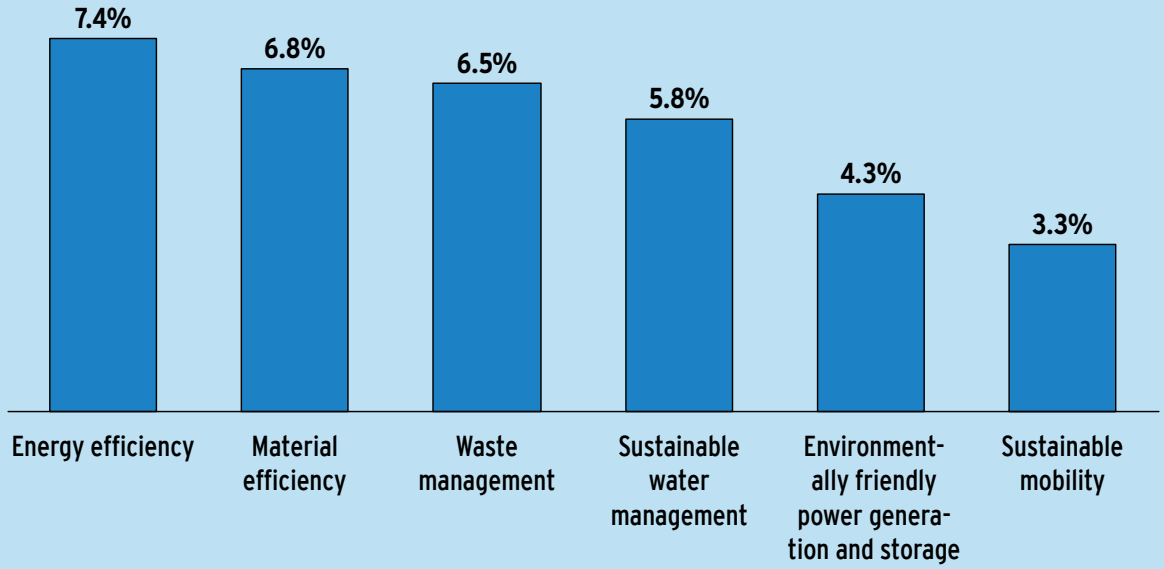
Figure 81: Companies by profitability (percentage of mentions)



Source: Roland Berger

As for profitability, almost one in four companies reports a profit margin [3] of 2 percent to 5 percent (see figure 81), while the **average profit margin for all companies in the environmental technology industry stands at 6 percent. The lead market to emerge as the most profitable is energy efficiency**: 11 percent of companies in this segment earned margins of more than 20 percent. Looking at average company profitability by lead market, we again find that the energy efficiency segment is the front-runner. The firms in this lead market enjoy an average profit margin of 7.4 percent (see figure 82).

Figure 82: Average profitability by lead market focus



Source: Roland Berger

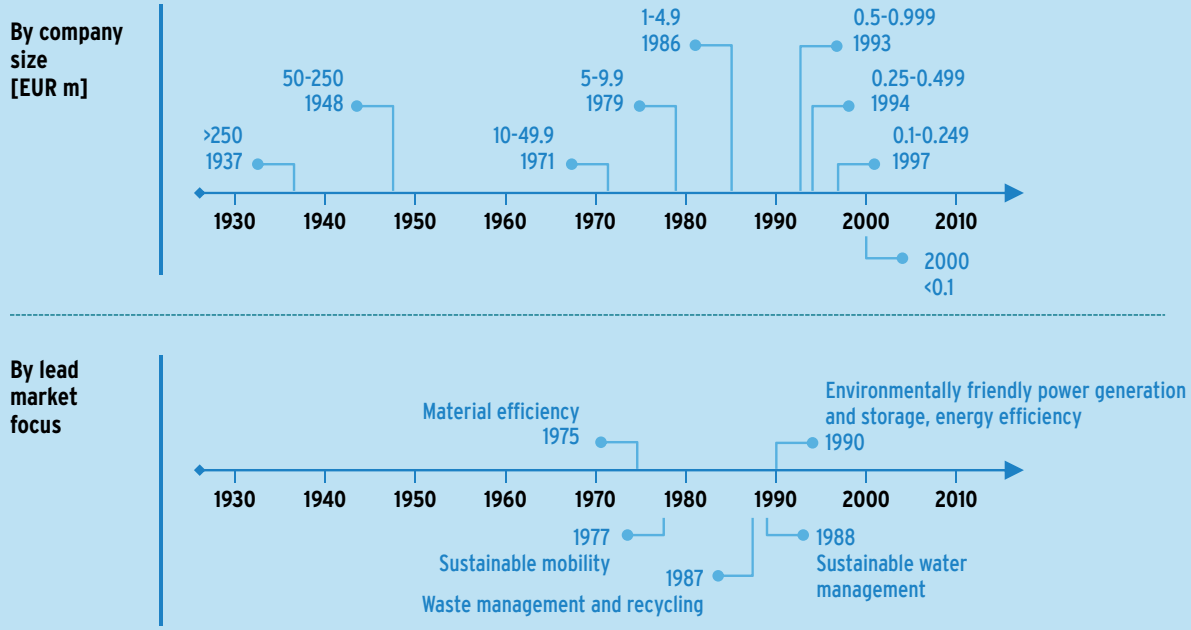
Age structure of green-tech companies

The current analysis also looks at longevity data to see if it backs up the theory that environmental technology is a relatively young industry in terms of the players involved. We further differentiated this data by company size and by lead market focus (see figure 83). The overall picture is that an average company is active on the market for 20 years before it generates annual sales of between EUR 500,000 and EUR 1 million. Moreover, it takes an average of 65 years to reach the sales mark of EUR 50 million per year.

The lead market for energy efficiency displays a particularly high number of small businesses and start-ups (annual sales of less than EUR 100,000), which together constitute a **24 percent share of the segment**. A breakdown of the age data by lead market on which a company focuses tells us which lines of business have gained importance over recent decades. For instance, the average founding date of companies in the lead market for sustainable water management is 1988. This relatively recent date points to the growing importance of water as a resource. In the lead market for environmentally friendly power generation and storage, it is clear from the average company age (around 20 years) that this segment has also become far more relevant in the last few decades.

3 Profitability is measured here by profit as a share of sales

Figure 83: Average age of companies, differentiated by company size and by lead market focus



Source: Roland Berger

Research and development

For all companies across the industry, the average **research and development expenditure relative to sales comes to 2.6 percent. This figure is quite alarming, because there are a considerable number of green tech companies far below the industry average.** In fact, more than a third have a research and development spend of less than one percent.

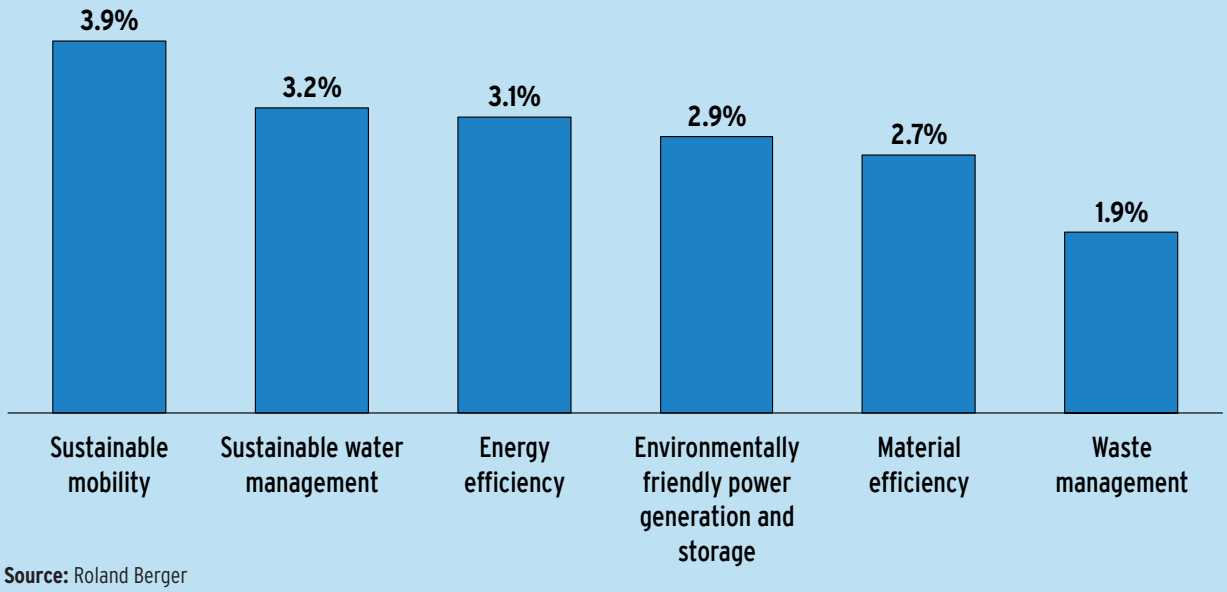
A breakdown of the **research and development spend for individual lead markets** presents a **highly varied picture** (see figure 84). The highest research and development expenditure (3.9 percent) is achieved by companies in the lead market for sustainable mobility. There is a **correlation here between company size and research and development activities**, since it is a segment in which many large-scale producers operate. The lowest research and development spending is found in waste management and recycling with an average of 1.9 percent. The connection between company size and research and development expenditure (percentage of sales) is confirmed for all the lead markets. As a rule, it can be said that the larger the workforce, the higher the research and development outlays. The average research and development expenditure of firms with fewer than 50 employees comes to 2.8 percent. Companies with 50 to 500 employees show an average research and development spending of 2.9 percent, and those with a workforce of more than 500 achieve 3 percent.

To consolidate or improve their strong positioning on international markets, German green tech companies must intensify their research and development efforts. We find a **close relationship between the profitability of companies and their research and development activities**, because profitability creates the financial scope needed for research and development investment. One of the main levers for boosting profit margins is productivity. Our survey of the industry status quo for productivity and the likely development of this parameter shows that higher productivity is high up on the agenda for most green tech companies.

The self-assessments given by companies of the outlook for their sales and workforce allow us to draw conclusions about the expected level of productivity growth in the various lead markets. The difference between sales growth projections and expected workforce growth can be interpreted here as an indicator of productivity. Companies surveyed from

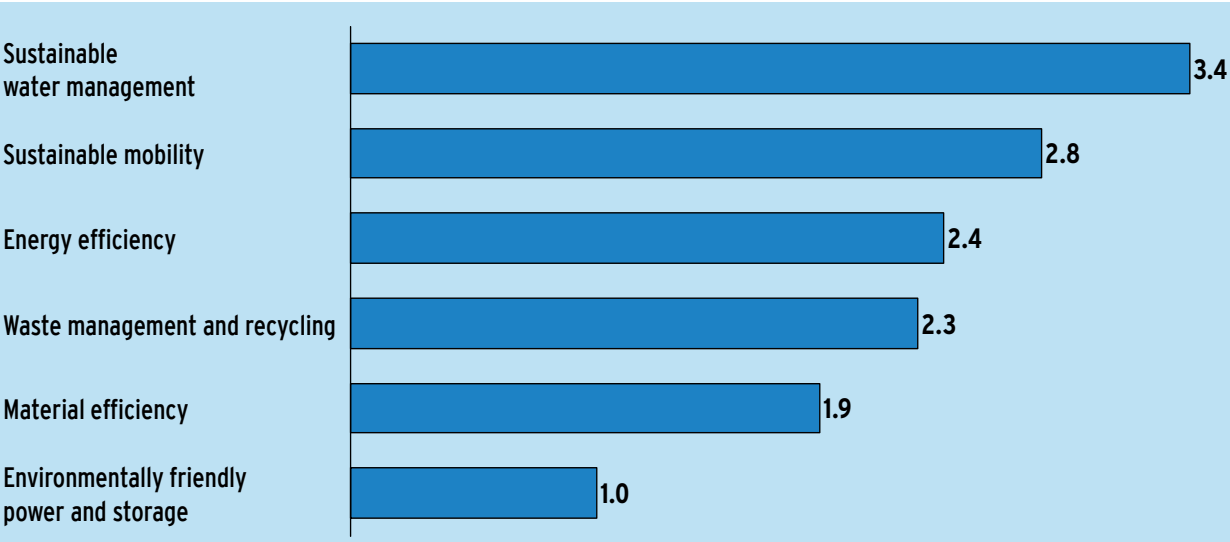
the sustainable water management segment anticipate the highest growth in productivity (3.4 percent) of all the lead markets (see figure 85). The lead market for environmentally friendly power generation and storage is ranked at the opposite end of the expectations scale, with productivity growth calculated at just 1 percent. In principle, we would expect the highest productivity gains to come from technologies in an advanced stage of their lifecycle. If companies are to realize the full growth potential described above, they must drive up productivity levels. This challenge is especially important for those businesses that operate in highly competitive and mature markets. To maintain or improve their competitive position, they must invest to boost productivity.

Figure 84: Average research and development spend (percent of sales) by lead market



Source: Roland Berger

Figure 85: Annual difference between projected sales growth and workforce growth through 2015 by lead market focus (in percentage points)



Source: Roland Berger

Internationalization and regional links

For the domestic green tech industry, Germany remains the most important market for both supplies and sales, although foreign markets are gaining ground. In the coming years, the internationalization of German green tech will continue to increase.

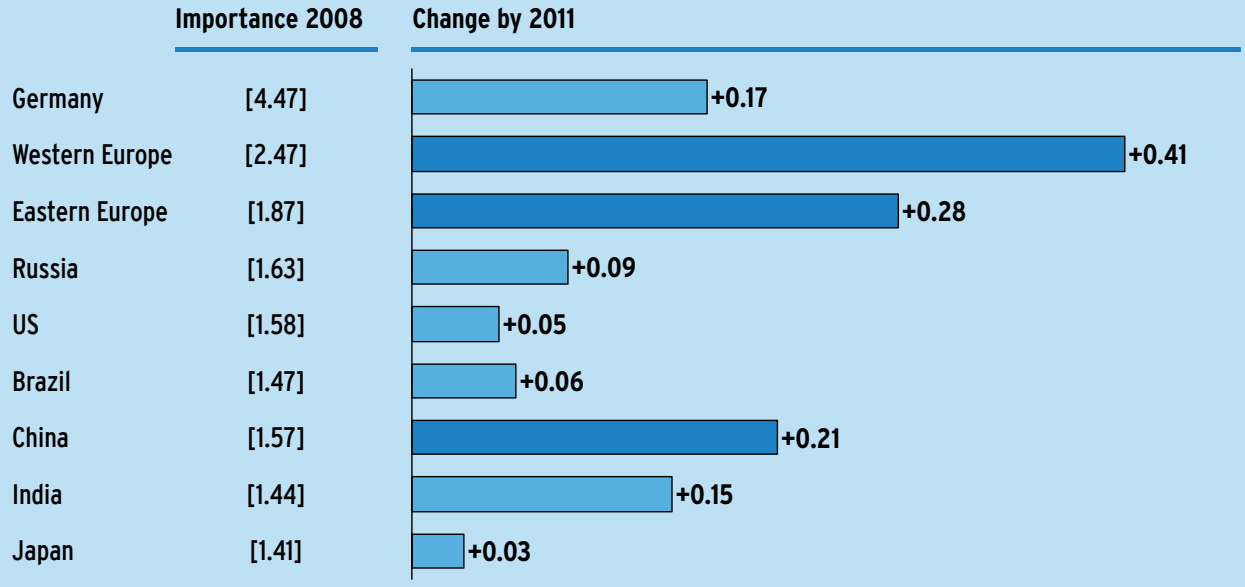
The analysis of the latest company data produces an export rate of around 23 percent. This means that, **on average, the companies generate almost a fourth of their sales abroad**.

Within Germany, we find a **strong regional orientation** among many companies in the sense that a company's "home" state tends to be its biggest sales market. On average, companies generate about 46 percent of their sales in their respective federal state.

Green tech companies were also asked about the importance they attach to various regions as sales markets. The survey shows that **Germany and Europe** are regarded as most relevant to their current business. On a scale from 1 ("least importance") to 5 ("most importance"), Germany is ranked by far the highest (4.64 points), followed by Western Europe (2.88), Eastern Europe (2.15), People's Republic of China (1.78) and Russia (1.72) (see figure 86).

Figure 86 benchmarks the changes against the 2008 survey for the GreenTech Atlas 2.0. Companies now attach greater importance to all the different sales markets. This can be interpreted as a further indicator of the dynamic growth of the environmental technology sector. In terms of increased importance, the latest survey identifies the top three regions as Western Europe, Eastern Europe and China.

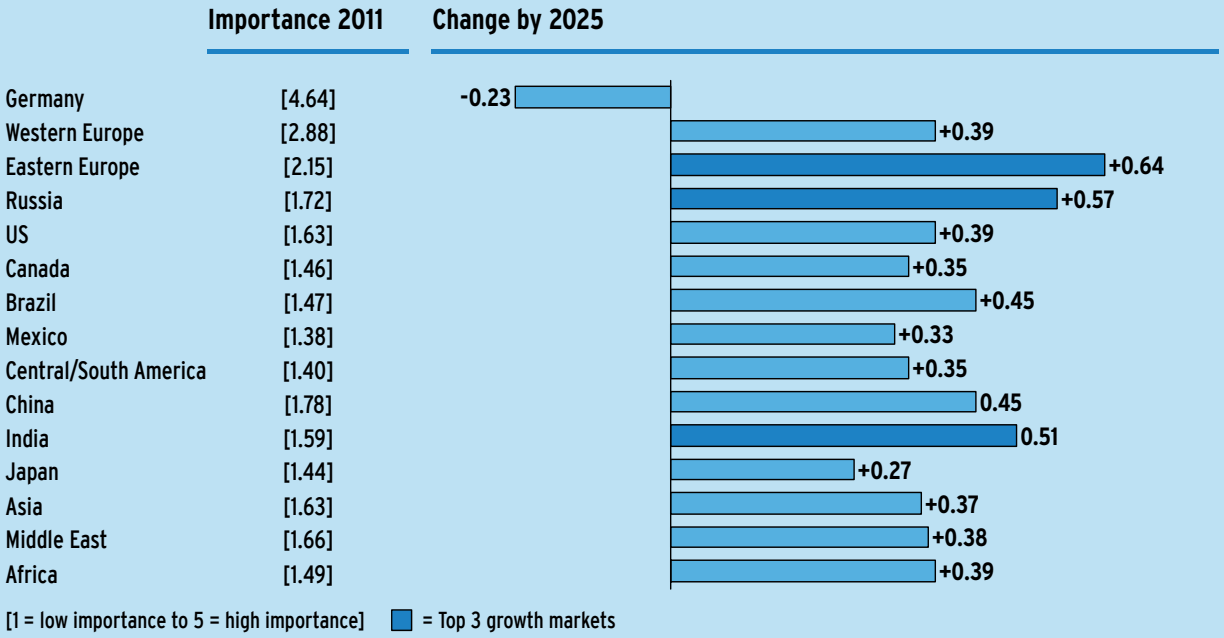
Figure 86: Change in the importance of sales markets domestic/international – Comparing 2008 and 2011



Source: Roland Berger

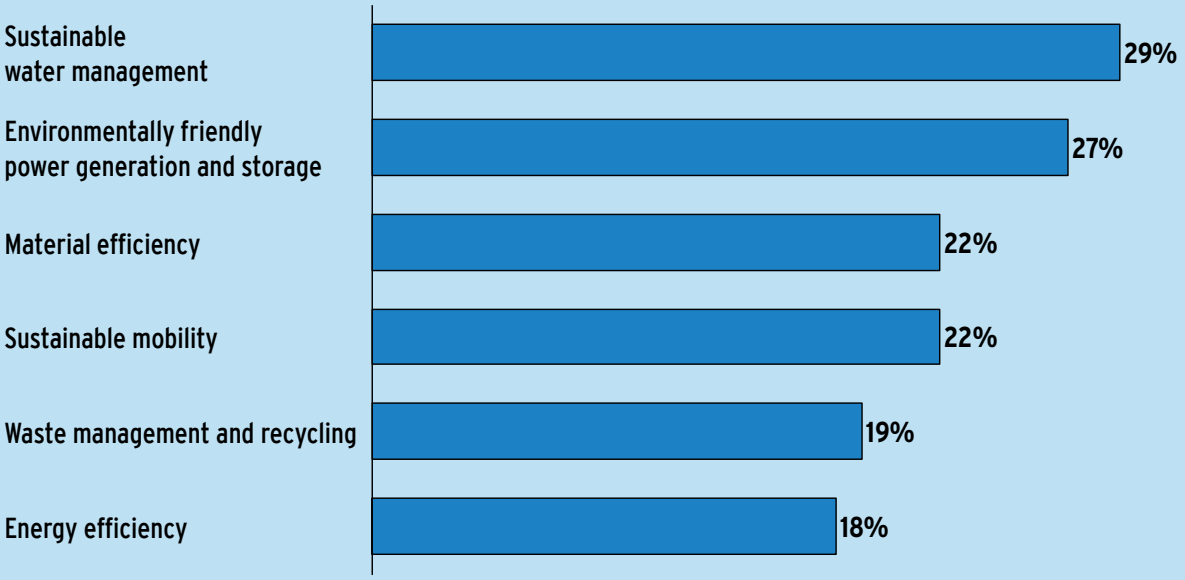
Companies assessed not only the current importance of individual markets, but also their long-term importance. The survey asked for an estimate of likely **relevance in 2025**. Germany is generally expected to lose some of its centrality, but companies recognize that the domestic market will continue to play the key role. **The biggest gains on the status quo are registered for Eastern Europe and the BRIC economies (Brazil, Russia, India and China)** (see figure 87). The players believe that the top five markets for German green tech products and services in 2025 will rank as follows: In first place comes Germany (4.41), followed by Western Europe (3.27), Eastern Europe (2.79), Russia (2.29) and China

Figure 87: Expected change in the importance of domestic/international markets – Comparing 2011 and 2025



Source: Roland Berger

Figure 88: Internationally aligned companies (foreign sales at least 30 percent of total volume) by lead market focus (percentage of mentions)



Source: Roland Berger

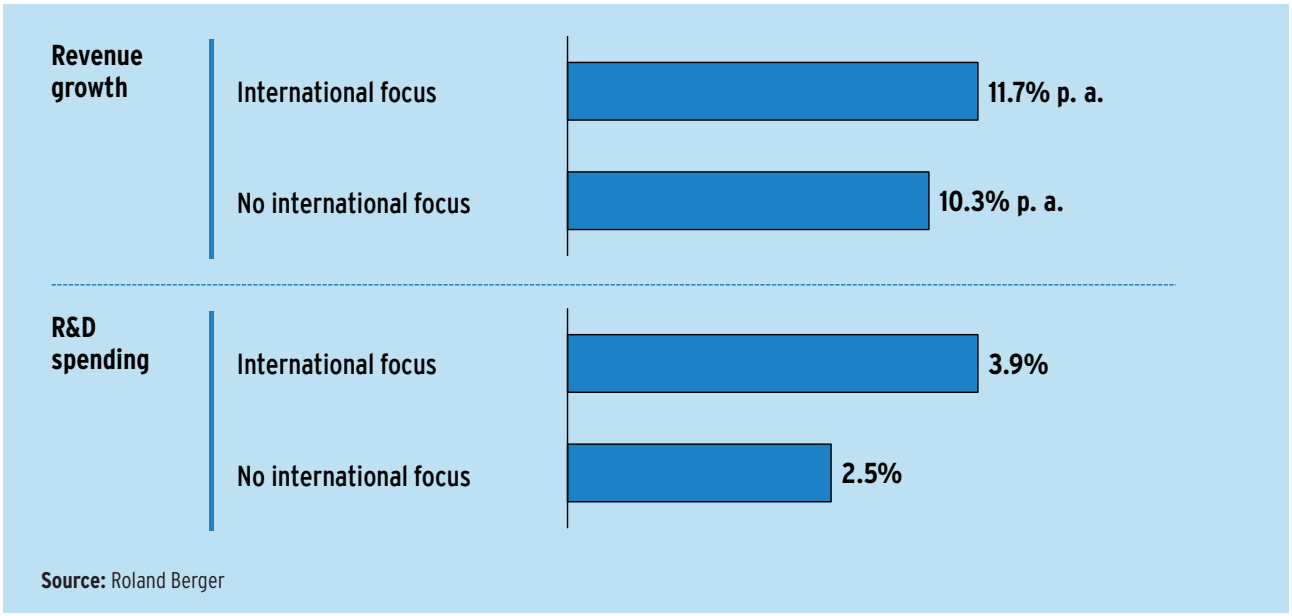
(2.23). The top five most important markets now will be the top five in 2025. The only difference is that China and Russia, currently ranked fourth and fifth respectively, are expected to have swapped places by then.

Looking in detail at the data given by companies on their export activities, we find that the **degree of international alignment differs widely from one lead market to another** (see figure 88). 29 percent of companies in the lead market for sustainable water management and 27 percent in the lead market for environmentally friendly power generation and storage earn over a third of their revenues abroad. By contrast, companies in the lead markets for energy efficiency and for waste management and recycling are still overwhelmingly geared toward sales in Germany. However, a stronger export orientation could prove promising here, too, since these two segments have particularly strong sales potential in the international arena. Globally, the lead market for energy efficiency is forecast to grow at an average annual rate of 3.9 percent until 2025. For waste management and recycling, the figure is 3.2 percent.

The latest analysis again explores the **relationship between a company's foreign commitments, sales expectations and research and development activities.** The survey finds that, on average, companies with a strong international focus (export rate of 30 percent or more) expect to see annual sales expanding by almost 12 percent until 2015. Their growth projections hardly differ from the expectations of companies with a domestic focus. The latter group predicts annual growth of approx. 10 percent (see figure 89).

In the research and development field, however, we find a **stronger discrepancy between the "global players" and the domestically focused businesses**. Companies with an export rate exceeding 30 percent have average research and development spending of 3.9 percent (2010), while companies without an international focus average 2.5 percent. The gap is due to the fact that it is the larger companies that generally operate on foreign markets, and the scale of research and development activities usually increases with company size. Conversely, this correlation offers an explanation for the lower research and development spending apparent among companies geared toward the domestic market (see figure 89).

Figure 89: Average research and development spending (as percentage of sales) in 2010 and expected annual sales growth until 2015 – Comparing companies with an international (export rate over 30 percent) and a domestic focus



Source: Roland Berger

Service portfolio along the value chain

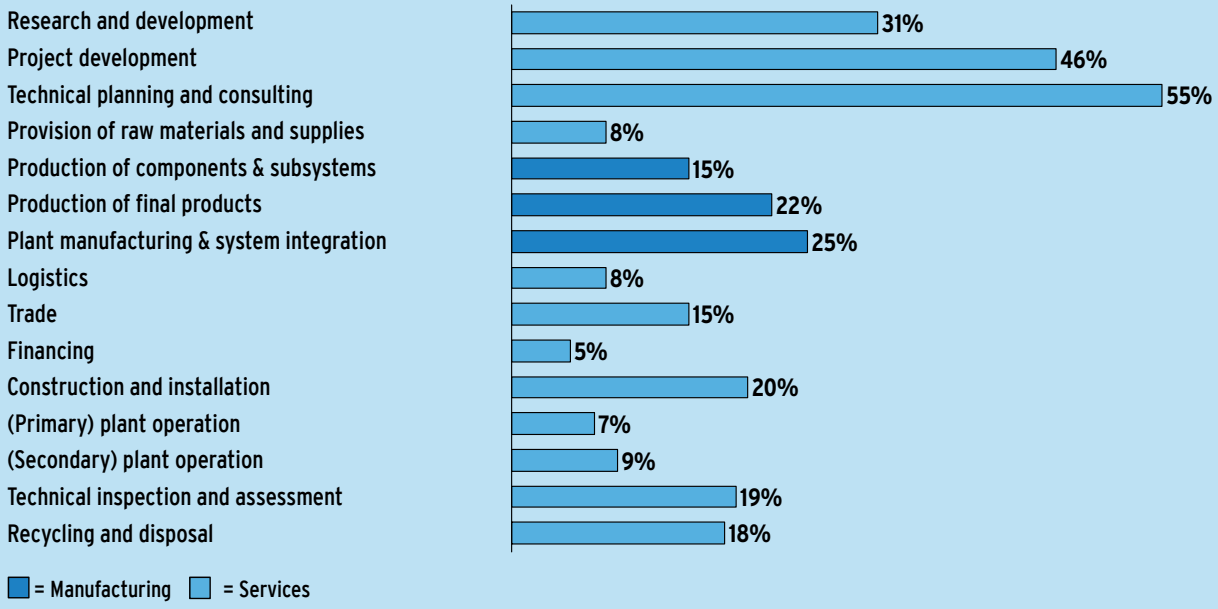
The findings of the latest survey clearly show that the **German companies provide services for every link in the value chain**. The dominant categories among these services are technical planning and consultancy, project development and research and development (see figure 90).

Almost all green tech companies offer services. The proportion of manufacturing companies stands at 40 percent. Over half (55 percent) of companies offer technical planning and consultancy as part of their portfolio. This high proportion reflects the large number of engineering and consulting offices operating throughout the environmental technology industry. One third of all enterprises supply the market with services in research and development. A breakdown of company offerings highlights the importance of research and development as well as planning and development processes for German green tech. Companies are particularly well positioned for these first links in the value chain. The analysis of the **service profile** confirms that environmental technology in Germany displays the **typical features of a knowledge-intensive and technology-driven industry**. This profile has proved to be a considerable strength, giving Germany a competitive edge over foreign markets.

The company data was also analyzed to determine the **core business activities** within the various **lead markets**. The next sections look in detail at the various technology lines pursued by the respondent companies in each market.

In the lead market for **environmentally friendly power generation and storage** (see figure 91), biomass exploitation represents a large proportion of the top five technology lines, accounting for 30 percent [4] of all companies active in this segment. As a technology with applications all along the value chain, biomass exploitation covers many different activities, including the production of biogas as an energy source and reserve, biomass as a fuel, biomass for heating, such as in the form of pellets, or biomass as a

Figure 90: Portfolio of services along the value chain (percentage of mentions)



Source: Roland Berger

4 The percentage values give the proportions of mentions of individual technologies relative to all the companies surveyed

resource for electricity generation in biomass cogeneration plants. The technology lines mentioned most frequently in the survey cover a broad spectrum of energy generation methods. But surprisingly, energy storage seems to play a very small part in the activities carried out within this lead market.

In the lead market for **energy efficiency, activities are largely focused on the building sector**. Of all companies surveyed, 21 percent classify their products and solutions in the technology line heating/air-conditioning/ventilation (see figure 91). By contrast, the technology lines concerned with energy efficiency in machines and equipment receive only a small proportion of mentions.

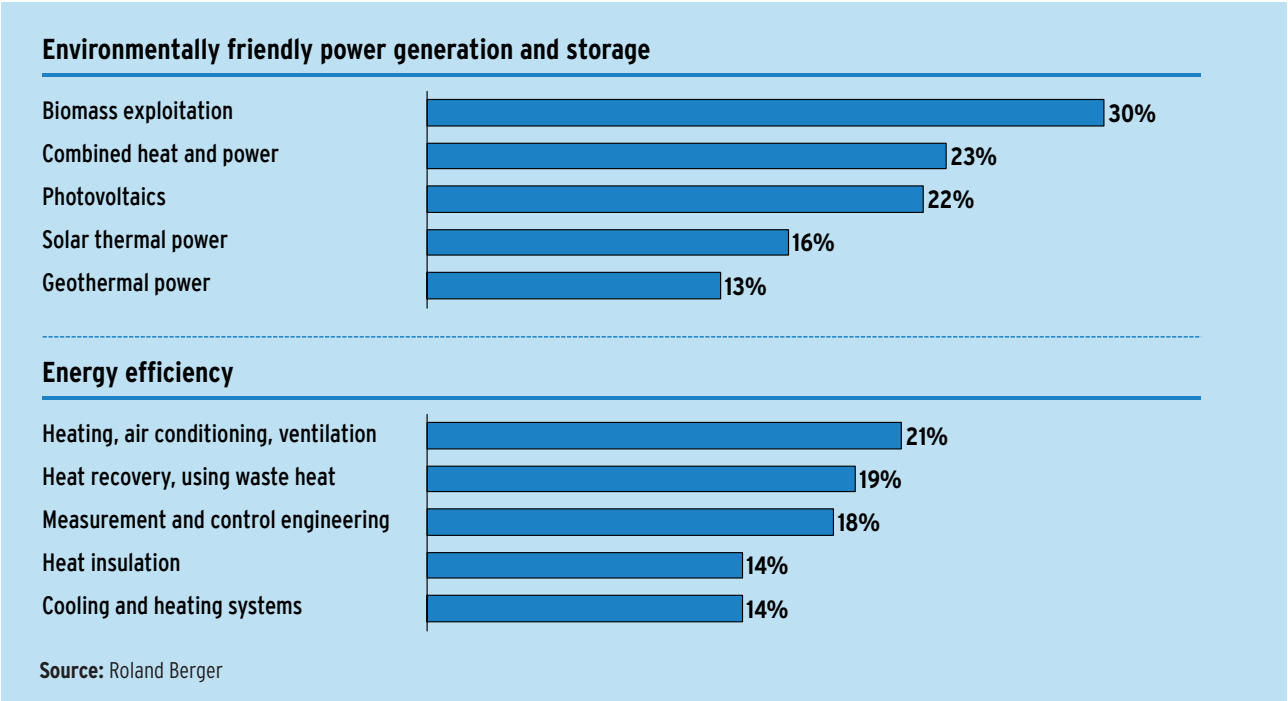
In the lead market for **material efficiency**, we find a particularly strong emphasis on **efficient manufacturing methods**. The most frequently named technology line in this connection is measurement and control engineering (see figure 92). By contrast, this lead market displays only a weak presence of technologies designed to achieve savings by improving tribological properties (1.5 percent) and technologies for producing paints and lacquers from renewable resources (1.9 percent).

The **top five technology lines in the lead market for waste management and recycling** represent a wide range. All of the lead market technologies are strongly represented here, with waste separation (18 percent) scoring highest (see figure 92). The technology line least represented in this lead market is scrap vehicle recycling (4.1 percent).

The lead market for **sustainable water management** displays a **fairly equal distribution of strongly represented technology lines**. Water treatment (15 percent) ranks highest in the top five technology lines, followed by centralized wastewater treatment (14 percent) (see figure 93). Little mention is made of technology lines concerning water efficiency for hydropower plants (4.1 percent) and household uses (5.1 percent).

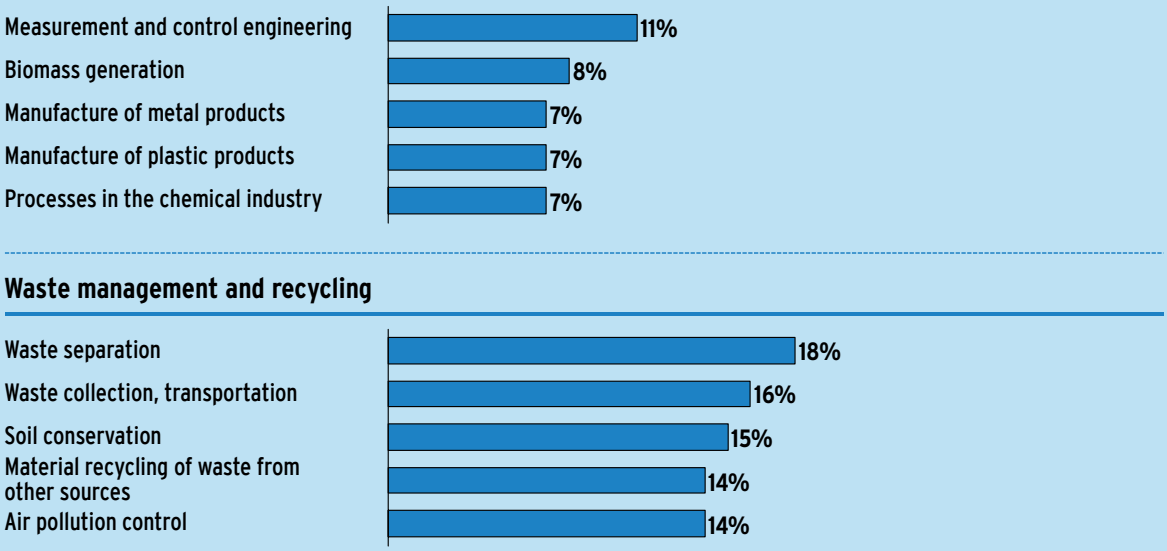
In the lead market for **sustainable mobility**, we again find a **fairly equal spread of the top five technology lines** (see figure 93). The technology lines with the fewest mentions in this segment are energy-saving tires (1 percent) and car sharing (1 percent).

Figure 91: Top five technology lines in the lead markets for environmentally friendly power generation and storage and for energy efficiency (percentage of mentions; based on all survey participants from all lead markets)



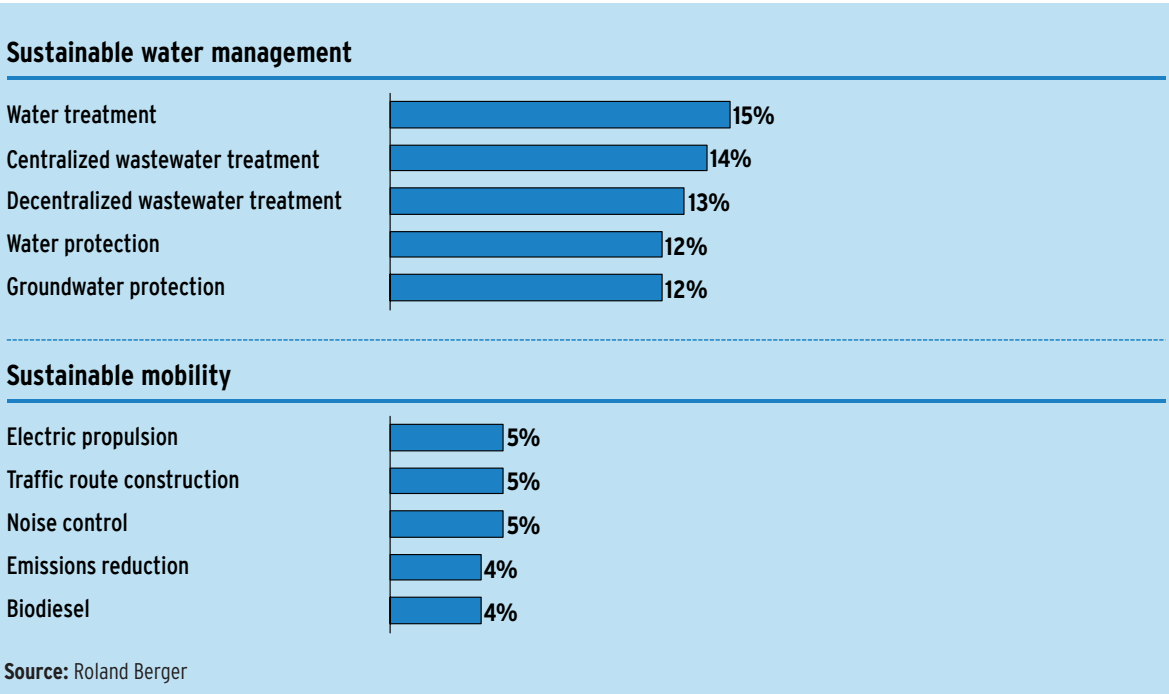
Source: Roland Berger

Figure 92: Top five technology lines in the lead markets for material efficiency and for waste management and recycling (percentage of mentions; based on all survey participants from all lead markets)



Source: Roland Berger

Figure 93: Top five technology lines in the lead markets for sustainable water management and for sustainable mobility (percentage of mentions; based on all survey participants from all lead markets)



Source: Roland Berger

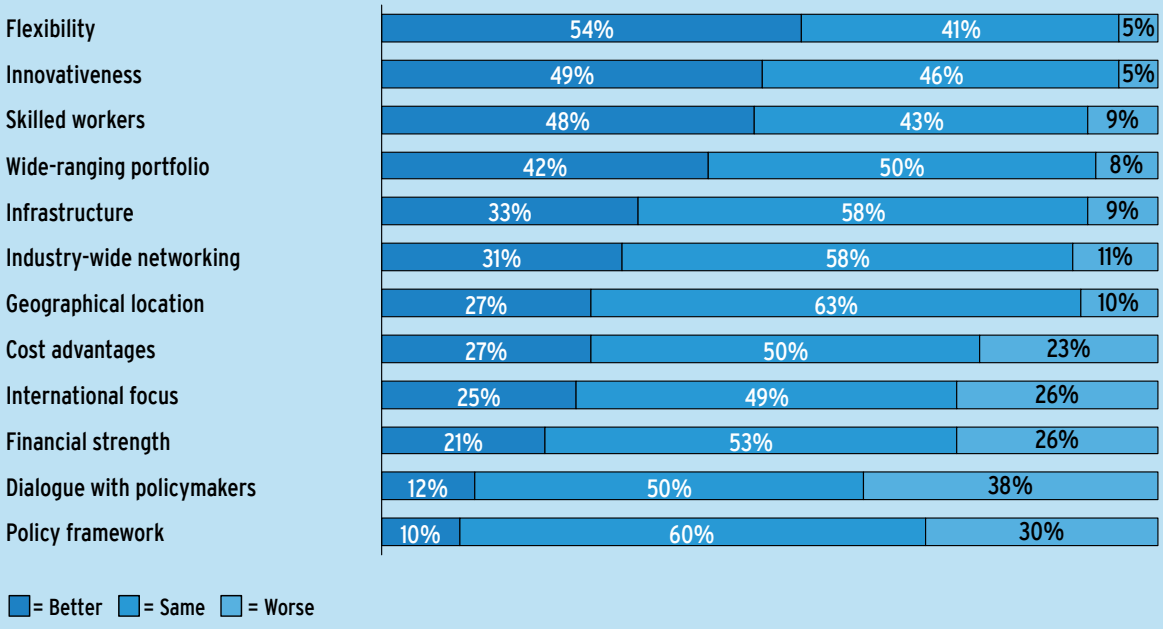
Assessment of competitive position and location factors

The current survey also considers how companies view their own **positioning**. They were asked to **compare themselves with their domestic and foreign peers in terms of a given list of location factors**. To rate each factor relative to competitors, companies could choose from three options: "better", "same" or "worse".

Green tech businesses identify their **strengths** above all in **innovativeness and flexibility as location factors** (see figure 94). The analysis of the survey data also makes it clear that companies see a need for improvement in the factors of policy framework and dialog with policymakers in order to become more competitive.

Company **assessments of their location factors vary markedly from one lead market to another**. One example is the way businesses rate their positioning in terms of cost advantages. Companies in the lead market for energy efficiency, which encompasses a particularly large number of small and medium-sized enterprises, regard themselves as "better" than their competitors on cost. By contrast, companies in the lead market for sustainable mobility, which are generally large-scale, tend to rate their cost position as "worse". The opposite pattern emerges when companies are asked about international alignment and financial strength. On these location factors, it is the large companies that tend to see their competitive position as "better", while small businesses believe they are "worse" than their peers.

Figure 94: Positioning on location factors relative to domestic and international peers – Company self-assessments



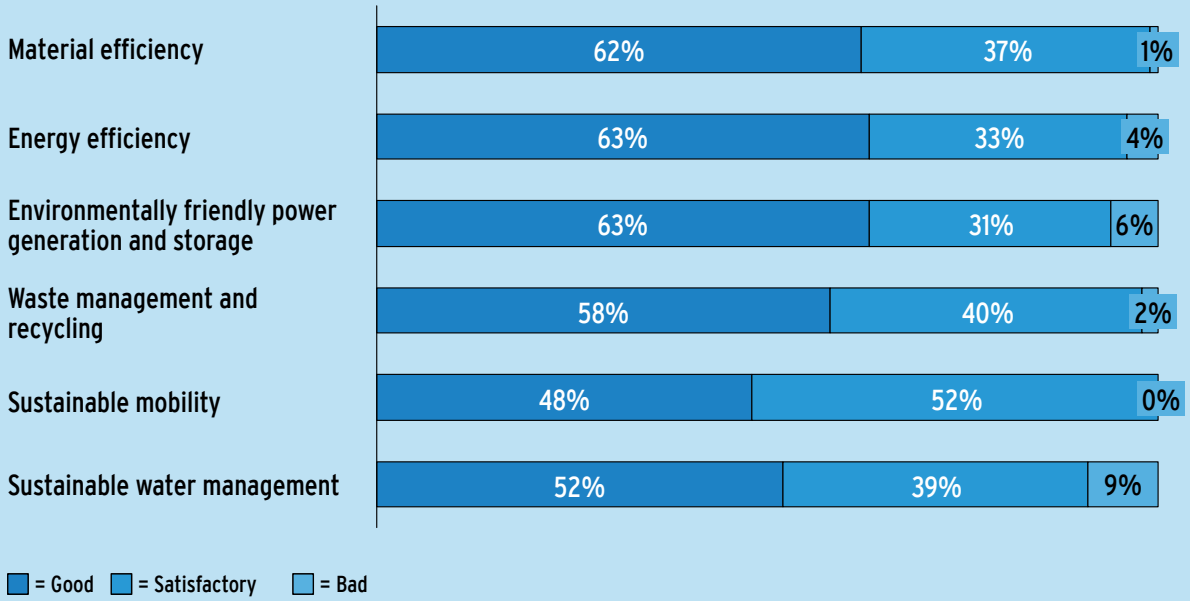
Source: Roland Berger

Current business situation and future prospects

Having come through the worst of the financial crisis and recession of 2008/2009, the **great majority of companies are generally satisfied with business developments in the environmental technology industry. Almost two thirds (59 percent) of companies rate their current business situation as "good"**, 37 percent as "satisfactory" and only 4 percent as "bad" (see figure 95). The mood is best among those companies active in two lead markets: environmentally friendly energy production and energy storage, and energy efficiency. They reported the highest level of satisfaction with current trends. A pattern found across all the lead markets is that larger companies tend to regard their business situation more positively than small companies.

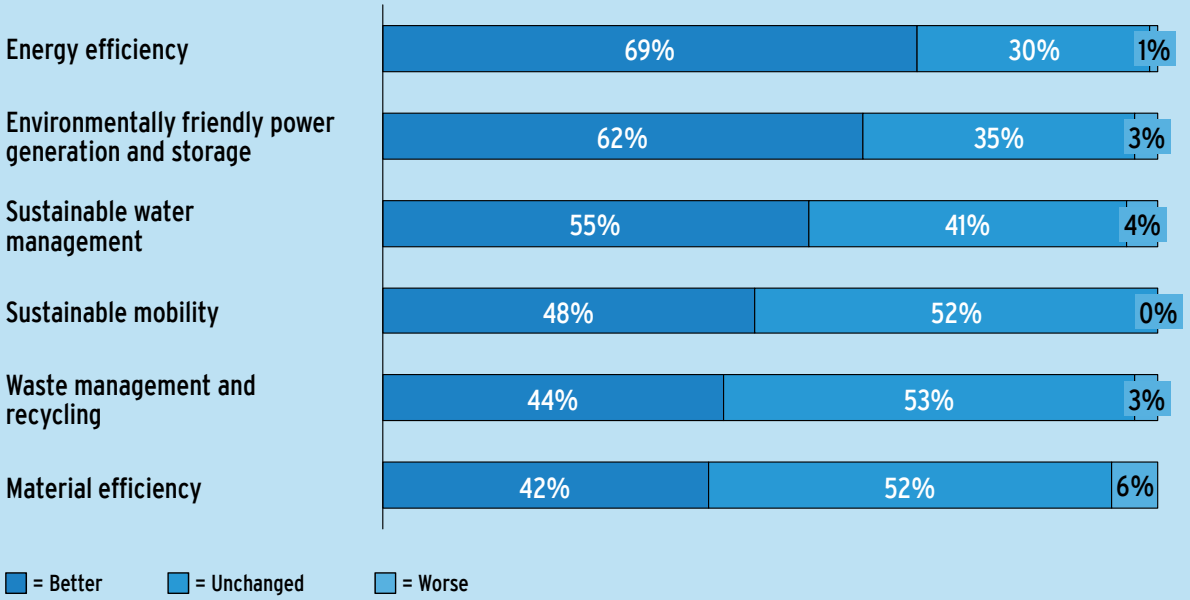
Most green tech companies are optimistic about their economic future. Over half (56 percent) rate their business expectations for 2012 as "better" and 41 percent as "unchanged". Only a tiny proportion (3 percent) expect business to be worse. The lead markets for energy efficiency and for environmentally friendly power generation and storage demonstrate the greatest confidence. This emerges from a breakdown of the overall business mood by lead market (see figure 96). Two thirds of the players in each of these two lead markets believe that business will improve. In analyzing business expectations, we find a **correlation between optimism and company size**. Among the companies

Figure 95: Self-assessment of current business situation by lead market



Source: Roland Berger

Figure 96: Breakdown of business expectations by lead market



Source: Roland Berger

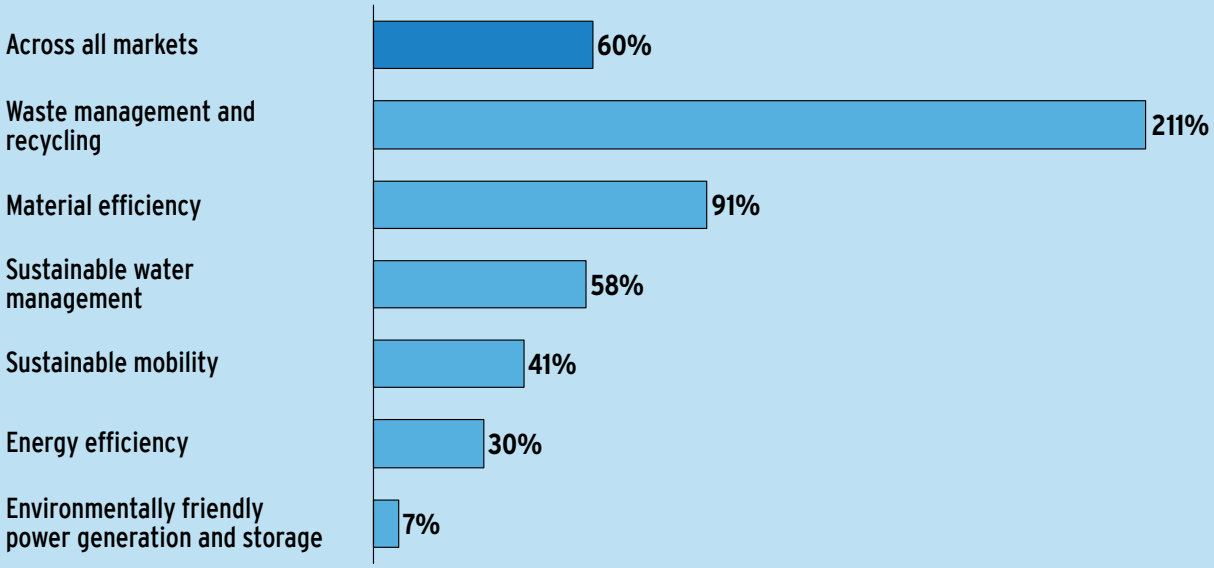
generating annual sales of more than EUR 50 million, 71 percent expect "better" business opportunities going forward, while this optimism is shared by only 55 percent of smaller companies (annual sales of less than EUR 10 million).

To gauge the mood among the green tech players, we compiled a **business climate index** as part of the industry survey. Calculated from data for the respective year, the index is produced by combining two categories: business climate ("assessment of the current business situation") and business expectations. The industry-wide index goes from 0 to 100. The maximum would indicate that every company in the industry rates both its current business situation and its future business outlook as "good". The business climate index, as calculated for all the lead markets, stands at 33.5 for 2008 and 53.6 for 2011. Business climate indices are also calculated in the same manner for the individual lead markets.

The change in the business climate index is an indicator of how strongly the environmental technology industry has emerged from the financial crisis and recession of 2008/2009. In fact, the **business climate index underwent an absolute rise of 60 percent from 2008 to 2011** (see figure 97). Looking at how this index improvement breaks down in the various lead markets, we find that the waste management and recycling segment has done best of all. The absolute rise of 211 percent recorded here is well above average, reflecting the upturn in recycling due to price gains in raw material markets. When commodity prices collapsed with the onset of the economic crisis toward the end of 2008, a period of dampened prices seriously squeezed profit margins in the recycling sector. A return to high commodity prices ushered in by economic recovery has brightened the outlook in waste management and recycling. The lowest improvement in the business climate index is found in the lead market for environmentally friendly power generation and storage (an absolute rise of 7 percent).

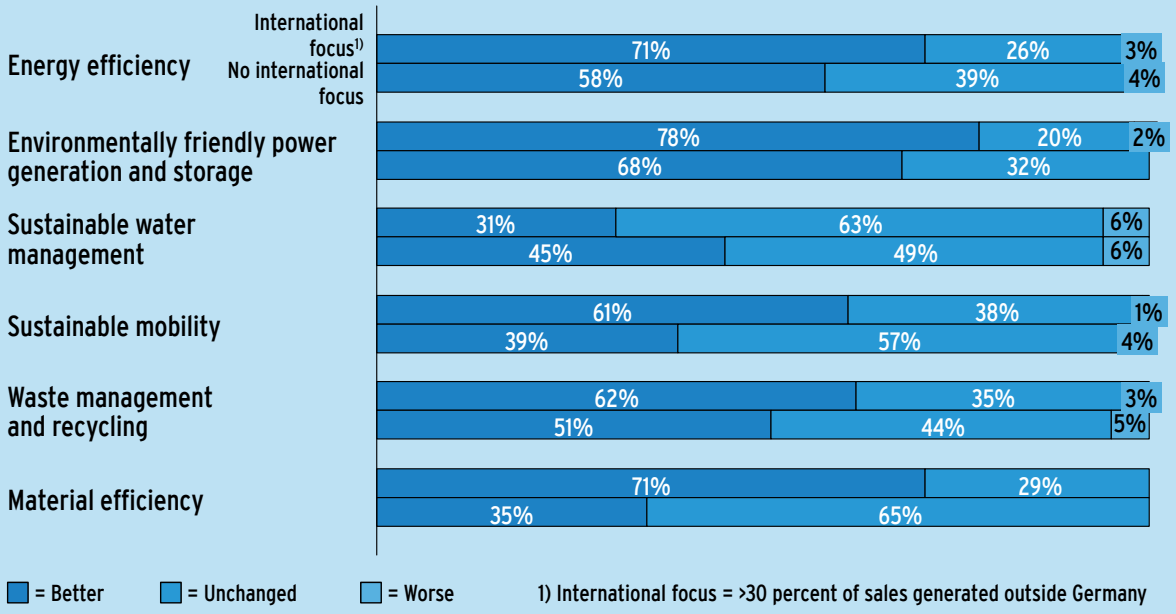
The current analysis confirms the **connection between a company's international focus and its assessment of future business prospects** (see figure 98) already established in the first two editions of the GreenTech Atlas (2006 and 2008). Companies that generate more than a third of their sales outside Germany tend to have more positive business expectations than companies largely focused on their domestic market. The greater optimism shown by players with an international focus is presumably rooted in their knowledge of the considerable market opportunities for green tech "made in Germany" worldwide and in their determination to use this potential to build their business.

Figure 97: Changes in the business climate index between 2008 and 2011



Source: Roland Berger

Figure 98: Business expectations by lead market and international focus



Source: Roland Berger

The state-level perspective

Whereas the sections above deal with the environmental technology industry in Germany as a whole, we now take a more detailed look by exploring regional differences. Here we analyzed **environmental technology and resource efficiency at the level of individual federal states**. This level of description focuses on three themes in particular: internationalization and regionalism, technology focuses, and company self-assessment of location factors.

Internationalization and regionalism

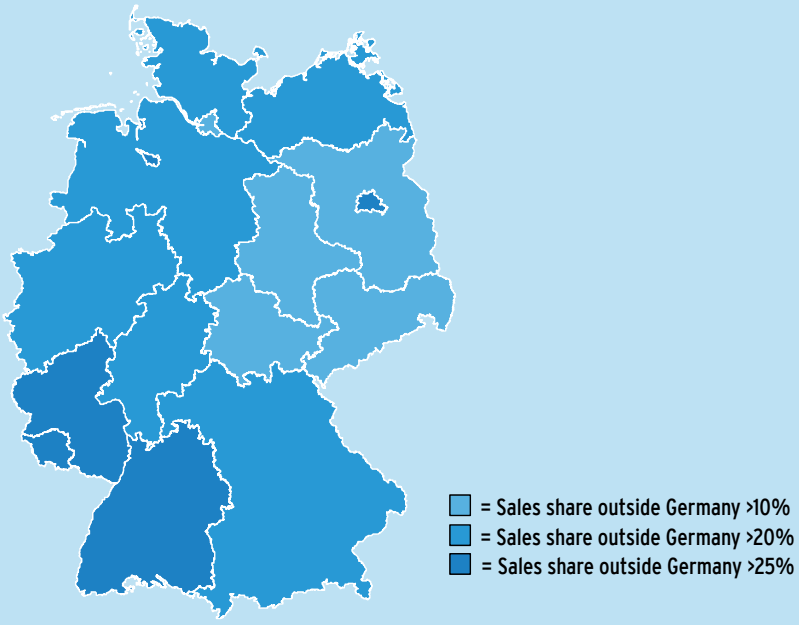
The global markets for products and services in the field of environmental technology and resource efficiency will expand both in the medium and long term. For suppliers from Germany, many of whom are considered technology leaders in their market segments, this means good opportunities to participate in burgeoning international markets and to use this trend to grow their businesses. It is in this context that we should see how the **business activities are geographically aligned in the individual federal states**.

On the level of Germany as a whole, environmental technology companies generate on average almost 23 percent of their sales abroad. This average export rate is not weighted by company sales. The map in figure 99 shows average export rates for all the green tech companies based in a particular federal state. The state averages are displayed in three categories: export rate higher than 10 percent, export rate higher than 20 percent, and export rate higher than 25 percent.

The survey added detail to the company profiles in the database by asking respondents about the importance they attach to individual sales markets. Our analysis shows that **China has a strong presence in almost all of Germany's federal states**. Apart from a few exceptions, the industry in every federal state places the People's Republic of China in the top three target markets for green tech exports. The other two main destinations are given as the Russian Federation and the countries of the Middle East. The map in figure 100 clearly shows how they are prioritized in most federal states as markets for environmental technology and resource efficiency. Japan is conspicuously absent as a sales market.

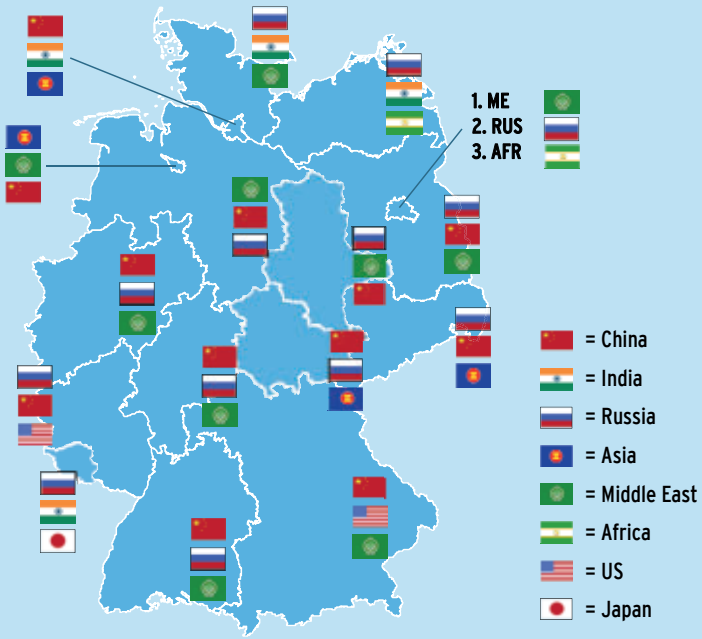
In general, we find that environmental technology and resource efficiency is an industry with a strong regional orientation within Germany. Calculated as a Germany-wide average, green tech companies generate 46 percent of their revenues within their own federal state. Figure 101 shows the share of sales generated by companies within their "home state".

Figure 99: Average export rate (not weighted by company sales) by federal state



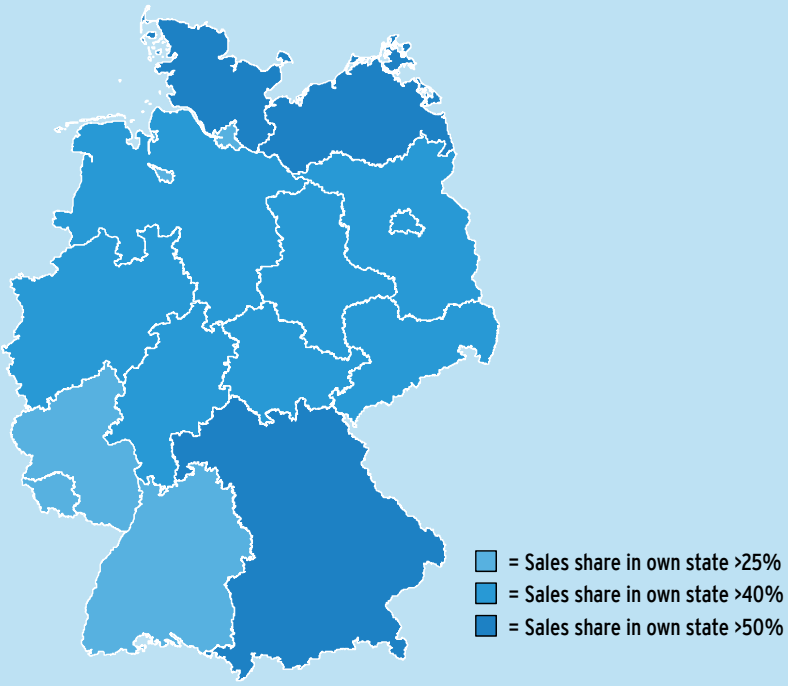
Source: Roland Berger

Figure 100: Top three markets outside Europe from a company perspective



Source: Roland Berger

Figure 101: Sales generated by a company in its „home" state (average share of total sales)



Source: Roland Berger

The map of Germany classifies states in three groups: In Category 1, the locally based environmental technology companies generate more than a quarter of their total sales in their own state; in category 2, this average share exceeds 40 percent; and in category 3, it is above 50 percent.

Focuses of technology in the federal states

In terms of the main **specializations within the market for environmental technology and resource efficiency, the picture varies greatly from one federal state to another**. This finding is hardly surprising. An industry that typically has close links with many other sectors, green tech has built many fields on foundations previously laid by "traditional" industries. And, in Germany, these industrial foundations are highly differentiated, with each region having its own specific profile. In addition, there are various natural factors that shape the development of green tech in individual states. For instance, the centers of wind power generation obviously first developed in the coastal states of northern Germany. The following overview shows which technology lines were most frequently named by companies in each federal state when asked about the focus of their activities. The concept of "technology lines" covers products, methods and services. Figures 102a and 102b show the top 3 technology lines based on frequency of mentions (not weighted by company sales). A symbol behind each technology line indicates the lead market to which it belongs.

The survey confirms that **the dominant technology lines in each federal state reflect the regional features of the environmental technology industry**, such as wind power in Bremen or photovoltaics in Berlin. A common characteristic that emerges here for states right across Germany is the strong presence of technology lines in the lead market for environmentally friendly power generation and storage. The technologies in this field occur most frequently in company portfolios. The only exceptions to this Germany-wide tendency are Mecklenburg-West Pomerania and Saxony-Anhalt. In Mecklenburg-West Pomerania, the most common technology lines are water conservation and water treatment from the lead market for sustainable water management, followed by soil conservation from the lead market for waste management and recycling. In Saxony-Anhalt, the top two technology lines are waste separation and energy recovery from waste, from the lead market for waste management and recycling. Looking at trends in the technology lines offered by companies, the survey points to the growing importance of biomass exploitation as well as cogeneration plants (CHP) in every state.

Weighting of location factors

As part of the survey of the environmental technology and resource efficiency industry, companies were asked **about their strengths with regard to twelve location factors** (see figure 94). The question read: "How strongly do you rate your company on the following location factors in environmental technology and resource efficiency compared to your competitors (domestic and international)?" The possible answers for each factor were "better", "same", "worse". In other words, assessments were made relative to competitors.

The findings show that companies across Germany perceive innovativeness and flexibility as particularly positive location factors. They see themselves lagging behind their competitors with regard to policy framework and dialog with policymakers. On these two points, a majority of respondents believe they are in a "worse" position. In terms of cost advantages, assessments differ markedly among the various lead markets and among companies of different sizes. Smaller companies in the lead market for energy efficiency rate their position on costs as "better" than their competitors. At the other end of the spectrum, large-scale companies in the lead market for sustainable mobility believe they are generally "worse" placed on costs. Company size also correlates with the divergence observed for international alignment and financial strength. For both location factors, large-scale corporations tend to regard themselves as "better" than competitors, whereas small and medium-sized enterprises generally see themselves as "worse".

We have already seen in figure 94 how companies Germany-wide assess location factors. To gain a more detailed picture, the statistical breakdown by federal state included an analysis of possible **differences from state to state in how the companies weight location factors**. The results show that **self-assessments are very homogenous across all the states**. Across the country, there are three location factors on which companies regard themselves "better" placed than their competitors at home and abroad: innovativeness, flexibility and skilled workers (see figures 103a and 103b).

Figure 102a: Top three technology lines (by frequency of mentions) and their respective lead market by federal state

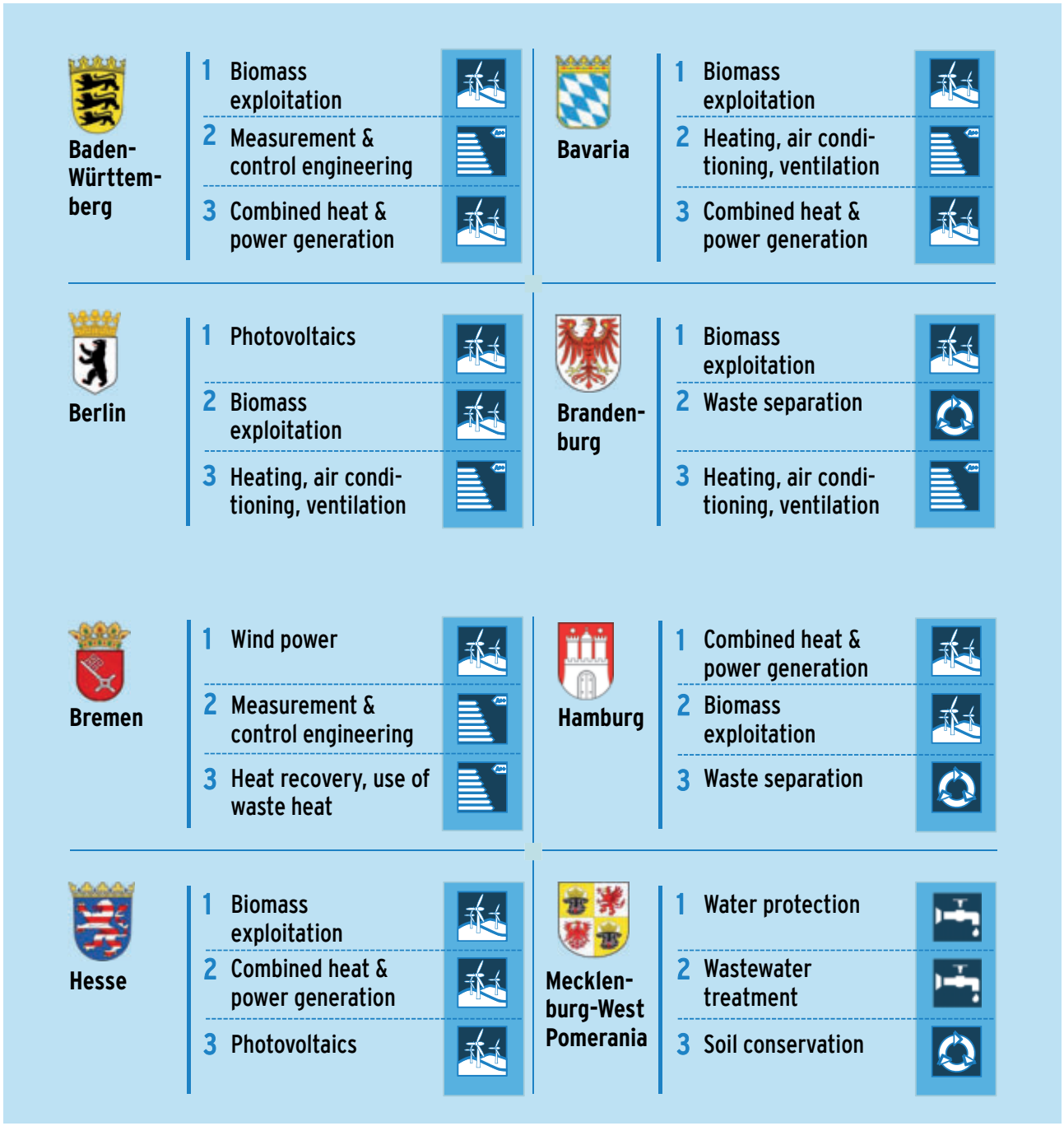


Figure 102b: Top three technology lines (by frequency of mentions) and their respective lead market by federal state

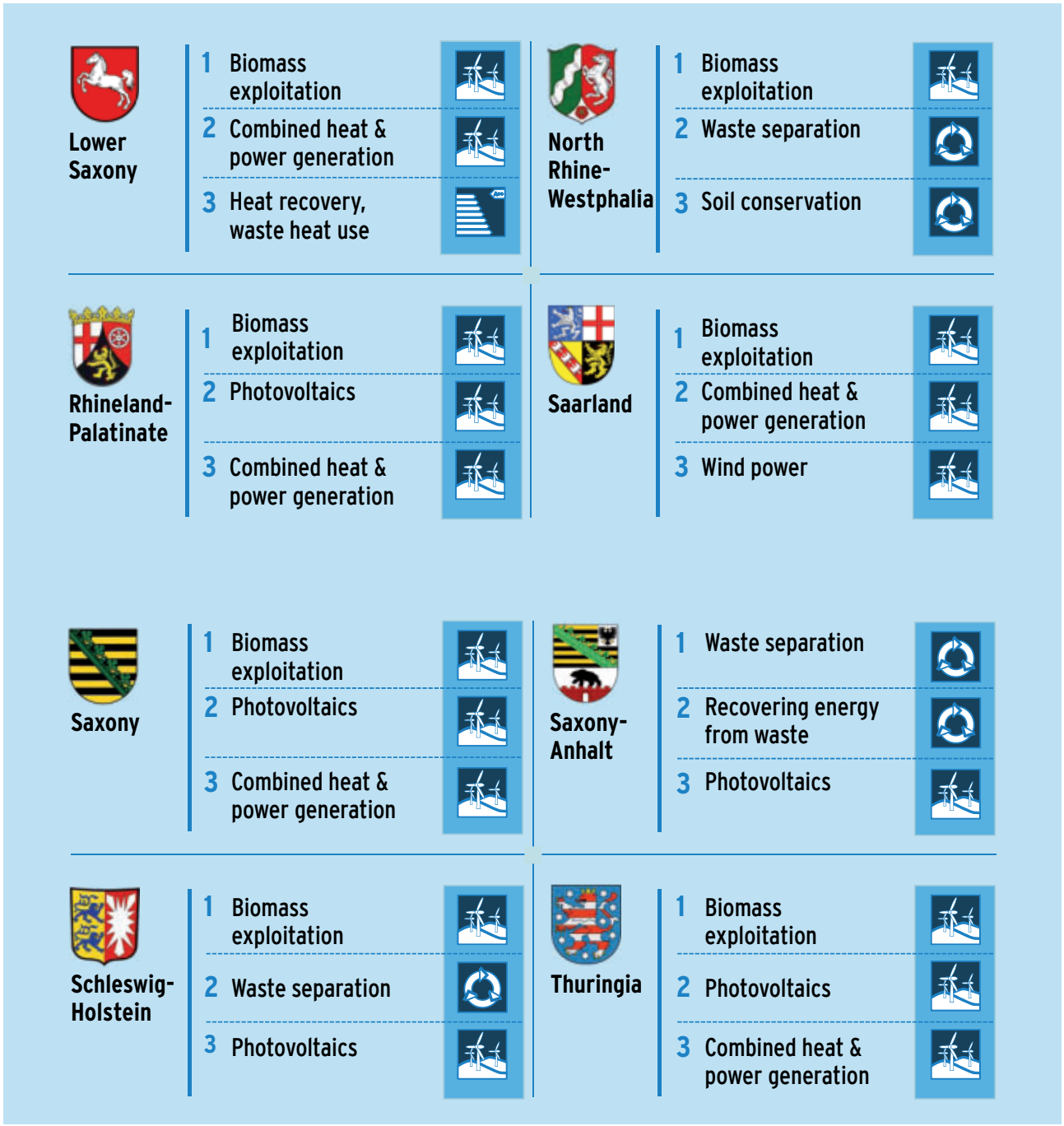
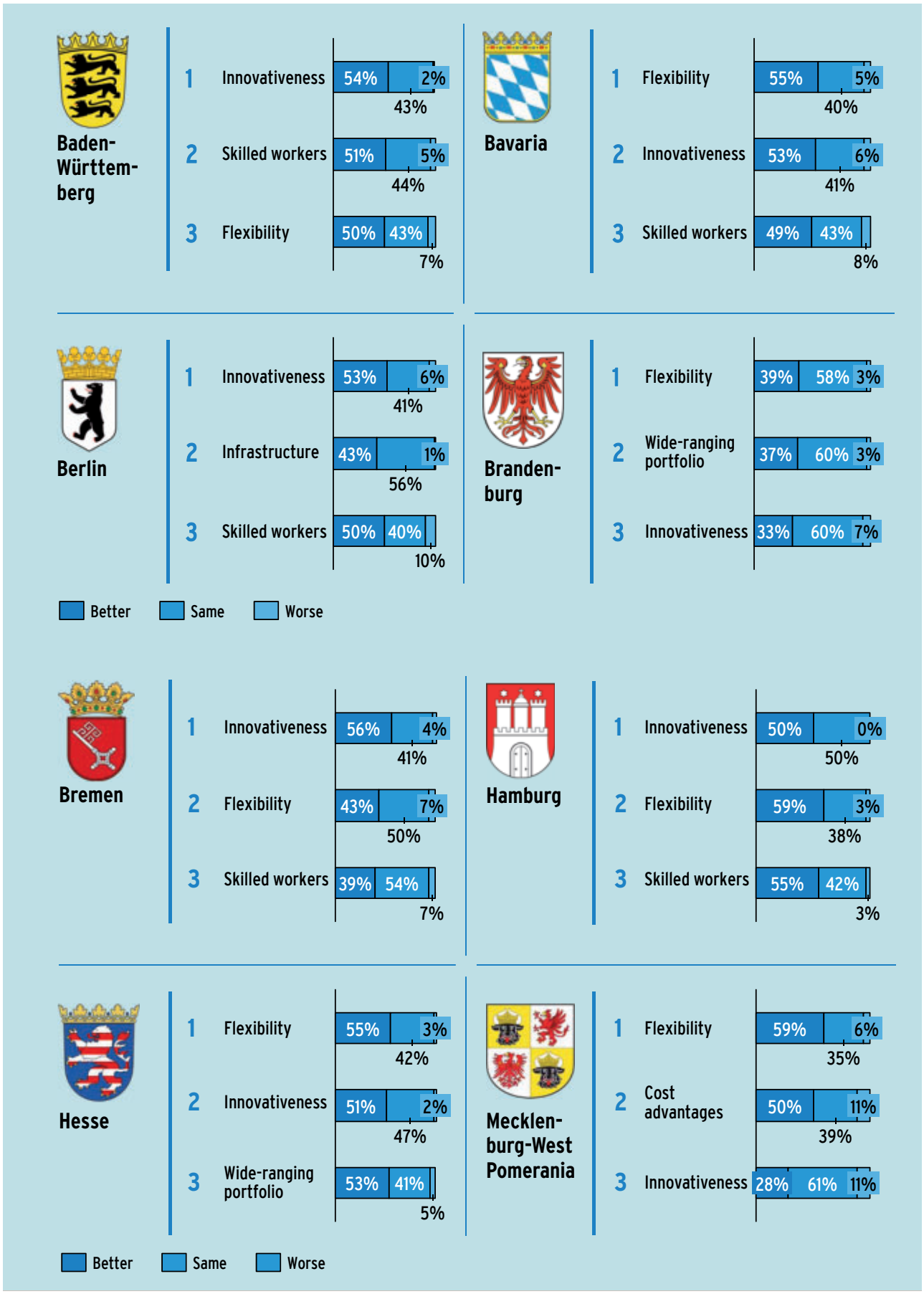
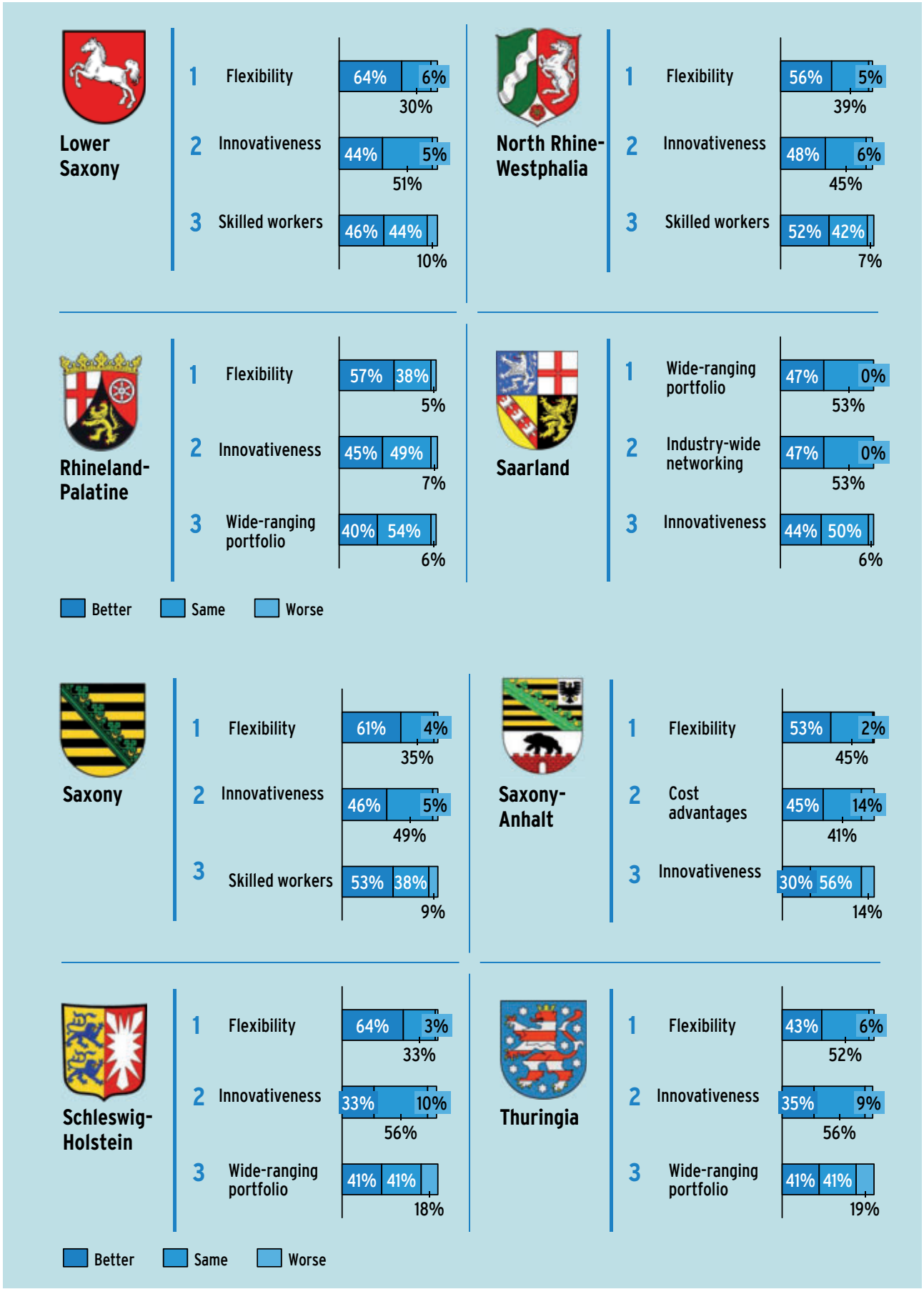


Figure 103a: Top three location factors from a company perspective by federal state

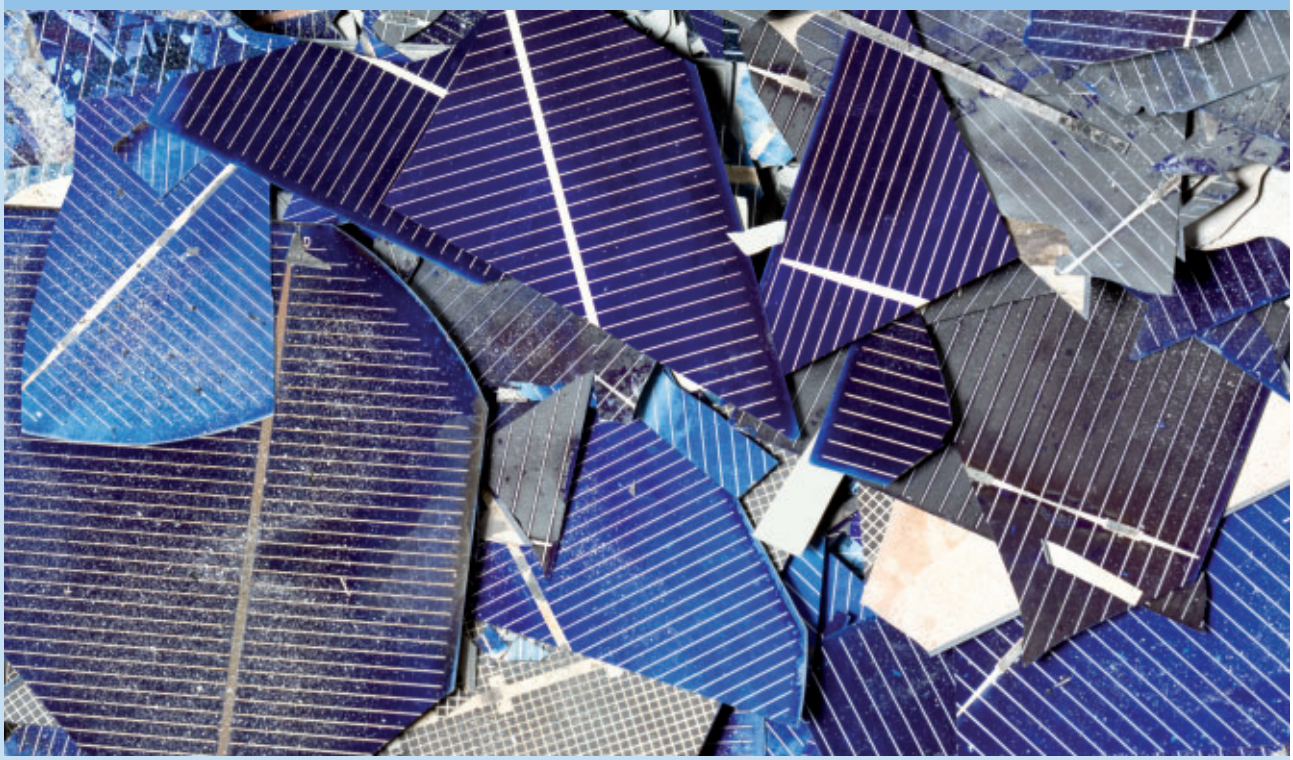


Source: Roland Berger

Figure 103b: Top three location factors from a company perspective, by federal state



Source: Roland Berger



Supportive measures in federal states (German Länder)

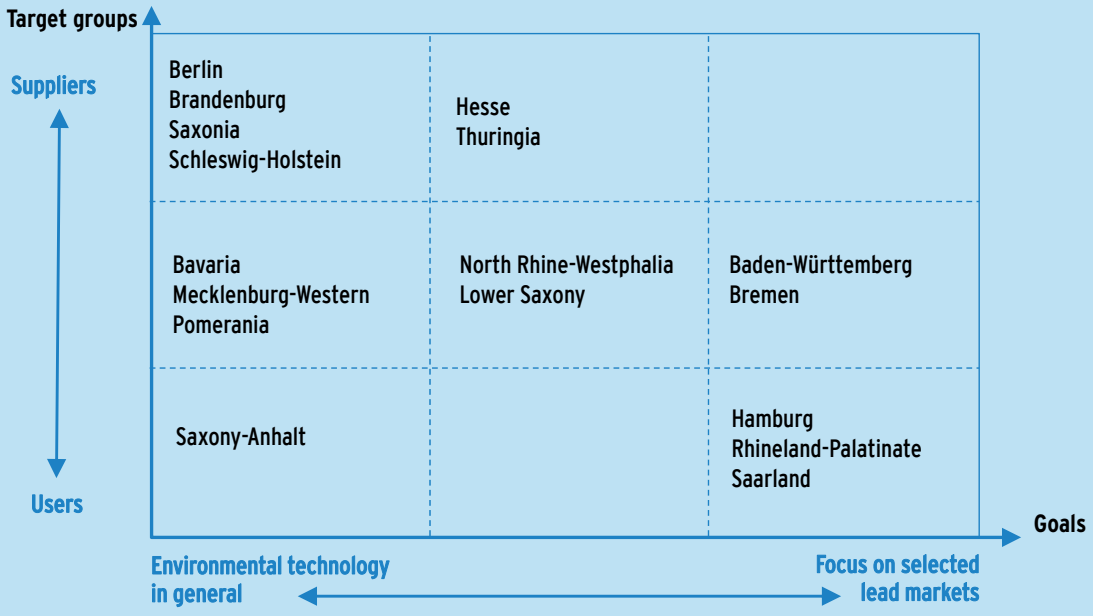
As climate change and resource scarcity continue over the coming decades, demand for products and procedures in the area of environmental technology and resource efficiency in domestic and foreign markets is set to grow. All the signs point toward the green tech industry enjoying continued expansion. German companies in particular stand to profit from this development, as they already enjoy an excellent position in most areas on global "green markets". It is therefore highly likely that environmental technology and resource efficiency will become one of Germany's key industries – with a corresponding positive impact on growth and employment in Germany.

Given this excellent outlook, **supporting environmental technology and resource efficiency forms a key priority for the federal government, individual federal states and municipalities**. The focus here is on the wide range of activities that the federal states are developing in order to tap the potential of green technology. The federal states support the industry both directly by helping green tech companies, and indirectly by stimulating demand for products in the area of environmental technology and resource efficiency. Differences occur in the breadth of supporting instruments employed: we find both supporting measures aimed at specific lead markets and those aimed at the environmental technology and resource efficiency market as a whole. Figure 104 provides an overview of the strategic direction of supporting measures in the different federal states. The vertical axis shows the target group at which the measures are directed; in other words, whether the measures employed by the federal state in question focus primarily on the suppliers or the users of environmental technology. The horizontal axis shows the overall goal of the measures employed by the federal state: promoting environmental technology in general or focusing on specific lead markets.

Supporting environmental technology and resource efficiency is not just good for green tech companies, of course. The whole of society benefits from technology that is environmentally friendly and uses up less natural resources as it speeds up the **structural change toward a green economy**.

The following pages provide an **overview of the wide range of measures currently in use to promote green technology**. They include many exciting ideas and innovative approaches. We have not tried to come up with a comprehensive list of all the measures in place in the different federal states. Instead, we **highlight specific, particularly effective measures**. Thus, for each federal state we present a single key project that supports green technology. The information in the profiles is based on interviews with representatives of the environmental and economic ministries in the federal states. Each profile follows the same pattern, including a description of the project, its focus, sector, budget, duration and finally target group.

Figure 104: Strategic direction of supporting measures by federal states – goals and target groups



Source: Roland Berger

Baden-Württemberg

The Baden-Württemberg Environmental Technology and Resource Efficiency Competency Atlas (Kompetenzatlas Umwelttechnik und Ressourceneffizienz Baden-Württemberg) is a comprehensive survey of the sector in the federal state. It contains profiles of companies and research institutions, including descriptions of their products, procedures, services and areas of research. The companies are classified according to six lead markets and more than 100 different fields of technology. The Atlas enables quick identification of potential cooperation partners on the basis of the services they offer. It thus creates a forum for easy networking and developing new business.

Website	www.kompetenzatlas-umwelttechnik.de
Focus	Innovation promotion, networks
Sector	Cross-sector
Type	Project
Budget	EUR 200,000 (one-time)
Duration	Began 2011
Target group	Businesses, networks, associations, research and development institutions, authorities, foreign partners

Bavaria

The Bavarian Environment Cluster brings together competencies of the various government departments in the areas of drinking and wastewater treatment, waste and recycling, alternative energy sources (in particular waste and biomass), air pollution control, resource efficiency and material flow management. The aim of the Environment Cluster is to help Bavarian businesses (especially small and medium-sized enterprises) to develop and manufacture marketable products. Its key areas of activity include promoting networking between industry and academic players, helping develop pilot projects and collecting information for specific target groups. Various working groups help companies develop tailored solutions and bring them to market. The Environmental Cluster further promotes internationalization by providing key information on foreign markets and potential subsidies, putting firms in contact with relevant partners.

Website	www.cluster-bayern.de/ www.umweltcluster.net/
Focus	Internationalization, innovation promotion, networks
Sector	Cross-sector
Type	n/a
Budget	n/a (funded by Bavarian Ministry of Economic Affairs)
Duration	Began 2006
Target group	Businesses, especially SMEs, colleges and universities, research institutes

Bayerisches Staatsministerium für Wirtschaft, Infrastruktur, Verkehr und Technologie

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Berlin Brandenburg

Joint Innovation Strategy of the States Berlin and Brandenburg (innoBB)

The Federal States of Berlin and Brandenburg have developed a joint innovation strategy. The aim of this strategy is to bundle the economic development of the capital region, particularly in knowledge-based areas, and make efficient use of the innovation potential and synergies within the overall region over the coming years. Joint innovative sectors, as future fields of excellence, will be expanded into sustainable, internationally competitive scientific and economic clusters. These clusters/future fields of excellence include "Biotechnology, medical technology and pharmaceuticals", "Power engineering" and "ICT and media". In addition, four overarching themes are identified, of which "Clean technologies" is especially important. This field includes all technological developments focused on the topic of sustainability, in particular the area of environmental and climate-friendliness (and/or neutrality), and which actively address the challenges of climate change.

Website	www.innovatives-brandenburg.de/de/2742.aspx www.zab-energie.de/de/3115.aspx
Focus	Innovation promotion, networks
Sector	Cross-sector
Type	Institution
Budget	n/a
Duration	Began 2010
Target group	Businesses and academic institutions

ZAB ZukunftsAgentur Brandenburg

TSB Technologiestiftung Berlin | Stiftung

Berlin Partner

Bremen

The goal of Bremen's "environment business initiative" (iuu) is to visibly bring together all the state's activities aimed at supporting environmentally-friendly business and, in so doing, to help companies in Bremen and Bremerhaven to meet the demands of sustainable business. The initiative unites under a single umbrella the "partnership environment companies" initiative, the "environment enterprise award" and the "Climate Protection Enterprise CO_2-20" award granted to companies that have cut their CO_2 emissions by 20 percent within the last five years. The initiative also encompasses support programs for application-oriented environmental technology and applied environmental research, plus programs providing advising on environmental efficiency and responsible business for companies. It thus complements Bremen's overall innovation strategy, which focuses on companies in renewable energies (especially wind power), maritime business/logistics and aerospace.

Website	www.umwelt-unternehmen.bremen.de
Focus	Internationalization, innovation promotion, networks
Sector	Cross-sector
Type	Support program/competition
Budget	n/a, financed by federal state and EU
Duration	Began 2003, some parts since 1995
Target group	Industrial companies and service providers with headquarters or other business premises located in the Federal State of Bremen, especially small and medium-sized enterprises

Hamburg

Unternehmen für Ressourcenschutz
beraten · vernetzen · fördern

The Enterprises for Resource Protection program targets Hamburg-based manufacturing and service companies and skilled craft enterprises. Its aim is to realize the existing potential for energy, water and raw material savings. The customer-based program stimulates voluntary investments in resource efficiency measures supporting climate protection. Its goals include providing financial support for investments in resource protection, cutting CO_2 emissions, using resources such as energy, water and raw materials efficiently, reducing companies' operating costs, strengthening preventive environmental protection, reinforcing Hamburg's position as a good place to do business and improving local quality of life. The Ministry of City Development and Environment acts as an umbrella organization, responsible for everything from financial subsidies to developing business solutions, identifying specialists and providing support and advice (on site, if required).

Website	www.klima.hamburg.de
Focus	Financing, innovation promotion, networks
Sector	Cross-sector
Type	Support program/competition
Budget	Approx. EUR 5 million p.a.
Duration	Since 2001
Target group	Manufacturing and service companies, skilled craft enterprises

Behörde für Stadtentwicklung und Umwelt

HK Handelskammer Hamburg

Handwerks-kammer Hamburg

ivh INDUSTRIEVERBAND HAMBURG E.V.

Hesse

Hesse Environmental Technology Action Line

The Hesse Environmental Technology Action Line is the Hesse Economics Ministry's central platform for the environmental technology sector. It promotes competitiveness and innovation among Hesse's manufacturers and service providers in the field of environmental technology and is a point of contact for environmental technology users, particularly with regard to resource efficiency and production-integrated environmental protection (German acronym: PIUS). The Action Line provides information, communication and cooperation possibilities for environmental technology providers and users, e.g. from the sectors of wastewater and water technology, waste and recycling technology, renewable energies and energy efficiency. It also advises companies, promotes technology transfer and markets the expertise of Hesse's environmental technology sector.

Website	www.hessen-umwelttech.de
Focus	Internationalization, innovation promotion, networks
Sector	Environmental technology
Type	Project
Budget	Approx. EUR 600,000 p.a.
Duration	Began 1999
Target group	Environmental technology companies

HESSEN
Hessisches Ministerium
für Wirtschaft, Verkehr
und Landesentwicklung

Coaching Bioenergy Villages

Mecklenburg-Western Pomerania

The Coaching Bioenergy Villages program in Mecklenburg-Western Pomerania aims to strengthen power generation from renewable sources. It supports new initiatives in the area of generating and using renewable energies, alongside existing bioenergy initiatives. The program is run by the Mecklenburg-Western Pomerania Academy of Sustainable Development and is supported by the Mecklenburg-Western Pomerania Future Fund, underlining its key status as an innovative project in the sustainable design of the federal state. It creates networks between key players, ideas, projects and discussion partners with regard to the sustainable use of renewable energies by establishing contact with the numerous initiatives in other states and at a national level. Coaching can include analyzing a municipality's potential and defining a concept on this basis, for example. Besides informing participants about the various funding options available, the program also provides technical assistance and implementation support.

Website	www.nachhaltigkeitsforum.de
Focus	Financing, networks
Sector	Cross-sector
Type	Project
Budget	Approx. EUR 100,000 p.a.
Duration	2009 to 2011, continuation being planned
Target group	Companies and municipalities

Lower Saxony

Innovationszentrum Niedersachsen GmbH

Innovation Niedersachsen

The Lower Saxony Innovation Center, part of the regional government, advises the government on strategy for technology and innovation policy across its various departments. Key tasks include stimulating, steering and evaluating technology-based initiatives and assessing technology within the various lines of funding of the Federal State of Lower Saxony. The aim of the Innovation Center is to support technological innovation as a driver of economic growth and sustainable employment opportunities in Lower Saxony. It focuses on key future technologies in areas such as environmental protection, production engineering, automotive technology and the life sciences. Its consulting services and support projects in the area of environmental technology are bundled into the Wind Power Research and Competence Center, the Renewable Raw Material Competence Center, the Lower Saxony Fuel Cell State Initiative and the Lower Saxony Bioenergy State Initiative.

Website	www.iz-nds.de
Focus	Innovation promotion
Sector	Cross-sector
Type	Institution
Budget	n/a
Duration	Began 2003
Target group	Industry in Lower Saxony, especially small and medium-sized enterprises

Niedersächsisches Ministerium für Umwelt und Klimaschutz

NBank Wir fördern Niedersachsen

Ressource.NRW Funding Competition

North Rhine-Westphalia

The Ressource.NRW Funding Competition is an established part of the EU-NRW Regional Competitiveness and Employment 2007-2013 program (ERDF) and is jointly financed by the European Union and the Federal State of North Rhine-Westphalia. The competition was first held in 2009/2010 under the auspices of the NRW Environment and Economics Ministry by the Efficiency Agency for North Rhine-Westphalia (EFA). In 2011/2012 the competition will be held for the second time, sponsored by the NRW Environment Ministry. The planned investment, research and development volume for this second installment is approximately EUR 88 million. The competition is aimed at business and academic players. Its aim is to transfer innovative efficiency approaches from theory into practice. Funding is available for resource efficiency projects that may be classified as "experimental development" or "industrial research", plus investments relating to the introduction of production-integrated and/or product-related measures with environmental relevance.

Website	www.efanrw.de/index.php?id=418&L=
Focus	Financing, innovation promotion
Sector	Cross-sector
Type	Support program/competition
Budget	Approx. EUR 4.7 million (funding by federal state)
Duration	Began 2009
Target group	Primarily small and medium-sized enterprises

EFA Effizienz-Agentur NRW

ExzellenzNRW Cluster Nordrhein-Westfalen

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Rhineland-Palatinate

EffNet Effizienznetz Rheinland-Pfalz

The glass and ceramics industry is an important sector in Rhineland-Palatinate and one that is significantly affected by current economic developments. Rhineland-Palatinate's "Concept for improving material and energy efficiency in the ceramics industry" aims to help businesses working in this area improve their competitiveness. On the basis of efficiency analyses, process-specific concepts are designed and tested. The companies are integrated into a network to enable information sharing along the entire value chain, creating opportunities for win-win effects arising from partnerships. The industry concept is a project of the Rhineland-Palatinate Efficiency Network (EffNet), the key partner for issues relating to resource efficiency, energy and the environment in the federal state.

Website	www.effnet.rlp.de/Projekte/EffNet-Projekte/
Focus	Networks, innovation promotion
Sector	Ceramics
Type	Project
Budget	EUR 216,000 (partly EU funds)
Duration	2010 to 2012
Target group	Companies in the ceramics and ceramic raw materials industries

RheinlandPfalz Ministerium für Wirtschaft, Klimaschutz, Energie und Landesplanung

RheinlandPfalz Landesamt für Umwelt, Wasserwirtschaft und Gewerbeaufsicht

EGR die rheinland-pfälzische energieagentur

Saarland

Klima Plus Saar

The Saarland's climate protection strategy involves reducing CO_2 emissions by 80 percent by the year 2050. This will be achieved through the use of low-carbon technologies, primarily from renewable energies and improved energy efficiency. The new Climate Plus Saar program targets a number of areas:

- Supporting cities, towns and municipalities in their strategic climate protection and energy planning
- Reducing heat requirements and hence heating costs by improving energy efficiency
- Not generating unnecessary power
- Increasing the market share of renewable energies
- Expanding the share of renewable energies in electricity generation to 20 percent by 2020 (a fivefold increase on 2009 levels)
- Stimulating technical innovation
- Running pilot and demonstration projects to check readiness for market and broad application

Website	www.saarland.de/81044.htm
Focus	Financing, innovation promotion
Sector	Cross-sector
Type	Support program/competition
Budget	EUR 5 million p.a.
Duration	2011 to 2013
Target group	Individuals, businesses (SMEs), industry and other associations

Saarland
Ministerium für Umwelt, Energie und Verkehr

Saxony

Saxony Economic Development Corporation

Since May 2008, the Saxony State Ministry of the Environment and Agriculture has been working with the Saxony Economic Development Corporation on the basis of a management service agreement, formalizing a partnership that first began in 2003. Once a year, a program of 10 to 12 individual measures is agreed upon including overseas visits, domestic measures with international relevance and network-building activities. The work is based on the results of the study "GreenTech – Made in Saxony" published in January 2009, which found that Saxony companies in the environmental technology sector still lag behind their competitors in areas such as internationalization, research and innovation.

Website	www.sab.sachsen.de www.wfs.sachsen.de
Focus	Internationalization, innovation promotion, networks
Sector	Environmental technology
Type	Support program/competition
Budget	n/a
Duration	Began 2003
Target group	Small and medium-sized enterprises, environmental technology companies

STAATSMINISTERIUM FÜR UMWELT UND LANDWIRTSCHAFT | Freistaat SACHSEN | WIRTSCHAFTSFÖRDERUNG SACHSEN | SAB Sächsische AufbauBank

Saxony-Anhalt

Best4VarioUse

The "Biomasse Best4VarioUse" project is a joint initiative by the Fraunhofer Institute for Factory Operation and Automation (IFF) in Magdeburg, 13 German partners and 4 Spanish partners. It forms part of the LIFE+ program funded by the European Commission and the Federal State of Saxony-Anhalt (Ministry of Agriculture and Environment). The project is intended to develop and apply top economic/ecological technologies for using biomass in agriculture, forestry and landscape conservation. The objective is to generate economically and ecologically efficient material flows and, in so doing, stimulate long-term competitiveness and employment opportunities. The project also aims to test, demonstrate and transfer the applicability of conventional and innovative technologies and methods for processing woody wastes and residues so that they can be used to generate power or produce new raw materials. This also includes determining and evaluating best practices and technologies for creating economic and ecologically efficient biomass material flows.

Website	www.best4variouse.iff.fraunhofer.de/
Focus	Internationalization, innovation promotion, networks
Sector	Environmental technology
Type	Project
Budget	Approx. EUR 4 million/3 years (total budget)
Duration	2009 to 2011
Target group	Companies and institutions in Saxony-Anhalt and Valencia

Life

SACHSEN-ANHALT
Ministerium für Landwirtschaft und Umwelt

Fraunhofer IFF

Fundación Comunidad Valenciana Región Europea
www.uegva.info

Cámara Valencia

Schleswig-Holstein

Innovation Consulting
Innovation Audit
Support Programs

The goal of the initiative is to support green technology companies in Schleswig-Holstein with targeted, innovation-based consulting, provided by technology experts and innovation consultants. Targeted innovation audits in particular can help firms analyze, develop and implement innovative projects. The innovation consultants also inform participants about specific sector developments and intellectual property rights. They belong to regional, national and international networks and see themselves as the link between business, academia and politics, enabling them to identify appropriate partners for cooperation projects. Businesses continue to receive the support of state programs such as "Environmental Innovations", "Innovation Assistant" and "Research, Development and Technology Transfer" (FET). The Business Development and Technology Transfer Corporation of Schleswig-Holstein (WTSH) provides advice on innovation and is responsible for running the support programs.

Website	www.wtsh.de
Focus	Innovation promotion, networks
Sector	Cross-sector
Type	Institution, support program/competition
Budget	Approx. EUR 1.5 million p.a.
Duration	Began 2008
Target group	Mainly small and medium-sized enterprises; all companies with headquarters or other business premises located in Schleswig-Holstein may apply

Wirtschaftsförderung und Technologietransfer Schleswig-Holstein GmbH
WTSH

Ministerium für Landwirtschaft, Umwelt und ländliche Räume Schleswig-Holstein

Thuringia

Förderprogramm THÜRINGEN GREENTECH

The "Thuringia – GreenTech" program aims to help develop environmental technology in Thuringia. Its object is to generate increased value creation, new growth and new jobs. The program encompasses a wide range of measures and activities in green technology, subsidized by the Thuringian Ministry of Economics, Technology and Labor using funds from the Free State of Thuringia, the German federal government and the European Union structural funds ERDF and ESF. The areas for which support is provided include investments in renewable energies, energy efficiency measures, national and transnational research and development projects, investments in introducing the latest technologies and technology transfer, joint R&D projects and networks/ clusters, the use of personnel in R&D, investments in human and physical capital for setting up or expanding operating sites and consulting costs generated by Thuringian companies. The program consists of a series of new and newly targeted financing and support instruments such as the Thuringian Agency for Energy and Green Technologies (ThEGA), research and technology funding.

Website	www.thueringen.de/imperia/md/content/tmwta/foerderprogramm.pdf
Focus	Financing, innovation promotion, networks
Sector	Cross-sector
Type	Support program/competition
Budget	Approx. EUR 150 million
Duration	Since 2010
Target group	Businesses, research and educational institutes, municipalities, local government, private consumers

ESF EUROPA FÜR THÜRINGEN EUROPÄISCHER SOZIALFONDS

EFRE EUROPA FÜR THÜRINGEN EUROPÄISCHER FONDS FÜR REGIONALE ENTWICKLUNG

FREISTAAT THÜRINGEN Ministerium für Wirtschaft, Arbeit und Technologie

Highlights of environmental technology and resource efficiency “made in Germany”

Snapshots of a dynamic and diverse industry

The success of the environmental technology sector in Germany is thanks to the efforts of a wide range of business, academic and political players. Our study would be incomplete if it looked at markets, products and processes solely on an abstract level without giving concrete examples of the wide diversity of environmental technology "made in Germany". On the following pages we therefore present a number of such examples: 14 portraits of companies and networks operating in different lead markets. Our bird's-eye view makes no pretension to completeness, nor have we applied any objective criteria to our selection: rather it is a series of snapshots of a vibrant, thriving industry.

As we saw in the chapter *The dawn of the green economy*, the transformation to a green economy is changing the entire economy. This transformation is based on two pillars: on one side, we have companies from different industries who are pursuing a sustainable business strategy; on the other, we have a strong environmental technology sector. It is enlightening to take a closer look at specific companies that are successfully applying the principles of the green economy today and so driving the "green transformation" of day-to-day business. Three factors are key for the further development of this concept and its success in global markets: innovation, networks and internationalization. The same three factors are also critical for the continued development of the German green tech sector.

- **Innovation**
  Many German green tech companies are positioned on global markets as quality and technology leaders. In markets such as renewable energy, local energy generation and energy efficiency, German companies are pioneers. They have a distinct edge over their competitors. However, they can only retain this position and build on it if they continue to lead the way internationally in terms of innovation. This requires substantial efforts in the area of research and development (R&D).

- **Networks**
  The fragmented nature of the industry is a potential competitive disadvantage when it comes to innovation. Small and medium-sized enterprises (SMEs) tend to find R&D more difficult simply because they lack the necessary financial and human resources. One answer is to forge partnerships with research institutions: the transfer of know-how and bundling of competencies benefit everyone involved. Another solution is for companies in different parts of the value chain to work together. Many small companies are highly specialized, but when it comes to major tenders, "package solutions" rather than individual modules are called for. Working as part of a network raises the odds for individual firms, especially in international markets. On the following pages we therefore also look at some particularly successful networks that bundle the skills of different companies, research institutions and associations.

- **Internationalization**
  Demand for environmental technology is growing apace in the global marketplace. German businesses can profit from this trend – as long as they step up their activities in foreign markets. We know from experience that the entry barriers to international business are higher for small and medium-sized enterprises than for large corporations. The environmental technology industry is highly fragmented, so any approach that smoothes the path to internationalization for SMEs is particularly important. For this reason, we include in our overview below some foreign partnerships in which German green tech companies are involved.

The examples that we present in this chapter shed light on how different actors in the field of environmental technology and resource efficiency utilize these three levers – innovation, networks, internationalization – to achieve long-term profitability. We focus particularly on young companies. Our snapshots aim to demonstrate the dynamic, innovative strength that is driving growth in the environmental technology industry. [1]

1 The information in this chapter is drawn largely from company websites, articles in the specialist press and other published materials.

For the sake of clarity, we use the following symbols to represent the three success factors:

Innovation

Networks

Internationalization

APK Aluminium und Kunststoffe AG

Schkopau
Recycling plastics

"Newcycling" – A new process closing the gaps in plastic recycling

For most of us, a drinks carton is a regular everyday object. But for the recycling experts, it is a technical challenge. When it comes to recycling materials, the purer they are, the better: the various different components of composite materials must be separated out before they can enter the recycling process. Recycling plastics is particularly challenging in this regard. Indeed, traditional recycling processes are often unable to separate plastic composites into their individual components – for example, where the plastics cannot be separated mechanically, are stuck together or are combined with metals. As a result, many plastic products cannot be recycled at all. And that is what APK is setting out to change.

APK Aluminium und Kunststoffe has developed a new process for recycling plastic composites and plastic-metal composites. It calls this process "Newcycling". Newcycling closes the gaps that currently exist in plastic recycling. APK uses a proprietary two-step procedure: the first step is a mechanical cleaning and separation process, the second a dissolving process. This two-step procedure allows it to regain specific raw material components in a targeted fashion from the feedstock material. The metals contained in plastic-metal composites do not dissolve and so can be separated out and regained in a pure form.

The plastics separated out by the proprietary Newcycling process show a high level of purity, comparable with new materials. This means that they are suitable even for use with foodstuffs. The process itself is also environmentally friendly in terms of energy efficiency and resource conservation. The main raw material used in the production of new polymers is petroleum. Long term, petroleum is becoming expensive and in short supply, while global demand for plastics is growing. As a result, recycling plastic is becoming increasingly vital.

APK produces three different types of regranulates: LDPE (low density polyethylene), HDPE (high density polyethylene) and polypropylene. From 2012, the company will also offer aluminum produced via Newcycling in the form of powder or briquettes.

The APK plant is located in the ValuePark® in Schkopau, Saxony-Anhalt, in what is known as the Middle German Chemical Triangle. The ValuePark® is an industrial park developed by the firm Dow Olefinverbund GmbH, situated between the cities of Halle (Saale) and Merseburg. It is considered a center of competence for plastics technology and was named a "Selected Landmark" in the German "Land of Ideas" competition.

www.apk-ag.com

Heliatek GmbH

Dresden/Ulm
Organic photovoltaics based on oligomers

"Third-generation solar cells" – A faster journey from lab to fab

It was during a high-school geography class that Dr. Martin Pfeiffer's interest in renewable energy was first sparked. Renewables, he learned, would only ever play a marginal role in the overall energy supply, an area dominated by coal, oil and nuclear power. He was not convinced. "From that moment on, I wanted to find out more. When I finally had the opportunity to work in this area, I jumped at it," he says. Today, Dr. Pfeiffer is Chief Technology Officer at Heliatek and a recognized expert in organic semiconductor technology. He is also cofounder of the companies Novaled and Heliatek.

Novaled was founded in 2003 and specializes in OLED (organic light-emitting diode) technology. Heliatek, on the other hand, focuses on organic photovoltaics. The company was spun off in 2006 from the Technical University of Dresden (Institute for Applied Photophysics) and the University of Ulm. These roots meant that it brought together expertise in the fields of organic optoelectronics and organic oligomer synthesis. Today, the company employs around 70 staff at its sites in Dresden and Ulm. Its mission is to drive the development of organic photovoltaics forward and open up new applications for "third-generation solar cells".

Organic photovoltaic (OPV) cells are solar cells made from organic chemical components, in other words, hydrocarbon compounds. Their special electron structure give them the characteristics of amorphous semiconductors. In first-generation crystalline solar panels, silicon wafers are used as raw materials. Second-generation solar panels – thin-film solar panels – also use amorphous silicon cells as the raw material, alongside new materials such as cadmium telluride and copper indium diselenide.

Expectations run high of organic photovoltaics. It is flexible, thin, light-weight, semi-transparent and shatter-proof, making organic solar technology a possibility in places where installing panels was previously unthinkable. For example, a film with organic photovoltaic modules can be stuck on a window as easily as putting up a poster. Wafer-thin modules can be sewn into cases for laptops or cell phones, thereby supplying the device with power. Such new applications are not the only advantage of organic photovoltaics, however: their proponents also point to their less resource-intensive production process. The value chain for manufacturing crystalline solar panels is both long and costly, while organic photovoltaics offers many potential savings, especially in mass production. The production process does not require clean-room conditions and uses less energy and raw materials than older processes; it also uses no toxic materials. All in all, these advantages mean that organic photovoltaics combines high levels of profitability with low electricity production costs. This compensates for its lower level of efficiency: silicon cells show up to 18 percent efficiency and thin-film cells up to 13 percent, whereas organic solar cells have about 8 percent efficiency.

While other manufacturers continue to use polymers (large molecules), Heliatek believes that oligomers represent the most promising road forward for organic photovoltaics. In particular, oligomers allow better process control during production, offering higher efficiency and a longer lifespan.

Thanks to its many years of research, Heliatek has its own proprietary know-how. The company holds fundamental patents for the manufacture of organic solar cells with doped transport layers. Its tandem cell technology – also patented – allows two solar cells to be stacked on top of each other, making it possible to absorb a broad solar spectrum; the tiny solar power station works even in weak light conditions and with small incident light angles. The active layers (the tandem cell) are just 500 nm thin.

Heliatek is currently transferring organic photovoltaics based on oligomers from lab to fab. It plans to manufacture flexible organic solar cells using what is known as a "roll-to-roll" process, a process already well established in the OLED industry. The company hopes to begin series production in 2012.

The roll-to-roll process uses vacuum deposition (evaporation) to apply the oligomers to a PET film that acts as the substrate. According to Heliatrek, production costs can be quickly reduced by increasing production volume, making the process considerably cheaper than that used for the production of crystalline solar modules.

Heliatek is being supported on its journey from lab to fab by both industrial and venture capital companies, including BASF, Bosch, RWE and Wellington Partners. It also receives financial support from the Free State of Saxony, the Federal Ministry of Education and Research, the Federal Ministry of Economics and Technology and the European Union.

www.heliatek.com

PYUA GmbH

Kiel
Functional apparel, sustainably manufactured

Freeriding outfits "made in Europe" from recycled polyester yarn

"RIDE FREE, BUT ECORRECT" is the marketing slogan used by PYUA since its market launch in 2008. The company produces outfits for off-piste skiers and freeriding snowboarders. PYUA, based in Kiel, is the first manufacturer of sports articles whose products are almost entirely made from recycled materials. PYUA also produces all the items in its collection in Europe. In this way it can guarantee that the entire production process meets the environmental production guidelines and social standards laid down by the European Union. The shorter transportation routes also protect the climate as they generate fewer CO_2 emissions.

PYUA is one of a group of labels that prove that eco-fashion doesn't have to compromise on design or functionality. In the specialist press, PYUA apparel has been called a "collection for a new generation of snow wear". The freeriding outfits are sold via specialist sports shops and are described by the manufacturer as "100% waterproof, 100% breathable and 100 % recyclable."

PYUA's outfits are made almost entirely from pure recycled materials with "bluesign" certification. To receive this certification, companies must adhere to five fundamental principles across their entire production chain: resource productivity, consumer safety, occupational health and safety, and no contamination of air or water. In this way PYUA guarantees that the materials it uses are manufactured according to sustainable criteria.

The garments manufactured by PYUA use ECO CIRCLE materials, described by the company as the world's first recycling system for polyester products. Polyester is produced using petroleum. Recycling polyester products cuts consumption of this resource: energy consumption and CO_2 emissions for the ECO CIRCLE closed-loop recycling system are 80 percent lower than for polyester production from primary raw materials. The ECO CIRCLE system recycles used polyester apparel, breaking it down, granulating and cleaning it to produce polyester yarn that is equivalent in terms of quality and functionality to new polyester. The recycled polyester yarn can then be used to manufacture new garments.

PYUA outfits are durable but sooner or later they are thrown away, too. When it comes to recycling their own products, the company also aims to "set new standards in the recycling of used functional apparel." It works with two German companies that specialize in recycling textiles: K. & A. Wenkhaus GmbH (Hamburg) and FWS GmbH (Bremen). "Our main concern was to optimize the take-back process," says Timo Perschke, founder and CEO of PYUA. The company therefore developed a special system together with K. & A. Wenkhaus and FWS: the two recycling companies manage the take-back process – not via the retail trade but through the used-clothes containers found in every town and city in Germany. Garments deposited in these containers are sorted by hand so it is possible to identify any used PYUA outfits and return them to us for recycling. "That means we can promise that our PYUA products really are recycled into new products," says Perschke.

In 2011, for the second time PYUA received the Eco Responsibility Award, an environmental prize granted by ISPO, the international trade fair for sporting goods and sports fashion. The jury praised PYUA's "coherent overall concept and constant further development and optimization of sustainable value-creation processes."

www.pyua.de

saperatec GmbH

Bielefeld

Disposal and treatment of photovoltaic production waste and solar modules

Hidden treasure in solar waste – Recovering precious metals and rare earths from photovoltaic modules

The environmental balance-sheet of solar panels during their working life is very positive: the tiny power stations converting sunlight into electricity generate vastly more power during their lifetime than is required to produce them in the first place. Moreover, they do so without generating harmful emissions.

This sets the bar high for solar power in terms of its ecological credentials. European photovoltaics manufacturers would like to see solar modules that meet sustainable criteria throughout their lifecycle, from production to disposal. Recycling solar panels is therefore becoming more and more important. This is where saperatec comes in. The Bielefeld-based company was founded in December 2010 and hopes to establish itself firmly on the market with its innovative technology for recycling photovoltaic modules.

Let's be clear: The disposal and recycling of solar panels is no simple matter. Solar panels contain dangerous components, such as cadmium telluride in thin-film panels and silver and lead in crystalline panels. How these materials are processed during production also poses significant challenges for recycling. Solar panels consist of many solar cells that have been bonded together. To make them weatherproof, they are packed between panes of glass and film. This bonding and coating has serious implications for recycling as the different elements have to be separated out before individual components can be recycled.

With current technology, some 80 percent of the material used can be recycled. However, the only materials recovered are glass and aluminum – other components such as silver and silicon still end up in hazardous waste disposal sites. The 80 percent that can be recovered meets the recovery rate laid out in the EU's Waste Electrical and Electronic Equipment Directive (WEEE), likely to be extended to include the photovoltaics industry in spring 2012. Yet with 96 percent of the raw material potentially recoverable, there is still considerable room for improvement.

The company saperatec has developed an innovative technology that can break down composite materials into their individual components and "de-layer" wafers and other materials. The start-up is focused on the disposal and treatment of photovoltaic production waste and thin- and thick-film solar modules. It uses environmentally friendly materials and has developed an alternative method for separating the bonding and coatings of solar cells with the help of specially developed liquids. Moreover, it is a technique that works at room temperature rather than the high temperatures required by conventional techniques, thereby consuming much less energy.

saperatec's business model aims to create a win-win situation. The photovoltaic modules are recycled using environmentally friendly techniques; at the same time, raw materials that are in short supply and expensive, such as rare earths and precious metals, are recovered from the solar scrap and can be recycled. This prevents valuable resources from going to waste. With its innovative technology, saperatec can recover elements such as indium, selenium and tellurium from the production waste generated by the photovoltaics industry and end-of-life photovoltaic modules.

The efficient, profitable process developed by saperatec was largely what convinced Gründerfonds Bielefeld-Ostwestfalen and High-Tech Gründerfonds to provide the start-up with EUR 1 million in venture capital. saperatec is using this financial injection to develop production facilities in Bielefeld.

Cofounder and CEO of saperatec Dr. Sebastian Kernbaum is confident about future business: "The recycling market for photovoltaic modules is set to grow strongly in the coming years. saperatec will grow with it." The company expects to see the first major wave of end-of-life solar modules around the year 2015. From then on it foresees a continuous flow of used material. In 2010, for example, 1.4 million tons of modules with a lifespan of 25 to 30 years were sold. The flow of input material for the photovoltaic module recycling specialists is therefore unlikely to dry up any time soon.

www.saperatec.de

TerraNova Energy GmbH

Düsseldorf
Converting biogenic waste into regenerative fuel by means of hydrothermal carbonization

Bio-coal from sewage sludge

"It took our earth over four million years to form coal from biomass – TerraNova Energy manages the same job in four hours!" The headline on TerraNova Energy's website sounds almost too good to be true. But at their demonstration plant at the central sewage treatment plant in Kaiserslautern, operating since April 2010, TerraNova Energy is happy to prove that its boast is not just empty words. The company, founded in 2008 and based in Düsseldorf, uses hydrothermal carbonization to convert biogenic waste into renewable solid fuel.

Humid waste biomass – sewage sludge or residues from the food and beverage industry, for instance – are of limited value as the raw material for energy production using conventional biogas production or pyrolysis. But TerraNova Energy's plants employ a new technique that converts humid waste biomass directly into regenerative solid fuel without passing through expensive intermediate stages.

Hydrothermal carbonization, or HTC, copies the natural process of coal generation in a sped-up version. Biomass is dehydrated at a temperature of 200°C and pressure of between 20 and 35 bar, and with exclusion of air and the addition of catalysts. The reaction product is a coal sludge that by virtue of its fine particle structure can easily be mechanically dewatered to a dry matter content of well over 50 percent. The resulting bio-coal can, after drying, be supplied as blasting carbon dust or in the form of pellets.

One of the advantages of hydrothermal carbonization is that almost the entire carbon contained in the biomass is retained. When this bio-coal is subsequently burned, only the volume of CO_2 is released that was previously extracted from the climatic cycle during the growth phase of the biomass. This "clean coal" is thus a regenerative, CO_2-neutral energy source that meets the requirements of biomass according to the German Renewable Energy Heating Act (EEWärmeG) and qualifies for the remuneration for generation of electrical power under the German Renewable Energy Sources Act (EEG).

TerraNova Energy's automatic units can process between 1,200 and 12,000 tons of biomass per year, depending on their size. They are designed for local use; in other words, they can be installed directly at the source of the biomass, for instance at a sewage plant. The systems come in standardized containers and include necessary features such as a chemicals storage area and integrated control room. They are suitable for both contracting and BOT (build-operate-transfer) models. In the latter case, TerraNova Energy acts as builder and operator before transferring the system to the customer after an agreed period of use, say ten years.

According to TerraNova Energy its system has a number of advantages over other methods of treating and converting sewage sludge. For example, the sludge is treated and converted in a single process step. It is transformed directly into a renewable solid fuel that can be stored and transported as necessary. Anaerobic stabilization – the use of oxygen to prevent methane formation – is unnecessary, which means lower energy costs for sewage plants. CEO Marc Buttmann also highlights the energy efficiency of the hydrothermal carbonization process: "Other biomass technologies, such as traditional biogas production, involve a 50 percent loss of chemical energy in the biomass before they produce energy. In our process, the energy efficiency is around 80 percent."

For its development of hydrothermal carbonization for local systems, TerraNova Energy was named a "Selected Landmark" in the 2011 German "Land of Ideas" competition. The award recognized the firm's innovative strength – a strength that the company is keen to continue demonstrating in the future. Current plans include extending the application of hydrothermal carbonization to new areas of application, such as the production of a soil conditioner (Terra Preta) and the recovery of phosphor and other nutrients from sewage sludge.

TerraNova Energy works closely with a number of academic institutions, including the Faculty of Chemistry at the University of Kaiserslautern, the Institute for Environmental Engineering (ISA) at Aachen University (RWTH) and the Institute for Applied Material Flow Management (IfaS) of the Trier University of Applied Sciences on the Environmental Campus Birkenfeld. The last of these institutions is also where the roots of the company lie; Professor Michael Bottlinger and his team have been investigating hydrothermal carbonization here since 2006.

www.terranova-energy.com

TerraTransfer GmbH

Bochum
Automated monitoring networks

Real-time monitoring of environmental data via the Internet

Monitoring water levels using traditional methods is a time-consuming task: you need to physically travel to the monitoring station, read off the data and record it. Collecting environmental data from the ground or air is equally cost-intensive. Recording and analyzing data in this manner also inevitably involves a certain delay. Yet real-time information is invaluable when it comes to areas such as flood protection.

Back in 2007, while still geography students at the Ruhr University of Bochum, Marcel Delker and Sven Schulz recognized this gap in the market. As part of an externally funded project they worked on a number of monitoring systems that could collect data automatically and transfer it to a computer. Their initial attempts were promising. In 2008, after graduation, they founded the company TerraTransfer together with a number of engineers and IT specialists with the aim of preparing an automated monitoring system for launch on the market.

TerraTransfer, based in Bochum, has remained true to its original business model. The company develops and sells measuring systems for real-time monitoring of environmental data via the Internet, focusing on the areas of hydrology, climatology and soil science.

The "GPRS – Datalogger: Water Monitoring Realtime" product exemplifies how the company's systems function. The water level is recorded by a data logger fitted with a highly accurate sensor. The data logger then sends this information to a database so it can be accessed online via an Internet browser. The data logger communicates with the database via GPRS and does not rely on electricity and telephone networks; in fact, the hardware is optimized for locations that lack such infrastructure.

TerraTransfer's "online water manager" software steers the monitoring devices and checks they are functioning properly. It also presents the data that is transmitted. This data can be downloaded in simple Excel-compatible formats or fed into the customer's own software environment. If the client so wishes, TerraTransfer can provide these services from its own server. The online water manager also provides what the company calls an "alarm management" system, whereby the client is informed immediately by e-mail or text message if the water level exceeds a specific threshold.

TerraTransfer's other monitoring systems work on the same basic principle. Products include a GPRS data logger for monitoring soil moisture and a real-time weather monitoring system for measuring wind direction, wind speed, radiation (global, infrared and albedo), temperature, precipitation (amount, duration and intensity), air pressure and relative humidity.

As with many start-ups, the early phase was difficult for the five-person team at TerraTransfer. It took some time before the company established its innovations on the market. However, with the help of a demo device, the young entrepreneurs managed to acquire their first customers – and when these customers in turn recommended them to others, the company finally made its breakthrough. Today, TerraTransfer's list of clients is relatively long, including numerous businesses and institutions engaged in water management.

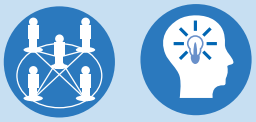
TerraTransfer works with the Swiss company STS Sensor Technik Sirnach as its foreign distribution partner. Thanks to this partnership, the company's products are now available in more than 30 countries.

The firm's founders work closely with the Geography department of the Ruhr University of Bochum on the AHEM (automatic hydrological real-time model) project. The project, due to run until 2012, aims to develop an optimized run-off prediction model based on automatic local measurements.

The company has already garnered a number of awards. In 2011 it was nominated for the German Business Founder Award (Deutscher Gründerpreis) in the Start-up category. The jury commended it as "a company that has succeeded in replacing the time-consuming and inevitably infrequent manual measurement of data by combining existing hardware components with smart software in an innovative fashion, making a new quality of data analysis possible." The jurors also recognized TerraTransfer's "major growth potential", with 30,000 water monitoring stations in North Rhine-Westphalia alone.

www.terratransfer.de

DEMAX – Decentralized Energy and Network Management with Flexible Electricity Rates



A consortium of six partners from industry and academia under the direction of the Fraunhofer Institute for Solar Energy Systems (ISE)

A pilot system simplifying data exchange between local electricity producers and users

In the first half of 2011, the share of renewable energies in electricity production in Germany passed the 20 percent mark for the first time. This development poses significant challenges for the structure of energy provision in Germany. Local electricity generation systems – photovoltaic plants, wind turbines, cogeneration power plants, and so on – must be connected to each other and integrated into the electricity grid. Fluctuating levels of renewable energies being fed into the grid is also a problem: sunshine or strong winds cannot be planned in advance or controlled when they come. To ensure stability, the amount of electricity fed into the grid and the amount taken out must be balanced. If the share of green electricity is to grow, mechanisms are needed to achieve this balancing act between supply and demand. Alongside expanding storage capacity, load management has a vital role to play. Load management aims to adjust the electricity consumption of private households and industry as far as possible in line with supply. For it to be effective, local electricity providers and consumers must be interconnected via "smart grids".

This is where DEMAX comes in. Sponsored by the German Federal Ministry of Economics and Technology under the InnoNet program, six players from industry and academia have together developed an innovative energy management and communication system. The partners, coordinated by the Fraunhofer Institute for Solar Energy Systems (ISE), are as follows: Görlitz AG, SenerTec Kraft-Wärme-Energiesysteme GmbH, EWS (Elektrizitätswerke Schönau), SSV Software Systems GmbH, the Steinbeis Innovation Center and in.power GmbH.

With the help of this pilot system, local suppliers and loads from the commercial and private sectors can participate in the energy market. According to the press release issued by the Fraunhofer ISE, communication is carried out through an open, Internet-based communications protocol.

The solution that the partnership between small and medium-sized enterprises and the Fraunhofer ISE has come up with is the DEMAX gateway. A gateway is what makes it possible for networks to communicate with each other despite the fact that they use different protocols. It is therefore a essential prerequisite for a functioning smart grid, in which many different network connections are needed for communication between network operators, metering companies, electricity providers and consumers. The DEMAX gateway is able to meet this communication challenge as the scientists at Fraunhofer ISE have developed an implementation that fulfills the "MUC Standard" and is freely available to the public. "With the open MUC software platform, we can record relevant billing data from electricity, gas, heating/cooling and water consumption in a modular way. The metering technology for single and multi-family houses can be kept to a minimum, i.e. cost-effective," says Christian Sauer, responsible project leader at Fraunhofer ISE.

The Steinbeis Innovation Center for Embedded Design and Networking (sizedn) contributed significantly to the development of this technology with its wireless m-bus technology. EWS (Elektrizitätswerke Schönau) piloted the system in a small field test project, offering its customers innovative and flexible electricity tariffs. Görlitz AG, a specialist in metering technology, contributed its expertise in the acquisition and integration of energy data.

An important part of the pilot project was the integration of cogeneration plants into the grid. Another main component of the DEMAX gateway is therefore the embedded system developed by experts at SSV Software Systems. This system makes it possible for the SenerTec Dachs cogeneration plant to be incorporated into the smart metering system, leading to optimal operation of the plant and its integration into the virtual power plant. Here, the project drew on the expertise of in.power, an independent direct marketer of local renewable energy that bundles small and medium-size power plants into large marketable units.

At the end of the three-year DEMAX project, the participants are positive: "The project results verify that through the use of intelligent energy and network management, fluctuating and controllable energy suppliers can already be integrated cost-efficiently into our energy system today." [2]

2 Fraunhofer-Institut für Solare Energiesysteme ISE (2011).

Netzwerk Ressourceneffizienz

An open platform for companies, researchers, associations and multipliers

A forum for dialog on resource-efficient products, processes and services

"By 2020, Germany will be the most resource-efficient country in the world, at the forefront of sustainable management of energy and raw materials. Those are the markets of tomorrow." Thus begins the founding charter of Netzwerk Ressourceneffizienz – the Network for Resource Efficiency – set up in 2007.

To achieve this goal, the network provides an open platform on which companies, engineers, researchers, business associations and other multipliers such as charitable foundations and non-governmental organizations can share their expertise about the efficient use of resources. The network was initially coordinated by the Wuppertal Institute for Climate, Environment and Energy and supported by the Federal Ministry for the Environment (BMU) and the Federal Environment Agency (UBA) in cooperation with the German Materials Efficiency Agency (demea) and the Efficiency Agency of North Rhine-Westphalia (Effizienz-Agentur NRW). Following the initial start-up phase, in August 2011 responsibility for running the Network passed from the Wuppertal Institute for Climate, Environment and Energy to the VDI Center for Resource Efficiency and Climate Protection (VDI ZRE).

The Network for Resource Efficiency functions as a platform for sharing information and experience. It provides a framework for members to enter into dialog about resource-efficient products, processes and services in addition to resource-efficient management. Right from the outset, the network has aimed to involve a broad spectrum of players, including representatives from the business, political and academic worlds. It thus aims to help disseminate promising approaches to boosting resource efficiency.

Besides companies, institutions represent an important target group for the network. Business associations, unions, chambers of commerce and environmental and consumer organizations are key multipliers who can ensure that resource efficiency remains high on the political and public agendas. The network seeks to act as a catalyst, coordinating and facilitating activities and pilot projects carried out by its members. It also aims to contribute to improvements in the overall framework for resource efficiency by using the wealth of experience of its members.

With these goals in mind, the network organizes a wide range of activities on both a regional and a national level. It organizes conferences to showcase examples of best practice or networking activities, for example, and to provide the opportunity for live dialog. It also publishes a newsletter containing information about different aspects of resource efficiency as well as details of forthcoming events.

The network places a particular focus on the needs of small and medium-sized enterprises, organizing special events for this target group, often on specific regional or industry-related topics. Its goal here is to provide information about the efficient use of resources, presenting successful examples from the region or industry in question. Providing more than just theoretical support, the network offers practical help implementing efficiency measures in companies and information about funding options for innovative technologies.

www.netzwerk-ressourceneffizienz.de

StreetScooter

Aachen
A network of businesses and research institutions dedicated to sustainable mobility concepts

The electric short distance vehicle – "We must first establish the technology on the market by making it affordable"

Under the government's National Development Plan for Electric Mobility, Germany is planning to put one million electric vehicles on its roads by 2020. That target is still some way off, however: at the end of 2010 there were fewer than 2,000 electric vehicles in Germany. One of the biggest hurdles to electric mobility establishing itself on the market is the price of the vehicles themselves: "We need an affordable electric vehicle. People are just not prepared to pay more for electric mobility than they are used to paying for conventional vehicles," says Professor Günther Schuh, Chair of Production Systems at RWTH Aachen University. This is something of a sore point when it comes to electric vehicles: The few electric cars that are actually available on the market – and there aren't that many of them – currently cost considerably more than comparable models with traditional combustion engines. For example, the list price for Mitsubishi's i-MiEV, the first series-produced electric car, is nigh on EUR 35,000, while the Mitsubishi Colt 1.1 ClearTec Edition, a comparable non-electric model, costs just EUR 13,000.

If drivers have to pay substantially more for a vehicle with a shorter driving range, there is a distinct risk that electric vehicles will never achieve critical mass on the market. Yet they need precisely this critical mass in order to realize the economies of scale that could bring their price down. That's something that Professor Achim Kampker, Chair of Production Management at RWTH Aachen University, is setting out to change. In 2009 he founded the company StreetScooter GmbH. His credo is as simple as it is ambitious: "We cannot wait until an expensive technology establishes itself on the market and becomes affordable for everyone. We must first establish the technology on the market by making it affordable."

The StreetScooter, a vehicle in the new category of "short distance vehicles" or SDVs, hopes to provide the solution. The idea behind the vehicle is "low range, low price" – being specially designed for short distances means that costs can be kept low. "We build only what customers really need. The rest we do without," says Professor Kampker, founder and CEO of StreetScooter. By 2013 the company hopes to produce a small series of 2,000 vehicles priced at around EUR 12,000. A set service fee for the battery, maintenance and repairs, and electricity charges, come on top of that. If the vehicle goes into mass production by 2013, Kampker envisages a price tag of around EUR 5,000 plus monthly service costs of EUR 150 to 200.

The prototype StreetScooter has a range of 120 kilometers and space for three adults plus a child's seat. It is the first tangible fruit of a network of around 70 different companies and research institutions working together to develop sustainable mobility concepts, known as "Concept Zeitgeist". As of November 2011, there were around 20 companies involved in the consortium. The firms range in size from fewer than 10 employees to over 20,000, but the majority are small and medium-sized operations. The other 50 members of the consortium are partners, companies and research institutions that are involved in research, development and production. Professor Kampker sees this diversity as key to the company's success: "Nobody has to have 'gas running through their veins' in order to make a valuable contribution to Concept Zeitgeist." The consortium also welcomes car-sharing and renewable energy businesses.

How this approach works in practice can be seen from the wide range of shareholders involved in the project. They include the Dutch leasing company Athlon Car Lease, Lübeck-based OTM GmbH which specializes in the production of lithium-ion cells, Rehau VZ AG which has developed a polymer-based modular battery concept for the StreetScooter, and the major automotive suppliers Dräxlmaier GmbH, Kirchhoff Group, Wittenstein AG and Aumann GmbH.

Conspicuously absent from the roll-call are the major automakers. "We have consciously avoided the big automotive manufacturers. This is our way of breaking up established structures and supporting small and medium-sized enterprises," says StreetScooter's website.

StreetScooter's network structure gives it real competitive advantages, according to Professor Kampker and his fellow campaigners. It allows them far more room for maneuver in designing and developing the vehicle than that enjoyed by established players. StreetScooter aims to integrate product and process development, using this lever to achieve the desired cost reductions for electric vehicles. The vehicle is

broken down into its various structural elements and one "lead engineering group" is put in charge of each module. Project teams work closely with the team responsible for production planning early on during the development phase, building the foundations for cost-efficient production processes later on. "By developing the vehicle and its production processes in parallel we are able to show how modern vehicles can be produced in a cost-efficient manner – and hence at an affordable price for consumers," says Kampker.

The team behind StreetScooter are convinced that e-mobility is not just a new drive system: it will bring about a paradigm shift in the mentality and structures of the industry. Concept Zeitgeist is about mobility as a whole. It involves more than simply putting a new type of electric vehicle on the road: it also means offering mobility services such as leasing, car-sharing, batteries, service and maintenance. Innovation is no good if demand is lacking – a problem that StreetScooter appears to have solved. In line with its strategy of focusing initially on fleet business, the company plans to first put an electric truck for Deutsche Post into series production. If all goes well, 20,000 of these delivery vehicles will eventually be seen on Germany's roads.

www.streetscooter.eu

German-Jordanian research and demonstration facility for decentralized wastewater technology

A network of universities, research bodies, businesses and political institutions

Multinational cooperation promotes sustainable water management in the Jordan basin

Jordan is one of the driest countries on earth. The country meets most of its water needs with groundwater. However, overexploitation of this valuable resource and a growing population are putting long-term water supplies at risk. Already, the water level of the Dead Sea is dropping by one meter a year.

The Jordanian government has responded by instituting a water strategy in 2009 in which conserving groundwater plays an important part. Through increased recycling of wastewater it hopes to relieve pressure on valuable water resources. Under the water strategy, the volume of recycled wastewater is to be increased by 256 million cubic meters each year until 2022 – a fourfold increase on 2010 levels.

Decentralized wastewater technology plays a critical role in the implementation of the water strategy. In 2010, a demonstration plant run by the Applied University of Al-Balqa opened in the town of Fuheis, some 20 kilometers from the capital Amman. The plant is the result of a collaboration between Jordanian and German partners. The network that enabled the construction of the demonstration plant includes the Jordanian Ministry of Water, the Applied University of Al-Balqa, the Helmholtz Center for Environmental Research (UFZ), the BDZ – an initiative for the promotion of decentralized wastewater treatment – and the companies Huber SE, ATB Umwelttechnologien GmbH, Ecoconsult and NAW. The project is supported by the German Federal Ministry of Education and Research (BMBF).

The project will be extended to larger hinterland areas over the coming years. It is hoped that it can serve other dry countries with growing water requirements as a model for the efficient, sustainable management of scarce water supplies. "The experience gained in Fuheis is helping us to optimize operating costs and the stability of the wastewater technology pilot plants in the arid Arab climate. Next, we want to put this know-how into practice on a larger scale," says project manager Dr. Roland A. Müller of the UFZ.

The demonstration plant in Fuheis is part of the SMART international research project (sustainable management of available water resources with innovative technologies). Israeli, Palestinian, Jordanian and German participants are working together to draw up an integrated water resources management strategy for the River Jordan's drainage basin. A total of 21 universities, research institutions, ministries and businesses are involved in the SMART consortium.

Given Jordan's large water requirements and small water volumes, the integrated water resource management strategy has to include all available resources: groundwater, surface water, brackish water, rainwater and wastewater. Most of the water in Jordan is in fact used for agricultural irrigation, for which treated and maximally germ-free wastewater is suitable.

econet China

An initiative of the German Chambers of Industry and Commerce in China for the promotion of German environmental technology in China

Supporting companies' first steps in the growing Chinese green tech market

In its 12th Five-Year Plan (2011-2015) the political leadership of the People's Republic of China places great emphasis on energy and environmental policies. Specifically, it aims to reduce energy intensity by 16 percent and CO_2 intensity by 17 percent by 2015.

In order to meet these targets, the Chinese central government plans to put the country's economic growth on a more sustainable footing. For this it needs suitable green technologies, which are often not available from domestic producers. Demand for sustainable products and processes is therefore likely to grow in the future, making China an attractive market for environmental technology bearing the "made in Germany" label. However, many players in the German green tech industry are small or medium-sized operations. They offer first-rate technological know-how but often lack the necessary experience in far-off markets such as China.

This is where "econet China" comes in. Its aim is to remove some of the hurdles to entering the Chinese market. It was set up by the German Chambers of Industry and Commerce in China to help German firms in the construction, energy and environmental industries position themselves on the Chinese market. To this end, the initiative offers a comprehensive portfolio of services.

econet China's services for German businesses include providing information on specific market segments and carrying out individual research projects. It can also carry out market entry studies on behalf of clients. The econet teams in Beijing and Shanghai organize delegations and company visits to potential Chinese partners. In addition, the organization comes to the aid of German companies attempting to make contact with Chinese firms, drawing on its extensive network and many years of experience doing business with China. On its website it provides an online directory where companies can enter their details. It also offers an "office in office" facility for organizations that have decided to enter to the Chinese market but want to keep the risks associated with the initial market entry phase to a minimum. Companies in this position can receive support from econet China on the personnel front: econet China will supply a local manager who is integrated into the econet China team but acts on behalf of the client company.

Besides services for individual companies, econet China plays an important role in promoting German environmental technology in China as a whole. It ensures Germany's presence on the market and acts a multiplier for German know-how in the area of green technology. A key part of its work is trade fairs, events and congresses. In September 2011, for example, it organized the Shanghai conference "Urban Strategies against Climate Change: Eco City, Low Carbon City or Green City?" attended by more than 300 town planners, architects and academics from both China and Germany.

Similarly, in November 2011, econet China organized the event "Green Manufacturing China 2011 – The Summit for Technology Solutions and Best Practices" in cooperation with Ringier, the Swiss Chamber of Industry and Commerce and the European Chamber of Commerce. Participants discussed solutions and strategies for making the Chinese production sector more sustainable. Resource intensity remains high in this sector: Chinese factories use 15 to 20 percent more resources per unit of production than the international average at present. Luckily, solutions and processes for boosting resource efficiency are a particular strength of German companies. Things look good for business in China.

www.econet-china.com

German Water Partnership e. V.

Networking the economy, research and politics

An umbrella brand for the German water sector in international markets

The German Water Partnership was officially inaugurated in April 2008 at the IFAT international trade fair for water, sewage and raw materials management in Munich. The idea behind the initiative was to bundle the competences of the German water sector and promote internationalization. The partnership – whose symbol is a drop of water in the colors of the German flag – enjoys political support from the German Foreign Office, the Federal Ministry for the Environment, the Ministry of Education and Research, the Ministry of Economics and Technology and the Ministry for Economic Cooperation and Development. These bodies are also supplying funding for the first five years of its operation.

The reasons behind this political support are clear: The water sector is an enormous growth market worldwide with global investment requirements amounting to an estimated EUR 400 to 500 billion. Emerging markets show particularly strong potential: their developing infrastructure for water supply and sewage disposal is barely able to keep pace with population growth, increasing industrialization and more intensive agricultural practices. Global demand is growing for technology throughout the entire water cycle – from catchment, filtration and disinfection to distribution and wastewater treatment.

German companies currently enjoy a strong position on international water markets. Indeed, every fourth exported item on the market bears the "Made in Germany" label. Competitors from other countries are mainly big corporations, whereas Germany's water industry is to a large extent made up of small and medium-sized enterprises with outstanding expertise in their specialist areas.

The predominance of smaller players among German companies in the water sector means that German competitors run the risk of being overlooked on international markets. Tenders for major infrastructure projects are aimed at companies that can offer entire packages rather than at small specialist firms. "International partners expect end-to-end solutions – solutions that individual German companies, especially small and medium-sized enterprises, are often simply unable to supply," says Dr. Michael Beckereit, Chairman of the German Water Partnership.

The German Water Partnership hopes to mitigate this potential competitive disadvantage by providing a sort of umbrella brand for German companies. General Manager Stefan Girod explains: "Our goal is to bundle the various companies with their different technologies, specific areas of expertise and services. They can then participate in relevant projects on the global market by working in association with other partners along the value chain."

This networking of business, academic and political players has clearly borne fruit, as shown by the number of members in the partnership: around 130 members joined in the first quarter after the initiative was launched, with a total membership of more than 330 today. The membership structure reflects the diversity of the water sector too, with representatives from along the entire value chain: universities and research bodies, public and private companies (engineering companies, component manufacturers, plant and system manufacturers, operating companies, etc.), associations and other institutions.

Thanks to the input and engagement of its members, the German Water Partnership has now grown into a vibrant network. Its members work together on various different levels. There are three task forces – covering the areas "Central Issues", "Innovation and Scientific Cooperation" and "Information" – and 17 regional sections: Africa, Brazil, Bulgaria, Central Asia, China, Croatia, Egypt/Jordan, the Gulf States, India, Iran, the Maghreb, Mexico, Romania, Russia, Turkey, Ukraine and Vietnam.

The object of the regional sections is to build robust networks, cultivate existing contacts, kick off projects and develop tailored solutions for specific challenges in the focus countries. The German Water Partnership is involved in a wide spectrum of activities, including running joint stands at key international trade fairs, participating in conferences, symposia and other events, and sending out delegations in cooperation with chambers of foreign trade.

Activities of this nature are of particular importance in countries such as Russia and China. Small and medium-sized firms find it very challenging to operate in these growth markets. When it comes to tenders for infrastructure projects, it is very difficult for small businesses without contacts or specific local knowledge to make it onto the shortlist. This is where the German Water Partnership can help: Its presence in local markets smoothes the way for its members.

An example: In Russia, the government plans to improve the supply of drinking water and wastewater treatment over the coming ten years with an annual investment of around EUR 1.9 billion. German players enjoy great success in the Russian water sector. The Russian regional section of the German Water Partnership supports this positioning with a wide range of actions. In October 2011 it organized the first "Russian-German Water Partnership Day" in Moscow, attracting not just companies from the water sector but also high-ranking officials from the Federation Council of Russia and from German and Russian government ministries.

The German Water Partnership is also active in China, a country with immense infrastructure needs in the area of water supply and wastewater management. German water technology can make a strong contribution here, and the Chinese market is one of the network's focus regions. German products and processes are presented under a single umbrella brand in China. The network also organized the "German Water Partnership Roadshow" in cooperation with the China Urban Water Association in the fall of 2011. At the event, participants presented possible methods for improving energy efficiency in sewage treatment plants and took part in discussions.

Another project – this time in Croatia – shows that the German Water Partnership is not just interested in short-term export successes. In June 2011, a training and competence center in the water sector was opened in the city of Karlovac. The object of the joint German-Croatian project behind it, coordinated by the German Water Partnership, is to train specialists in the water and sewage sector in Croatia and neighboring countries.

www.germanwaterpartnership.de

Agraferm Technologies AG

Pfaffenhofen an der Ilm
Planning, building and managing biogas systems

Specialist know-how in biogas systems smoothes the way into international markets

The Agraferm Group, based in Pfaffenhofen an der Ilm (Bavaria), is one of the few plant manufacturers offering specialist know-how in all types of biogas production – from renewable raw materials, organic household waste and industrial waste. Its key skills cover a wide range of activities, from the planning, construction and running of biogas systems to providing technical and biological assistance. The Group comprises a number of companies operating in these different areas, including Agraferm Technologies AG, BTA International GmbH, Agraserv GmbH and foreign subsidiaries in Luxembourg, Italy and France.

As well as building biogas systems, service provision is an important area of business for the Group. In fall 2011, Agraferm took over the provision of biological support for 23 renewable raw material biogas production systems of between 19 kilowatts and 1 megawatt on behalf of the energy company Danpower. This major contract also gives Agraferm responsibility for laboratory analyses and micro- and macro-nutrient analyses.

Agraferm's vision is to become "one of the most important and valued producers of biogas technology worldwide." To achieve this goal, it plans to further develop the specialist technical know-how that it has built up over more than two decades of experience in the sector.

Agraferm has particular expertise in the area of "high-load" fermentation of energy plants. "High load" refers to the organic loading rate of the fermenter: a loading rate below 2 kilograms of organic dry matter (ODM) per m^3 is considered low; anything over 5 kilograms is high load. The Agraferm Group has developed a technology that offers solutions with very high viscosities without compromising on operating reliability, flexibility or gas yield.

As part of its biological support service, the Agraferm Group also offers clients a product for improving the performance of existing biogas systems. Methanomex nutrients enable extremely high fermenter loads while ensuring stable operation, thereby improving cost-effectiveness. A further criterion for evaluating the cost-effectiveness of biogas production systems is their energy consumption. Here, again, Agraferm's systems outperform the industry average, according to company data.

The Agraferm Group targets growth not just in Germany but also further afield. It has developed a strategy for internationalization and is already active in the United Kingdom, Italy, Luxembourg, Poland, the Czech Republic, Slovakia and Latvia. Important milestones in the firm's international expansion have been entering the Italian and Luxembourg markets and commencing operations at the biogas facility in Taverham (Norfolk, United Kingdom) in fall 2011. The new biogas facility was built by Agraferm on behalf of Future Biogas Ltd. and will process around 25,000 tons of maize silage and grass cuttings a year, providing a cogeneration unit with approximately 1,413 kilowatts of power – electricity for 2,500 households.

Central and Eastern Europe is also an important target market for Agraferm. The Group has planned and built a two-megawatt biogas facility with integrated stillage-treatment system in Kalsnava, a municipality some 150 km from the Latvian capital Riga. The facility started operations in summer 2011. Agraferm carried out the project on behalf of SIA Biodegviela, a Latvian producer of ethanol. The company produces around 38,000 liters of bio-ethanol a day, creating some 160,000 m3 of stillage each year. Stillage is the by-product of distillation, a thin slurry containing protein, fat and minerals. Traditionally it is used in fertilizers and animal feeds, but thanks to Agraferm's technology it can be fed into the biogas facility to produce electricity and heat. "High-load fermentation, especially the fermentation of monosubstrates such as stillage, demands great skill as we are dealing with a sterile, high-temperature substrate," says Christian Heck, Director of Technology at Agraferm Technologies AG.

www.agraferm.com

Remondis AG & Co. KG

Lünen
Water and environmental services

Recycling and waste separation – A new era in waste management in Russia

"Waste management has enormous potential in Russia. But before we can turn rubbish into rubles, we need efficient collection and treatment systems." This was the conclusion reached by an article published by Germany Trade and Invest (GTAI), investigating the Russian recycling market and the great potential it harbors for waste management companies.

The Remondis Group has been busy exploiting this potential since 2008. A family company based in Lünen, now with almost 20,000 employees worldwide, Remondis has already set up joint ventures for managing household waste in four Russian cities.

The company is doing pioneering work in this largely undeveloped area in Russia. Today, over 90 percent of solid household waste in the Russian Federation ends up in one of the country's two-million hectares of landfills and dumps. Russia is the biggest country in the world in terms of land mass – some 17 million km^2 of it – but space for landfill is rapidly running out, particularly in the areas surrounding major conurbations. What's more, many of these landfills are environmental time bombs where hazardous materials have not been disposed of properly and toxic substances can seep into the underlying soil and groundwater. Compared to other countries, Russia's rate of recycling is relatively low: 40 percent for paper, 5 percent for plastic, and 35 percent for glass. The country has a long way to go in terms of recycling, with valuable resources rotting in landfill sites instead of being reused by industry.

Russia's government is eager to take action, however. It is currently discussing the idea of setting up a public holding company to do so. In the regions, public-private partnerships are already helping deal with the garbage crisis. Here, there are opportunities for foreign firms to get involved. Since its entry into the Russian market, the Remondis Group has focused on public-private partnerships of this type. Indeed, according to the GTAI, it is currently the only foreign investor that is active in the field of waste management in multiple regions of the Russian Federation.

In a 2009 pilot project, the public-private partnership REMONDIS Dzerzhinsk, formed by Remondis and a municipal partner, took over responsibility for managing household waste in the Nizhny Novgorod region. The waste collection infrastructure was reorganized and updated, with new garbage collection vehicles, garbage cans and waste facilities. Special containers for glass, paper, plastics and other waste were introduced, making it possible to sort waste.

When the project started, it was difficult even translating "sorting waste" into Russian: the concept simply didn't exist outside specialist circles. REMONDIS Dzerzhinsk launched a major public information campaign supported by the municipal authorities to explain to the area's 240,000 residents what exactly sorting waste means, how you are supposed to do it and what the point of it is. The campaign included posters, flyers, radio and TV commercials and working with schools.

Remondis has since copied the Dzerzhinsk model in other cities and regions in Russia. For example, in the District of Naro-Fominsk, south-west of Moscow, the company has again set up a public-private partnership with a former municipal company and taken over responsibility for waste disposal.

The latest Russian project of Remondis is in Saransk, a city of some 300,000 inhabitants, 650 kilometers from Moscow. REMONDIS Saransk is a joint venture between Remondis and the municipal company Spezavtohozyaystvo Saranskoe. Operations commenced in September 2011. REMONDIS Saransk is responsible for the collection and disposal of household waste. Once again, Remondis has invested heavily in new garbage cans and eight modern garbage collection vehicles.

The Remondis Group plans to expand its activities in the Russian regions further still. Its next step in Saransk, for instance, will be to get involved in rehabilitating landfill sites and to help modernize a waste sorting plant.

Remondis is involved in more than just waste management in Russia. In Arzamas, a city of 100,000 inhabitants situated some 400 kilometers east of Moscow, the company has founded a joint venture responsible for supplying water and collecting and treating wastewater.

www.remondis.de

List of tables and figures

Tables

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