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Renewable energy: a 2030 scenario for the EU

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Foreword

Utrecht, October 2012.

In February 2011, Ecofys published The Energy Report (TER), a global scenario for a transition to a fully renewable global energy system.

This report by Ecofys for WWF's European Policy Office (EPO) was written to specifically answer questions by WWF EPO with respect to the European implications of TER.
The reader is advised to read the global report in order to obtain additional background information pertaining to methodology and general input assumptions which have a direct bearing on the present report.

Selected sources for TER are:

Full report and Ecofys 4 page summary:	http://www.ecofys.com/energyreport
Full report and WWF 10 page summary:	http://www.panda.org/energyreport
Scientific paper:	http://dx.doi.org/10.1016/j.esr.2012.07.003
Scientific paper on bioenergy:	http://dx.doi.org/10.1016/j.biombioe.2011.12.049

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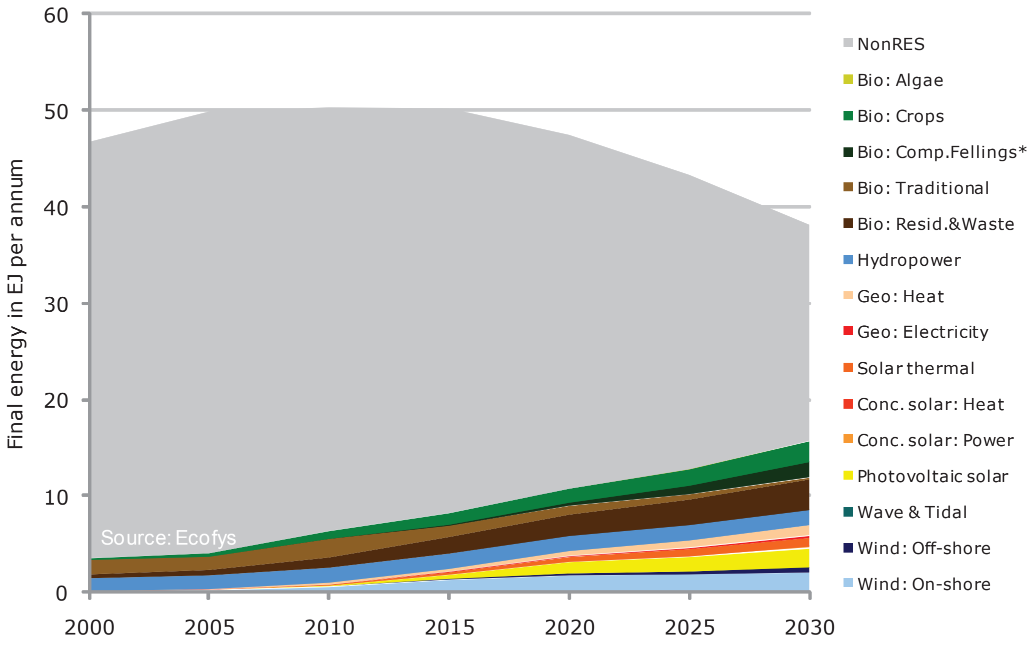
Executive Summary

The European Union has adopted clear emission reduction, energy savings and renewable energy targets for 2020: 20% emission reduction of GHG compared to 1990; 20% of primary energy savings and 20% renewable energy share in energy consumption. Even if the targets are met in 2020 this does not ensure that climate change is kept within 2° Celsius in the long run.

We have derived an ambitious, yet feasible energy scenario for the EU27 for 2030 which is consistent with WWF's global TER vision for a fully renewable global energy system by 2050. The energy pathway set out in the global TER study would be consistent with an emissions pathway to stay below the 2°Celsius target.

Our EU27 energy scenario envisages a RES share of 41% in 2030, which includes 19% from sustainable biomass. Within the power sector, which is easier to decarbonise than heat and fuels, the scenario reaches a 65% share of RES. Energy savings on primary energy are estimated to be ~38% in this scenario compared to the 2007 baseline. Energy related emission reductions compared to 1990 are estimated to be 50%.

Compared to other analysed EU scenarios for 2030 the TER EU27 analysis has low final energy demand and a RES amount comparable to other studies. The RES share is higher than those of the EU roadmap, but below the advanced scenario of EREC. The investment / cost / benefit balance for EU27 will be comparable to results at the global level with slightly higher net costs (relative to global TER results).



Development of the energy supply from RES and non RES until 2030

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1 Introduction

1.1 General background

The European Union has adopted clear emission reduction, energy savings and renewable energy targets for 2020 in[1]:

- 20% emission reduction of GHG compared to 1990
- 20% of primary energy savings[2,3]
- 20% renewable energy share in energy consumption including heating and cooling across EU27 and 10% share of renewable energy specifically in the transport sector, with legally binding national targets and action plans (NREAP)[4].

Even though analyses of the NREAPs show that the RE targets can be met if plans are fully implemented[5], this is not so clear for the 20% primary energy savings. The Energy Efficiency Directive (EED) is designed to close the gap, but it is not certain that the energy savings target will be met in 2020[6].

Even if the targets are met in 2020 this does not ensure that climate change is kept within 2° Celsius in the long run. To achieve that goal, both the European Council and Parliament have already set the objective in 2009 of reducing greenhouse gas emissions by 80-95% by 2050 (compared to 1990) and the European Commission published a 'Roadmap for moving to a competitive low carbon economy in 2050' in 2011 which makes the economic case for decarbonisation[7]. In all scenarios presented in this roadmap, renewable energy sources play a large role.

Despite these targets, the current financial crisis combined with cost reductions and a large growth in renewables and associated costs for government funded renewable energy schemes, have led to a reaction of some governments to cut down on these favourable schemes. On 6 June 2012 the European Commission presented a communication and impact assessment[8] in which it acknowledges that it needs to provide a stable investment climate much earlier than 2018 (when it is legally obligated to set post 2020 targets) to reach its ambitions for 2050. The options the Commission considers in the impact assessment are:

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[1] The EU energy and climate package, see http://ec.europa.eu/clima/policies/package/index_en.htm .

[2] The policy target to save 20% of primary energy in the EU in 2020 originates from the 2005 Green Paper on Energy Efficiency. The target was adopted by the European Council on 17 June 2010 as part of the new 'Europe 2020' strategy.

[3] Compared to the baseline of Primes 2007 for EU, as published in EC DG Energy and Transport, European Energy and Transport—Trends to 2030 Update 2007, 2008.

[4] EC. Directive 2009/28/EC of 23 April 2009 on the promotion of the use of energy from renewable sources. European Commission (EC), Brussels, 2009. See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF

[5] Ragwitz, A et.al., Assessment of National Renewable Action Plans; final report in REPAP2020, Fraunhofer Institute & Vienna University of Technology, 2011.

[6] On 24 June 2012 a final text was published which the European parliament approved on 11 September, see http://www.europarl.europa.eu/document/activities/cont/201207/20120705ATT48389/20120705ATT48389EN.pdf and http://www.europarl.europa.eu/news/en/pressroom/content/20120907IPR50808/html/Energy-efficiency-billions-to-be-made-in-savings

[7] COM(2011)112, 8 March; COM(2011)144, 28 March; COM(2011) 885/2.

[8] SDW/2012/149 and SDW/2012/164 and COM/2012/271.

1. Business as usual
2. Decarbonisation with no renewables targets
3. Post-2020 national renewables targets/coordinated support
4. Post-2020 EU renewable target/harmonised measures

In this ongoing debate on decarbonisation and renewable energy targets, WWF wants to be equipped for the discussion with its own realistic proposal. The background for WWF is that the world needs to transition from its current unsustainable energy paradigm to a future powered entirely by renewable energy sources. Only by making such a transition will we be able to avoid the very worst impacts of climate change. This global scenario, set in 2050, is presented in the WWF Energy Report[9]. It shows that this future is within our reach on the global scale, and provides insight into how it can be achieved.

1.2 Goal and Result

This report develops 2030 renewable energy and energy savings targets[10] for the EU which are in line with the methodology and goal (almost 100% RES in 2050) of The Energy Report (TER). Specifically, the report:

- Develops achievable and ambitious, sector specific, EU 2030 RE targets.
- Develops a complementary target for energy savings in the EU, expressed as an absolute amount of primary energy consumption in 2030.
- Compares the developed targets, as well as their methodology and assumptions, to 2030 targets produced by other organisations.
- Describes and explains the different considerations which WWF took into account when developing its 2030 RE and energy savings targets at the European level.

1.3 Structure of this report

In order to answer the questions above we have structured the report as follows:
In Chapter 2 we discuss the current progress on renewable energy in the EU. In Chapter 3, we present the adapted TER results on RES share for EU27 as well as results of other EU-wide energy scenario studies. In Chapter 4 we discuss the choices and assumptions behind the TER RES share in the EU on: energy efficiency, material efficiency, electricity imports, biomass and investments and savings. We end with conclusions in Chapter 5.

The report is designed to answer the questions WWF posed for this report. To make these questions explicit, we state them in *italics* at the beginning of each section.

[9] WWF The Energy Report, 2011: http://www.panda.org/energyreport
[10] These targets are derived from an integrated energy scenario. They must not be confused with the total mid- and long-term *potential* for renewable energy in Europe.

2 Context and current progress on Renewable Energy in the EU

In this chapter we analyse the current progress on RE in the EU27. In Section 2.1 the current RES share is shown per country and sector, in Section 2.2 the global progress on RES share is compared to the global TER analysis, in Section 2.3 the growth needed to reach the 2020 targets is analysed and in Section 2.4 the current emission reduction is analysed.

2.1 Progress towards EU 2020 RE targets

What progress has been made towards EU 2020 renewable energy targets (by sector and by country)?

In 2010, almost 13% of the gross final energy consumption in the EU27 was from renewable sources[11]; in 2000 this was 7.4%. Among all the member states, Germany is the largest producer of renewable energy, more than 1 EJ, while Sweden has the largest share in renewable energy consumption, more than 40%, partly because of its large hydropower production (see Figure 1 and Figure 2, respectively).

[11] Eurostat. Energy statistics of the European Union, 2012. http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/introduction [last accessed 24 August 2012]

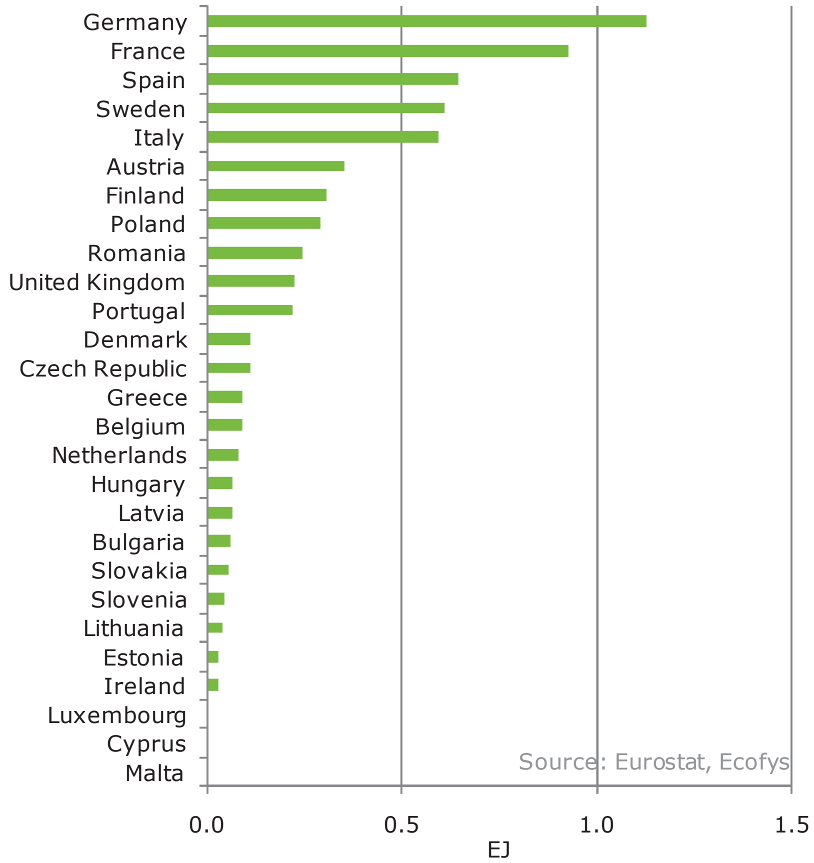

Figure 1 Absolute gross final RES consumption in all EU27 Member States in 2010 [EJ]. Source: Eurostat (2012)

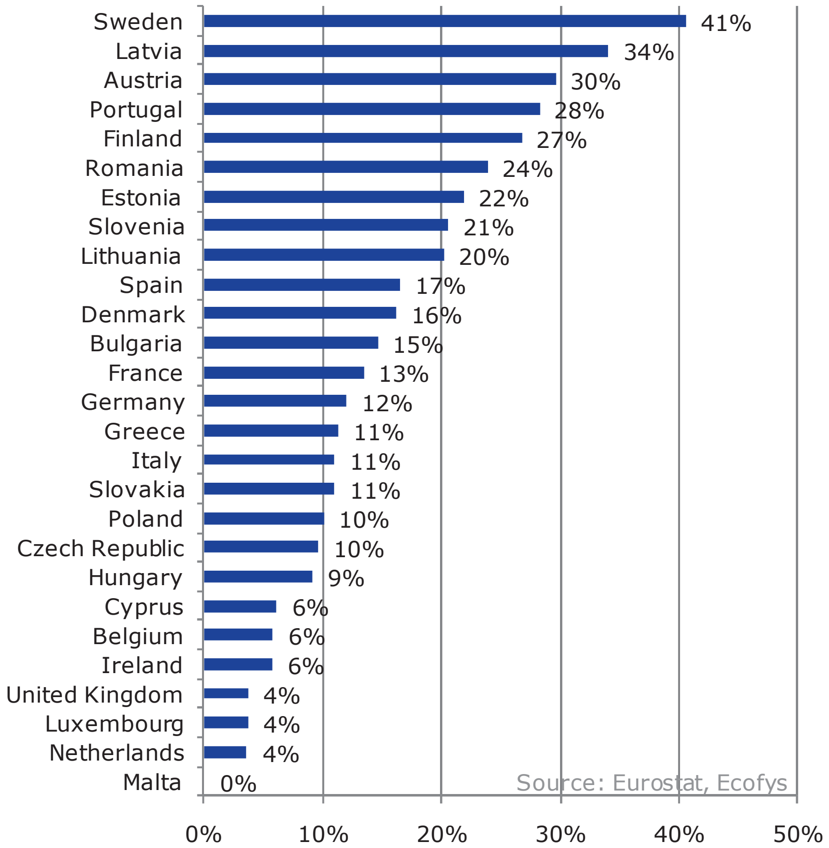

Figure 2 Share of RES in gross final consumption in all EU27 Member States in 2010 [%]. Source: Eurostat (2012)

Looking at the three main energy demand sectors[12,13] (Buildings, Transport and Industry) in Figure 3 and Figure 4, we observe that the highest renewable energy consumption (both absolute and in shares) takes place in the building sector. Closer analysis shows that this can mainly be attributed to the consumption of biomass for heating[11].

[12] Based on Eurostat (2012). In the figures, own energy consumption in conventional thermal power and heat installations and distribution losses are allocated to the three sectors, proportional to their (centrally generated) electricity and heat consumption.
[13] These three sectors make up for 96% of total final energy consumption.

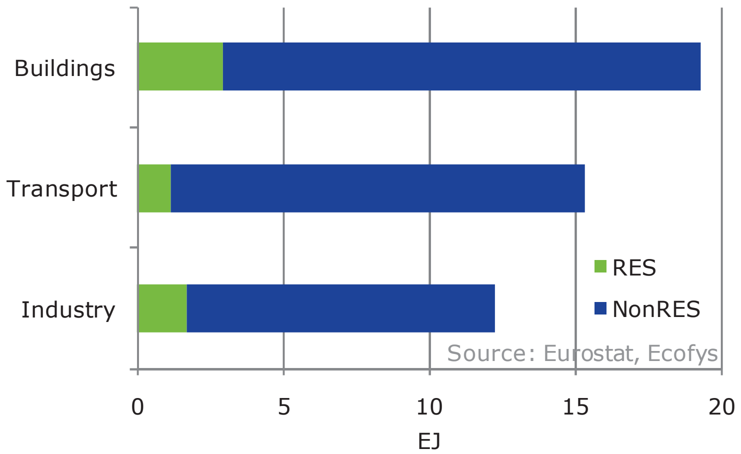

Figure 3 Absolute gross final RES consumption in the EU27 in 2010 [EJ], broken down per sector. Source: Eurostat (2012)/Ecofys (2012)

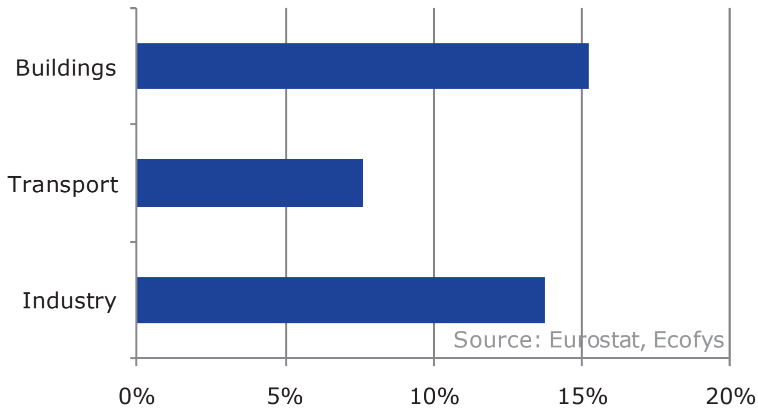

Figure 4 Share of RES in gross final consumption in the EU27 in 2010, broken down per sector. Source: Eurostat (2012)/Ecofys (2012)

2.2 Actual global progress on RES deployment compared to global TER analysis

Since WWF developed its global energy vision (The Energy Report, 2011) how does actual progress on RES deployment compare to that projected by WWF?

As can be seen in Table 1, in the global TER analysis, the global total final consumption in 2010 would have been 327 EJ, of which 59 EJ would have been from renewable energy sources. For comparison, according to the IEA (2012), global total final consumption added up to 330 EJ by 2009, of which 60 EJ came from renewable energy. The overall RES TER projections for 2010 are thus in line with the actual developments in renewable energy consumption in terms of final energy at the global level. However, this may have been achieved e.g. with a reduction in underlying activity, caused by the economic crisis, rather than large advances in energy efficiency. A renewed comparison in 2015 may look very different. Note that the actual development may be different, e.g. the RES mix in reality may include more biomass and less wind or solar than TER.

Table 1 Comparison of global TER analysis and IEA statistics on 2010 prognosis

	Global TER analysis 2010	IEA statistics 2010
Global total final consumption (EJ)	327	330
RES (EJ)	59	60
RES share	18%	18%

2.3 Continued growth of RES share in the EU

If the share of RES in the energy mix continues to grow at the same pace over the next 18 years as it has over the past 12 years, what will the RES share in the EU (by sector and by country) be in 2030?

Table 2 shows the historical and linearly extrapolated development in RES share per country; Table 3 shows the same per demand sector[11]. The extrapolation was based on the average annual increase between 2000 and 2010 for both RES and total final gross consumption (i.e. a linear extrapolation based on growth rates).

Table 2 Developments in RES share (of final gross consumption) in the EU27 Member States between 2000 and 2010 and extrapolated shares until 2030. Source: Eurostat (2012)/Ecofys (2012)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2015	2020	2025	2030
EU27	7%	7%	7%	7%	8%	8%	9%	10%	11%	12%	13%	*16%*	*18%*	*21%*	*23%*
Austria	26%	25%	24%	21%	22%	23%	25%	27%	28%	31%	30%	*31%*	*32%*	*33%*	*34%*
Belgium	1%	1%	2%	2%	2%	2%	3%	3%	3%	5%	6%	*8%*	*10%*	*13%*	*15%*
Bulgaria	8%	7%	8%	9%	9%	10%	10%	9%	9%	11%	15%	*18%*	*21%*	*25%*	*28%*
Cyprus	3%	2%	3%	3%	3%	3%	3%	4%	5%	6%	6%	*7%*	*9%*	*10%*	*11%*
Czech Republic	5%	5%	6%	5%	6%	6%	6%	7%	8%	9%	10%	*12%*	*14%*	*16%*	*19%*
Denmark	9%	9%	10%	11%	12%	12%	13%	14%	15%	15%	16%	*19%*	*23%*	*26%*	*28%*
Estonia	18%	17%	18%	18%	18%	18%	16%	17%	19%	21%	22%	*23%*	*25%*	*26%*	*27%*
Finland	25%	24%	24%	23%	25%	24%	24%	25%	27%	26%	27%	*27%*	*28%*	*28%*	*29%*
France	10%	10%	9%	9%	9%	9%	9%	10%	12%	13%	13%	*15%*	*17%*	*19%*	*20%*
Germany	4%	4%	4%	5%	6%	7%	8%	10%	10%	10%	12%	*16%*	*21%*	*25%*	*30%*
Greece	7%	6%	7%	7%	7%	7%	8%	8%	8%	9%	11%	*13%*	*15%*	*17%*	*19%*
Hungary	5%	5%	5%	5%	4%	4%	5%	6%	7%	9%	9%	*11%*	*13%*	*15%*	*17%*
Ireland	2%	2%	2%	2%	2%	3%	3%	3%	4%	6%	6%	*7%*	*9%*	*10%*	*11%*
Italy	5%	6%	5%	5%	6%	5%	6%	5%	7%	10%	11%	*14%*	*17%*	*20%*	*23%*
Latvia	32%	32%	31%	31%	33%	33%	31%	30%	30%	36%	34%	*35%*	*35%*	*36%*	*36%*
Lithuania	15%	16%	17%	17%	17%	17%	17%	17%	19%	21%	20%	*22%*	*24%*	*25%*	*27%*
Luxembourg	1%	1%	1%	1%	1%	1%	2%	4%	4%	4%	4%	*5%*	*6%*	*6%*	*7%*
Malta	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	*0%*	*0%*	*0%*	*0%*
Netherlands	1%	1%	1%	1%	2%	2%	2%	3%	4%	4%	4%	*5%*	*6%*	*6%*	*7%*
Poland	6%	7%	7%	7%	7%	7%	7%	7%	8%	9%	10%	*12%*	*13%*	*14%*	*15%*
Portugal	19%	20%	17%	21%	18%	16%	21%	22%	22%	24%	28%	*33%*	*37%*	*41%*	*45%*
Romania	16%	13%	14%	15%	17%	18%	17%	18%	20%	22%	24%	*28%*	*32%*	*36%*	*40%*
Slovakia	4%	7%	6%	5%	6%	7%	7%	9%	9%	12%	11%	*14%*	*17%*	*19%*	*21%*
Slovenia	17%	16%	15%	14%	16%	15%	15%	14%	15%	20%	21%	*22%*	*24%*	*25%*	*26%*
Spain	8%	9%	8%	9%	8%	8%	9%	10%	11%	14%	17%	*20%*	*23%*	*26%*	*29%*
Sweden	36%	35%	32%	30%	32%	36%	36%	38%	40%	41%	41%	*43%*	*45%*	*47%*	*49%*
United Kingdom	1%	1%	1%	1%	1%	1%	2%	2%	3%	3%	4%	*5%*	*7%*	*9%*	*10%*

Table 3 Developments in RES share (of final gross consumption) in industry, buildings and transport in the EU27 2000 and 2010 and extrapolated shares until 2030. Eurostat (2012)/Ecofys (2012)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2015	2020	2025	2030
Industry	9%	9%	8%	8%	9%	9%	10%	11%	12%	13%	14%	*17%*	*21%*	*25%*	*30%*
Transport	1%	1%	1%	1%	1%	2%	3%	4%	5%	7%	8%	*11%*	*14%*	*16%*	*19%*
Buildings	11%	11%	11%	11%	11%	11%	12%	13%	13%	14%	15%	*17%*	*18%*	*20%*	*21%*

NB: High share of RES in industry is also caused by a decrease in final energy demand in this sector.

Figure 5 shows the historical data (2000-2010) and extrapolation of RES deployment in final consumption in EU27. With linear extrapolation, 23% of RES share is reached in 2030 (12 EJ), in line with the results in Table 3.

As linear extrapolation may be underestimating an accelerated growth in RE, we also show an exponential extrapolation, which reaches a RES share of 39% in 2030 (20 EJ). Final consumption was linearly extrapolated in both cases.

The analysis shows that in order to reach the 2020 target of 20% RES share, higher than current growth rates are needed. Most National Renewable Energy Action Plans of the different Member States plan an accelerated growth towards 2020, in accordance with the Renewable Energy Directive. It must be noted that if final consumption decreases without a reduction in consumption of renewable energy, the RES share will grow.

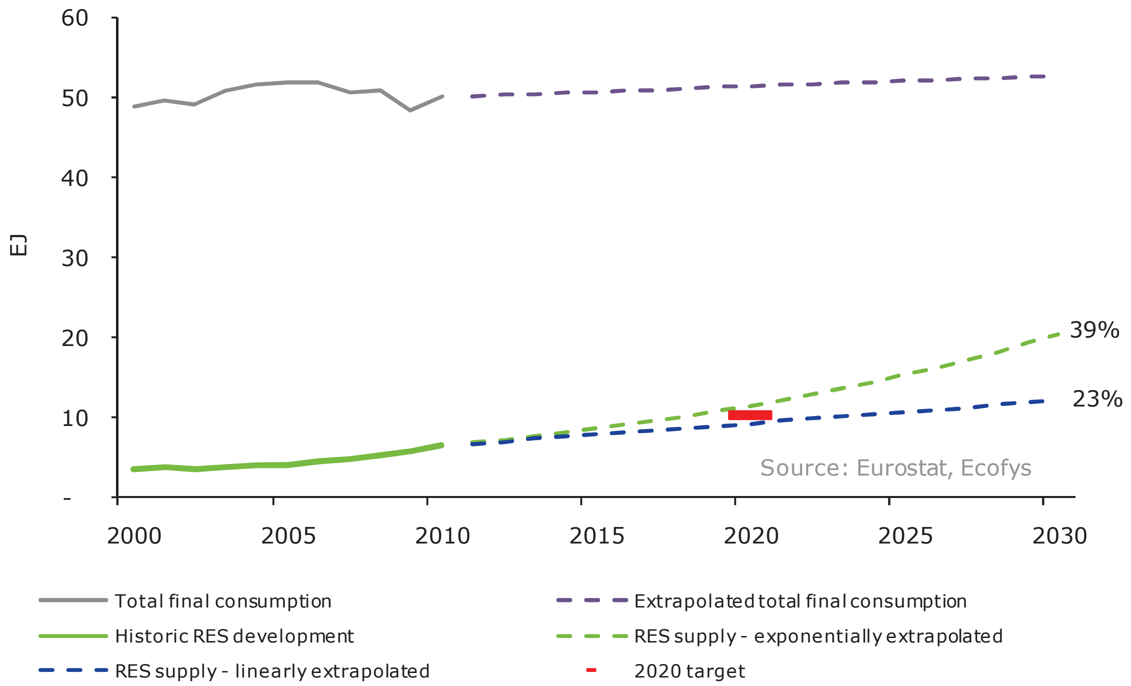

Figure 5 Extrapolation of RES deployment in final consumption from historical data: linear (blue) and exponentially (green) and historical final consumption. Eurostat (2012)/Ecofys (2012)

2.4 What contribution has renewable energy already made to reducing CO_2 emissions towards the 2050 target?

In 1990, EU27 energy related CO_2 emissions were just above 4 $GtCO_2/a$[14]. The EU roadmap 2050 visions range between an 80 and a 95% emission reduction compared to this 1990 value. For a 90% emission reduction target emissions should thus be reduced to 0.4 $GtCO_2/a$ by 2050. In 2010 emissions were 3.7 $GtCO_2/a$, i.e. a reduction of more than 3 $GtCO_2/a$ is required with respect to that year[15].

For comparison, the renewable energy capacity which has been added between 2000 and 2010 avoids around 0.4 $GtCO_2/a$, compared to the case where the same amount and type of energy would have been produced from non-renewable sources.

[14] EC. EU energy trends to 2030 – update 2009. European Commission (EC)- Directorate-General for Energy, Brussels, 2010. doi:10.2833/21664 http://ec.europa.eu/clima/policies/package/docs/trends_to_2030_update_2009_en.pdf

[15] Note that the reduction requirement of 3 $GtCO_2/a$ is a lower historic bound because energy using activities are expected to increase the reduction burden by 2050.

3 2030 EU renewable energy share from TER

This report develops 2030 renewable energy and energy savings targets for the EU which are in line with the methodology and goal (almost 100% RES in 2050) of The Energy Report (TER). The reader is advised to read the global report in order to obtain additional background information pertaining to methodology and general input assumptions which have a direct bearing on the present report. Appendix A provides the summary of the global TER report.

In this chapter we describe the sectoral energy intensity development towards 2030 in Section 3.1. This energy intensity development combined with the activity development leads to an estimated final energy demand per sector and carrier (electricity, high and low temperature heat and fuel). The final energy demand is matched to sources (renewable, fossils and nuclear) which can deliver this[16]. The share of RES in this scenario is limited by the deployment potential for some RES sources[17] and by system constraints for others (see Appendix B). The energy demand development and the (RES) energy supply system following from the TER analysis for EU27 are described in Section 3.2. The resulting CO_2 emissions follow in Section 3.3 and we make a comparison with results from other scenario studies in Section 3.4.

A more detailed discussion of the methodology followed with regard to the change in assumptions for Europe and comparison of TER results with historic data is given in Appendix A.

3.1 Sectoral development of energy intensity

For the development of energy intensity per sector we follow the methodology of the global TER analysis. For Europe these developments are described below per demand sector: industry, buildings and transport[18].

For industry this is summarised as follows:

- Aluminium, cement, steel and paper ('A' sectors in the global TER analysis) have *intensity[19] levels of 60% (aluminium, cement) to 70% (steel, paper)[20] in 2030* compared to 2000, by increased use of recovered input materials or alternative routes, ambitious refurbishment of existing plants to meet performance benchmarks, stringent requirements for using best available technology (BAT) in all new plants, and continuing improvements of BAT over time.

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[16] When taking into account their deployment potential over time and certain system constraints for supply driven RES (see Appendix B). Biomass is used as a last option after other RES.
[17] In the TER global analysis the deployment potential is a time dependent (increasing over time) realisable potential.
[18] Since historically the sectors industry, buildings and transport represent 96% of the final energy demand we report numbers only on these sectors separately. RES electricity is distributed to these sectors as share of electricity demand.
[19] Energy intensity in industry is measured in energy per tonnes product.
[20] For more detailed numbers, the reader is referred to Table 4 in Deng et al. (2012) doi: 10.1016/j.esr.2012.07.003

- On recycled steel OECD countries have a higher fraction of recycling rate than non OECD countries
- Other sectors e.g. food, chemicals ('B' sectors in the global TER analysis) are assumed to have an annual efficiency improvement of 2%, which may be obtained through improved process optimisation, more efficient energy supply, improved efficiency in motor driven systems and lighting, as well as sector-specific measures.

For buildings, the measures which *result in 40% (commercial) to 50% (residential) of heat intensity*[21] *in 2030 compared to 2005 and 90% (commercial) to 120% (residential) for electricity intensity*, are as follows:

- Existing pre-2005 stock (~75% of European building stock (floor space) in 2030):
  - Retrofitting to ambitious energy efficiency standards at retrofit rates of up to 2.5%, which is high compared to current practice, yet considered feasible. In 2030 ~45% of the European existing stock is retrofitted.
  - For a given retrofit, on average, 60% of the heating needs could be abated by insulation and ventilation systems with heat recovery mechanisms.
  - A quarter of the remaining heating and hot water need would be met by local solar thermal systems, the rest by heat pumps.
  - Cooling will be provided by local, renewable solutions where possible.
  - Electricity needs increase per floor area due to increased cooling demand.
- New stock (~25% of European building stock (floor space) in 2030):
  - Increasingly, new buildings will be built to a 'near zero energy use' standard, reaching a penetration of 100% of new buildings by 2030. By 'near-zero energy use' we mean buildings which have an energy use at levels comparable to the passive house standard developed in Germany. These highly energy efficient buildings have very low heat losses through the building envelope (insulation and improved windows) and almost no losses from air exchange (use of heat recovery systems).
  - The residual heat demand is covered by passive solar and internal gains, renewable energy systems in the form of solar thermal installations and heat pumps; this building type is an all-electric building.
- The electricity use in existing and new buildings is affected by an increase in appliances use and the requirements for powering heat pumps. This increase is only partially offset by an increase in efficiency of appliances, lighting and heat pumps.

For transport the measures, which *result in an intensity*[22] *of ~70% in 2030 compared to 2000 for freight transport and ~60% for passenger transport*, are as follows;

- Moving to efficient technologies and modes of employment, e.g. trucks with reduced drag, improved air traffic management or reduced fuel needs in hybrid buses.
- Electrifying the mode as far as possible e.g. electric cars or plug in hybrids in urban environments[23], and electric rail systems[24]
- As a last step, providing the fuel from sustainable biomass, where possible.

[21] Energy intensity in buildings is measured in heat or electricity needed per m2 floor space.
[22] Energy intensity in transport is measured in energy per person or tonnes km.
[23] 90% of the passenger kilometres will be provided from electric sources in urban environments in 2050.
[24] ~95% electricity in rail in 2030.

- A shift to plug-in hybrids and/or electric vehicles becoming the main technology choice for light duty vehicles[25].
- Long-distance trucks undergoing large efficiency improvements due to improved material choice, engine technology and aerodynamics[26]. A shift to fully electrified delivery vans covering 'the last mile'[27].

Most OECD-assumptions we used for efficiency development in the global TER analysis were relevant for Europe. Only in the building sector we shortened the time of implementation of passive houses in new buildings to align with the Energy Performance of Buildings Directive(EPBD)[28] to 2025.

3.2 Results on share and absolute amount of RES

What could WWF's overall and sectoral targets for the amount of RES in the EU's energy mix in 2030 be?

From TER we derive the amount and share of RES in the EU27 energy mix in 2030, overall and by sector—industry, transport, buildings. Below we will present these in separate graphs and tables.

[25] This shift will be complete in 2050.
[26] Rather than moving to electric transport which is considered less useful due to the prohibitive size and weight of batteries required with current technology.
[27] This shift will be complete in 2050.
[28] The EPBD(DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings. http://www.energy.eu/directives/2010-31-EU.pdf) , which stipulates that all new buildings must meet near-zero energy targets by 2020 across EU27 and public buildings after 2018.

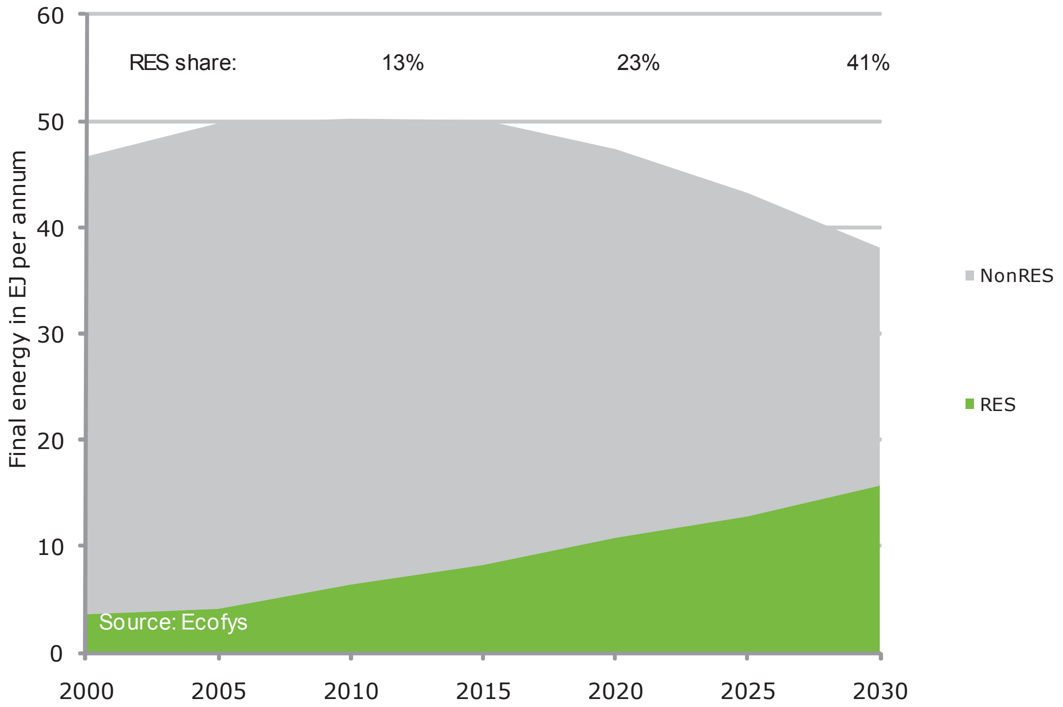

Figure 6 Energy supply for all sectors from RES and non RES until 2030[29]

For the total energy system in 2030 the RES share is envisaged to be 41% (16 EJ) in EU27[30]. Both the absolute growth in RES and the decrease in final energy due to efficiency improvements contribute to the growth in RES share.[31] The shape of the curve results from the interplay of different intensity decreases in the different sectors and different growth assumptions for the various RES sources.

In the TER global model the increase in intensity and RES share started in 2005 (TER base year is 2005). This means that in order to reach the 41% RES share in EU27, these actions should have started in 2005.

The RES share in final energy demand of heat is 35% in 2030. In fuels (industry and transport) it is 29%. The RES share in electricity is 65% in 2030.

The share from supply driven RES-E sources[32] in total power supply is ~43% in EU27. The remaining ~22% of renewable electricity is supplied by demand driven sources, i.e. hydropower, geothermal

[29] NonRES means non-renewables, i.e. fossil and nuclear sources.

[30] In TER heat pumps are treated as energy saving, rather than RE production. In the RES directive heat pumps are treated as RE production.

[31] Note that the total final consumption as defined in TER does not include "Own Use in Electricity, CHP and Heat Plants" and distribution losses, while this is included in the definition of renewable energy shares in the Renewable Energy Directive (DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL - on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.). This causes the gross final consumption in 2005 from Eurostat to be around 3.5% higher than the (2005) final energy consumption here.

[32] Supply driven power or non-dispatchable power options are those whose generation at any given hour depends on the availability of the energy source. e.g. PV, wind and ocean energy.

power biomass and CSP. The remaining 32% of electricity comes from non-renewables. In the TER analysis the share of electricity from supply driven sources is capped at a level below 100% due to system constraints (see more in Appendix B). For Europe, this limits the feed in of supply driven electricity in 2030[33] to around 45%.

Note that the deployment potential for supply driven RES sources exceeds this usage of RES electricity. Therefore, if our grid systems could be improved faster to take up more than 45% of supply driven renewable electricity by 2030 this potential could be used and the RES share could be higher. Note however, that even the 45% limit requires substantial re-structuring and investment.

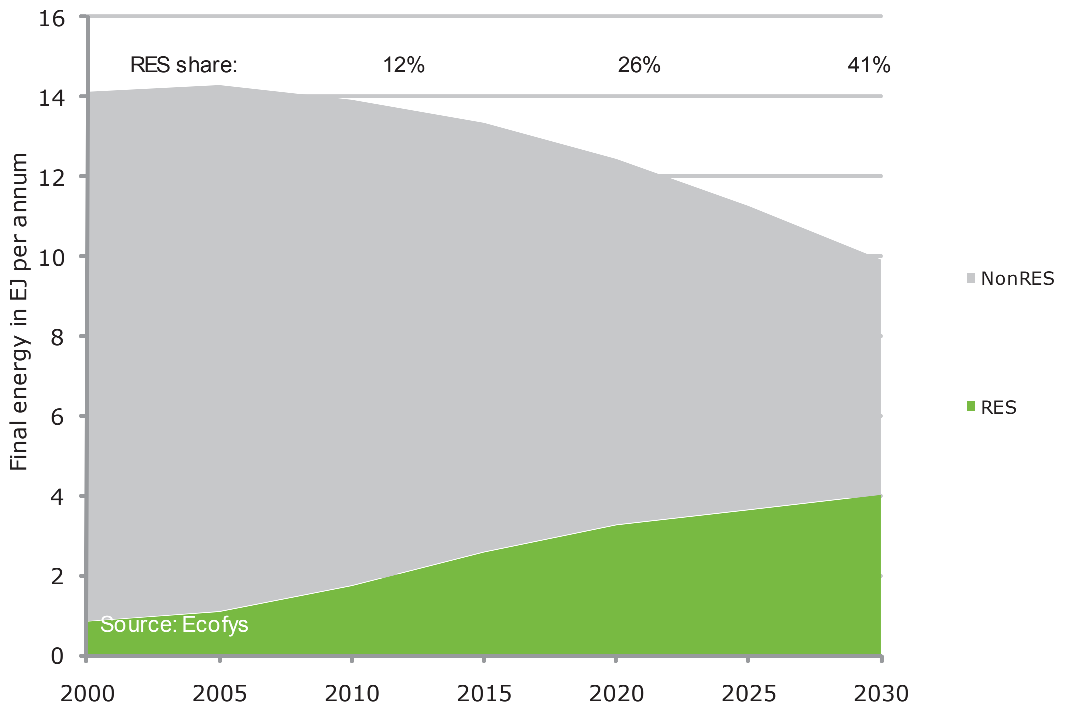

Figure 7 Energy supply for the industry sector from RES and non RES until 2030

As can be seen in Figure 7, the RES share for the sector Industry in 2030 is envisaged to be 40% (4 EJ) in EU27[34]. Note that in the early years adoption of RES is driven by growth in the deployment potential. In the later years this potential outstrips demand and power starts being limited by grid limits; in addition, total consumption starts to contract[35]. Therefore the RES share appears to flatten in the later years.

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[33] Of the supply driven sources wind and PV, wind off shore has a smaller share because it technical potential is smaller than that of onshore wind and PV; actual deployment can be different due to policy or other factors.

[34] In TER, coal transformation and gas works (mainly for steel production) are included in the final consumption, whereas this is excluded in the definition of the gross final consumption of Eurostat. In 2005, the coal transformation and gas works added up to about 1 EJ, i.e. 7 % of the industrial energy consumption. Consequently, RES shares in industry according to Eurostat will be slightly higher (~0.5%).

[35] In the TER EU27 analysis for industry, total consumption is driven by a decrease in activity and energy intensity, the background of this result is explained in TER, pp119-124 and TER appendix B1.

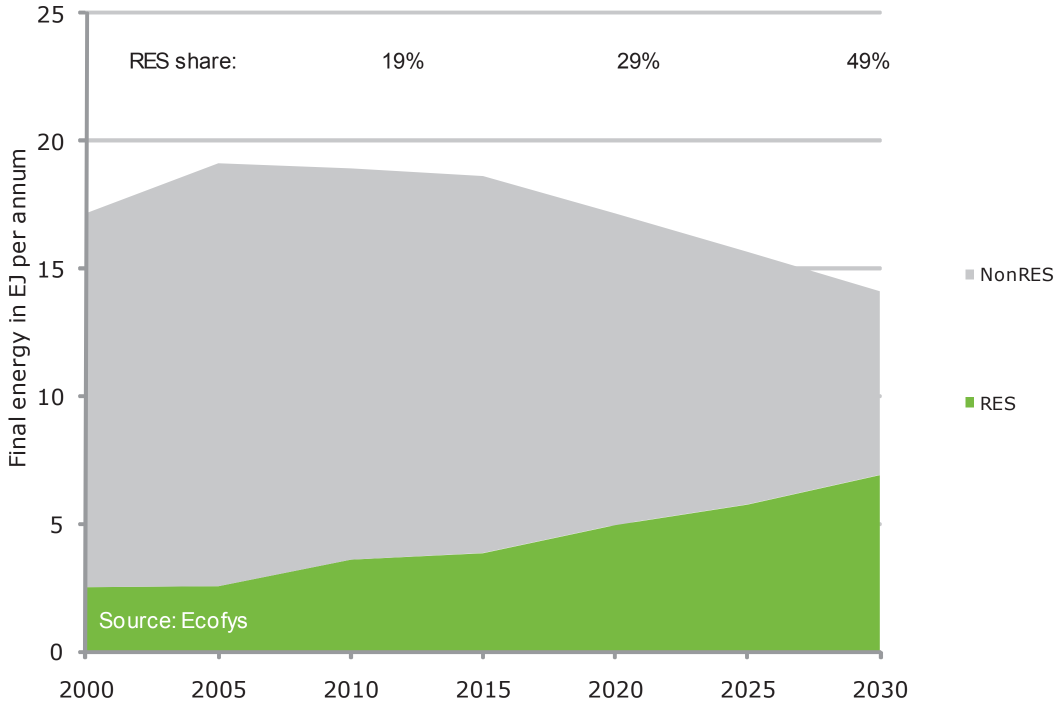

Figure 8 Energy supply for the building sector from RES and non RES until 2030

For the sector Buildings (Figure 8) in 2030 the RES share is envisaged to be 49% (7 EJ) in EU27.

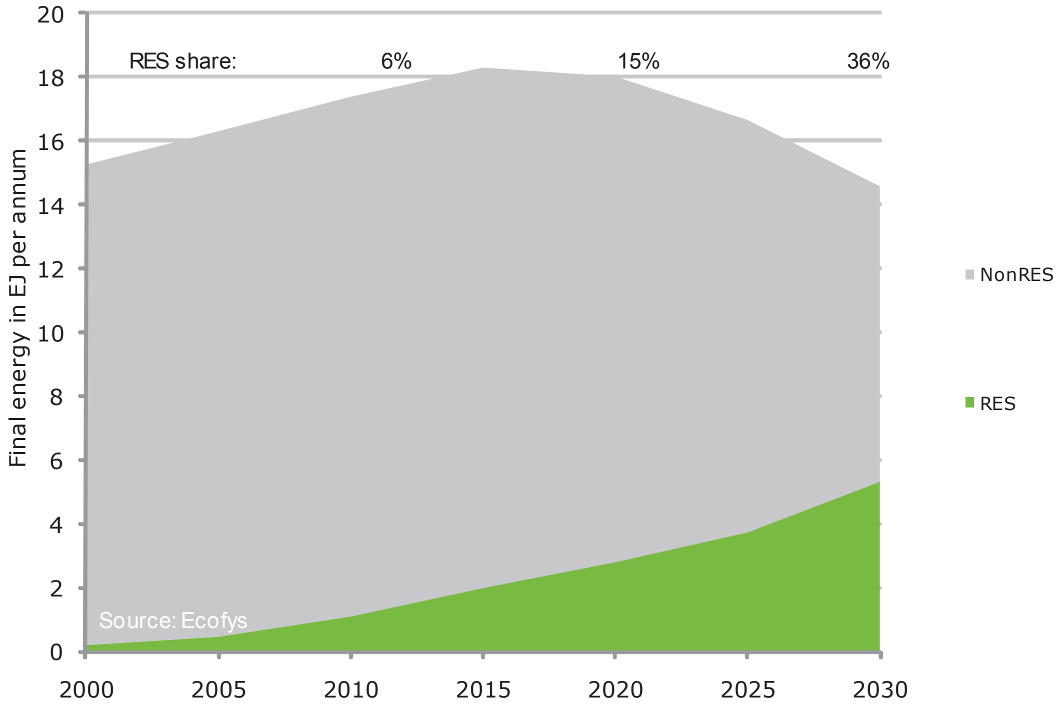

Figure 9 Energy supply for the transport sector from RES and non RES until 2030

For the Transport sector in 2030 (Figure 9) the RES share is envisaged to be 36% (5 EJ) in EU27.

An overview of the savings in 2030 compared to 2005 per sector and the share of the sector in both total final energy and total savings is shown in Table 4.

Table 4 Savings on final energy per sector

	Final consumption in 2030 [EJ]	% of total final energy in 2030	Savings by 2030 vs 2005 [%]	% in total saving in 2030
Industry	10	26%	31%	39%
Buildings	14	37%	26%	45%
Transport	15	38%	11%	15%
Total	**39**	**100%**	**22%**	**100%**

In Figure 10 and Table 5 the development of the energy supply from RES and non-RES is shown for EU27 from 2000 up to 2030. RES supply from solar, wind and bio-crops increases gradually, whereas traditional biomass use decreases, especially in later years. Solar thermal, geothermal heat and biomass from fellings start to play a role from 2015 onwards. Wave & tidal energy does not play a large role until 2030.

The biomass streams are defined in TER as follows[36,37]:

i. Traditional biomass: Direct use of unprocessed biomass. The unsustainable share of this use is phased out over time.
ii. Sustainable residues and waste: Sustainable residues and waste, originating from agriculture, forestry and municipal waste, such as the food processing industry.
iii. Sustainable complementary fellings[38]: This category consists of woody biomass gained from sustainable harvesting of additional forest growth and of the sustainable share of traditional biomass use.
iv. Sustainable energy crops: Energy crops include oil crops, starch and sugar crops and (ligno)-cellulosic crops.
v. Sustainable algae: Algae are not expected to play a significant role before 2030 but are shown for completeness.

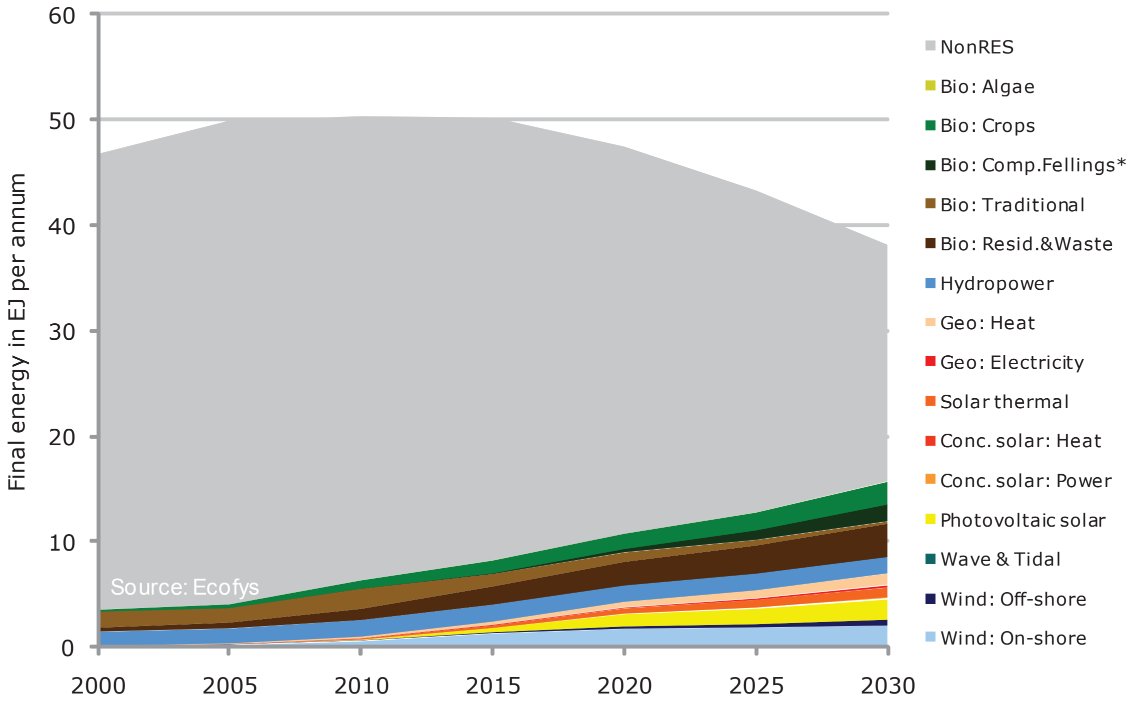

Figure 10 Development of the energy supply from RES and non RES until 2030

[36] S. Cornelissen, M. Koper, Y.Y. Deng, The role of bioenergy in a fully sustainable, global energy system. Biomass & Bioenergy 41 (2012) 21-33.
[37] TER, p. 157ff.
[38] TER, p. 179ff.

Table 5 Development of the energy supply by source and by carrier in the different sectors

Source	2000	2005	2010	2015	2020	2025	2030
Total electricity (EJ/a)	**8.6**	**9.4**	**9.8**	**10.0**	**10.2**	**10.5**	**10.7**
Windpower: On-shore	0.1	0.2	0.6	1.3	1.7	1.9	2.0
Windpower: Off-shore	0.0	0.0	0.0	0.1	0.2	0.3	0.6
Wave & Tidal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Photovoltaic solar	0.0	0.0	0.1	0.4	1.2	1.5	2.0
Concentrated solar: Power	0.0	0.0	0.0	0.0	0.0	0.1	0.2
Hydropower	1.3	1.4	1.5	1.6	1.6	1.6	1.7
Geothermal	0.0	0.0	0.0	0.1	0.1	0.1	0.2
Biomass	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Fossil fuels	6.9	7.5	7.2	6.2	5.0	4.6	3.7
Industry fuels & heat (EJ/a)	**11.0**	**11.1**	**10.8**	**10.3**	**9.6**	**8.6**	**7.5**
Concentrated solar: Heat	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass	0.2	0.3	0.8	1.3	1.7	2.0	2.3
Fossil fuels	10.9	10.7	10.0	9.0	7.9	6.6	5.2
Building fuels & heat (EJ/a)	**12.2**	**13.6**	**13.1**	**12.7**	**11.1**	**9.4**	**7.7**
Solar thermal	0.0	0.0	0.1	0.2	0.5	0.7	0.9
Geothermal	0.1	0.1	0.2	0.3	0.5	0.7	1.0
Biomass	1.6	1.4	2.0	1.3	1.1	1.0	1.0
Fossil fuels	10.5	12.0	10.8	10.8	9.0	6.9	4.8
Transport fuels (EJ/a)	**15.0**	**15.8**	**16.7**	**17.3**	**16.6**	**14.9**	**12.3**
Biomass	0.1	0.3	0.8	1.4	1.9	2.5	3.5
Fossil fuels	14.8	15.5	15.9	15.9	14.8	12.4	8.8
Grand total (EJ/a)	**46.7**	**49.9**	**50.3**	**50.2**	**47.5**	**43.3**	**38.2**

3.3 Results on CO_2 emission reductions

What is the impact a) overall and b) by RES sector, in terms of CO_2 emission reductions, of increasing the proportion of RES in the EU's energy mix?

From the European results above we derived the total emission reductions from the changes in the energy system.

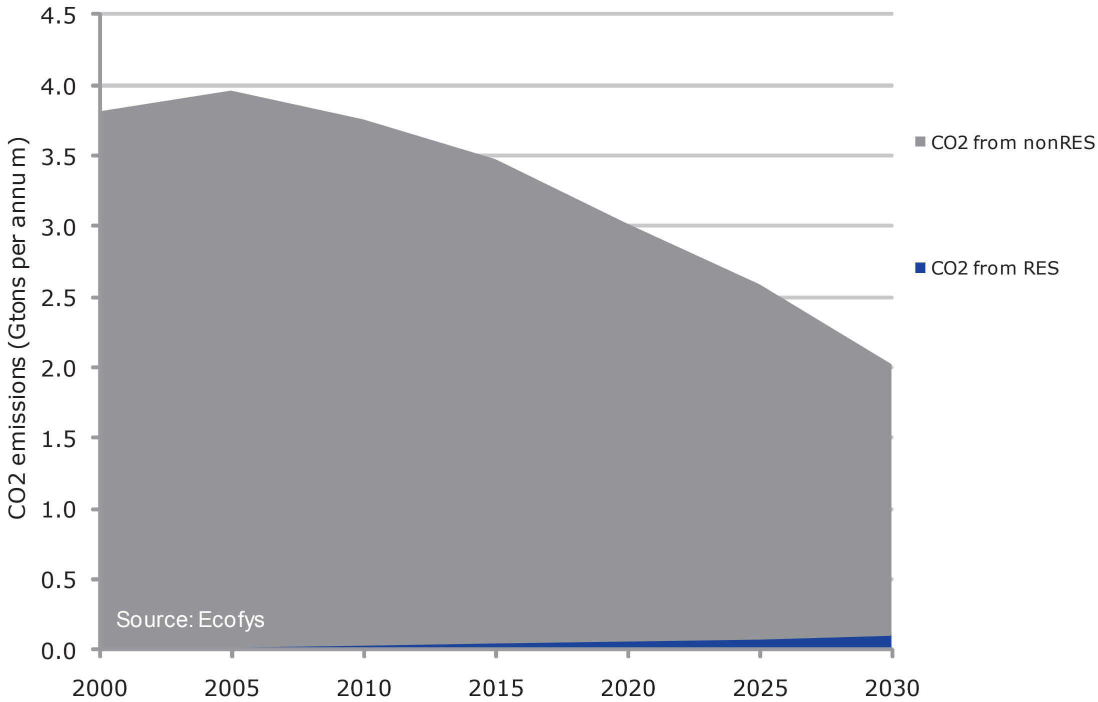

Figure 11 Total CO_2 emissions from energy consumption in EU-27 until 2030

Figure 11 shows energy related CO_2 emissions of the TER based energy system resulting in around 2 $GtCO_2$/a in 2030 in EU27. These are equivalent to reductions of ~50% compared to 1990. The remaining emissions in 2030 are primarily due to remaining use of fossil energy[39] (non RES in Figure 11), but emissions from biomass and hydropower (RES in Figure 11) have also been accounted for, using lifetime emission factors consistent with the TER approach[40].
This scenario for EU27 follows the global TER methodology and will therefore be consistent with an emissions pathway to keep climate change within the 2°C limit globally[41].

3.4 Assumptions and results of other EU-wide energy scenario studies

How does WWF's understanding of the potential future development of renewable energy in Europe differ from that of other recent reports on this issue (differing assumptions and choices etc.)

To be able to put the results of the TER calculation for the EU27 in the perspective of the ongoing policy debate a comparison is made between other EU scenarios in terms of GHG reduction, increasing energy efficiency or renewable energy production. We compared four EU27 studies:

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[39] The fossil energy system has been modelled starting with current shares in sources, slightly rising share of gas over coal and oil, phasing out of nuclear in 2040 and with the efficiencies of power generation as used in the global TER analyses for Europe in 2030; actual developments could be different and would impact CO_2 emissions.
[40] See TER, Section 4., p. 153ff.
[41] See section 5.2, in Deng et al. (2012): doi: 10.1016/j.esr.2012.07.003

- EU energy roadmap[42]: the high efficiency (high EE) and high renewables (high RES) scenario
- RE-Shaping (2011)[43]: RES potentials compared to two baselines with different efficiency (base and advanced)
- Greenpeace Energy [r]evolution[44]: the revolution (Rev) scenario
- EREC 45% by 2030[45]: the baseline and advanced scenarios

Scenarios can be differentiated along the following four dimensions:

- Goal of the scenario
- Technologies in- or excluded: nuclear, CCS, hydrogen
- Economic parameters: fuel prices, cost of generation
- Amount of efficiency assumed
- Results on energy demand, RE production

In Table 6 an overview of these differences is given (where data was available[46]) together with the resulting percentages of energy savings in primary energy compared to the projections for 2030 of the 2007 PRIMES baseline and the RES share in final energy. For each scenario different targets have been formulated, forming the basis of the scenario. For the EU Energy roadmap and Greenpeace Energy [r] evolution CO_2-emission reduction targets for 2050 compared to 1990 levels were formulated. For the EU Energy Roadmap this is 80%-95% reduction of GHG emissions and we look at the high energy efficiency (high EFF) and the high renewables (high RES) scenario. For the Greenpeace Energy [r]evolution scenario 95%. The EREC-scenario has defined a target of 45% RE in 2030. For RE-Shaping no target is defined, RE-shaping calculates an achievable potential[47]. It compares this to a baseline scenario (BAS) and an efficiency scenario (EFF) of PRIMES2007.

Summarising the scenario comparison results for 2030:

- Final energy is lowest in the TER EU27 analysis. This is a result of the efficiency measures taken.
- The TER EU27 analysis has the highest savings on primary energy of 38%. The saving on primary energy is 26–29% in 2030 in EU scenarios and the Greenpeace scenario. The other scenarios did not publish information on savings in terms of primary energy demand in 2030.
- The RES amount[48] in the TER EU27 analysis is with 377 Mtoe (16 EJ) comparable to most other scenarios. Only the EREC advanced scenario has a high absolute RES amount in final energy (572 Mtoe/24 EJ). Reshaping estimates the achievable potential somewhat lower at around 455 Mtoe. The EU roadmap scenarios are on the lower side with 282–341 Mtoe (12–14 EJ).

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[42] European Commission, Impact Assessment accompanying the document Energy Roadmap 2050 com 1565/2, March 2011. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2011:0288:FIN:EN:PDF
[43] RE-shaping - D10 Report Long Term Potentials and Costs of RES Part I: Potentials, Diffusion and Technological learning, 2011 and Green-X data 2011, 2012.
[44] Greenpeace, Energy [r]evolution, a sustainable EU 27 energy outlook, 2012.
[45] EREC, 45% by 2030 Towards a truly sustainable energy system in the EU, May 2011.
[46] In the scenarios analysed here, or as summarised in H. Förster et al. "Information for Policy Makers 2 Analysis of the EU's Energy Roadmap 2050 scenarios. SEFEP working paper 2012.
[47] Realisable potential accounts for non-economic barriers, this means it takes time dependent market penetration into account; in The Energy Report this is called deployment potential. Re-shaping is not a scenario study combining demand and supply; it does not report grid integration constraints for supply driven sources.
[48] Heat pumps are treated differently in the scenarios. Only in Re-shaping heat pumps are included in RES, they account for 96 Mtoe, we deducted this from the original number of 551 Mtoe; since in the other scenarios heat

- RES shares differ substantially from 28% in EU EE scenario to 48% in the advanced scenario from EREC. For the Reshaping scenarios (Base and Eff) the RES share differs because of a different efficiency, all other scenarios have different RES absolute amounts. An explanation for low RES share in EU scenarios and a high share in Greenpeace one[49] can be that:
  - Since most models are based on economic assumptions the costs of RES and fossil fuels influence the achievable potential. These cost assumptions differ substantially, from high RES investment costs and low fossil prices in the EU scenarios to lower RES investment costs and higher fossil prices for the Greenpeace scenario.

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pumps are not mentioned separately as RES. In EREC they are excluded from RES heat; as in Greenpeace energy [r]evolution. in TER EU27 heat pumps are accounted for in efficiency. In EU roadmap heat pumps are not mentioned separately, in the Primes baselines they are mentioned as 'end use efficiency'. Note that the RES directive includes heat pumps as RES.

[49] See footnote above.

Table 6 Overview of assumptions in, and results from different scenarios

	EU Energy roadmap		RE-shaping[50]		Greenpeace Energy [r]evolution	EREC 45% by 2030		TER EU27 result
General background								
Goal	80-95% GHG reduction in 2050		None		50-80% RES in 2050	45% RES in 2030		~100% renewable in 2050
Nuclear in scenario	Yes		No		Phased out 2040	n.a.		Yes
CCS in scenario	Yes		No		No	n.a.		No
Hydrogen in scenario	No		No		Yes	n.a.		Yes
Prices/costs								
Fossil fuel prices[51]	Lower than baseline EU		Not published		Higher than baseline EU	Not published		Around baseline EU
PV capital costs	High[52]		26% from 2000 level		Lower than EU Energy roadmap	Not published		Lower than EU Energy roadmap
Wind capital costs	High		87% from 2000 level for onshore; 72% for off shore		Lower than EU Energy roadmap	Not published		middle
Scenarios & results 2030	High EFF	High RES	Base	Eff	Rev	Baseline	Advanced	
Primary energy[53] in Mtoe (EJ)	1330 (56)	1388 (58)	Not published		1333 (56)	Not published		1169 (49)
Savings[54]	29%	26%	Not published		29%	Not published		38%
Final Energy in Mtoe (EJ)	1021 (43)	1092 (46)	1479 (62)	1156 (48)	931 (39)	1189 (50)	1216 (51)	914 (38)
RES final energy in Mtoe (EJ)[48]	282 (12)	341 (14)	455 (19)		389 (16)	498 (21)	572 (24)	377 (16)
RES share[55]	28%	31%	37%[56]	48%	42%	42%	48%	41%[57]
Biomass[58] in Mtoe (EJ)	163 (7)	189 (8)	180 (8)		Not published	236 (10)	255 (11)	171 (7)
Biomass share in RES	58%	55%	40%[59]		Not published	47%	45%	45%

[50] Data from Green-X, Feb 2012, model description can be found at: http://www.green-x.at/
[51] Comparison is with Primes 2007 baseline numbers.
[52] High 2030 = Around mid price 2012 Germany.
[53] Eurostat definition: gross inland consumption – non energy use.
[54] As in the EU 2020 energy savings target of 20% on primary energy, it is compared to the 2007 Primes baseline; this is 1873 Mtoe in primary energy in 2030.
[55] In final energy.
[56] This is original number from RE-shaping, not recalculated for heat pumps, since it is not clear how it is treated in the numbers quoted. This number is therefore not fully comparable to the other scenarios.
[57] In TER heat pumps are treated as energy saving, rather than RE production. In the RES directive heat pumps are treated as RE production.
[58] In final energy.
[59] Excluding heat pumps.

4 Key Choices and assumptions behind TER RES share in EU

In this chapter the results of key choices and assumptions are discussed in more detail, such as energy efficiency (Section 4.1), material efficiency (Section 4.2), electricity imports (Section 4.3), biomass (Section 4.4) and investments and saving (Section 4.5).

4.1 Energy efficiency

The intensity decreases discussed in Section 3.2, result in a lower final energy demand per sector and overall in the TER analysis for EU27. Compared to 2005 final energy demand is estimated to decrease with 22% overall, 31% in industry, 26% in buildings and 11% in transport.

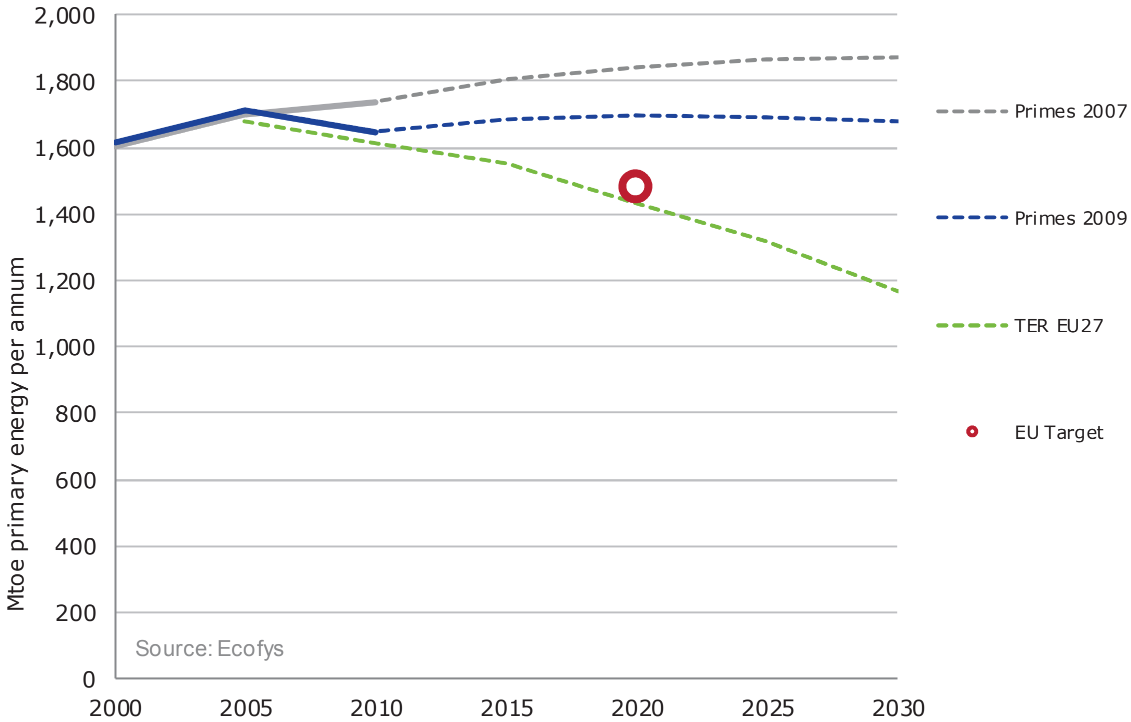

Figure 12 Primary energy: Primes baselines (2007 in grey and 2009 in blue), TER EU27 results (green) and EU target and linear extrapolation of target to 2030 (red)

These efficiency increases together with the use of RES resources result in much lower overall primary energy demand in 2030 compared to the baseline. Expressing the overall demand in terms of primary energy allows comparison with the PRIMES 2007 and 2009 baselines[60] and thus with the 20% energy savings target of the European Union in 2020. In Figure 12 these baselines are shown together with the TER EU27 analysis and the EU 2020 target.[61] For 2030 the TER assumptions would result in a primary energy reduction of ~38% compared to baseline 2007. In 2020 the TER27 analysis gives a primary energy reduction higher than 20% EU target.

As was shown in Section 3.3 these assumptions combined with the use of renewables lead to energy related CO_2 emission reductions of ~50% in 2030 in EU27 compared to 1990.

4.2 Material efficiency

Summary of the global TER analysis approach on material scarcity
In the global TER, material scarcities and their relation to renewable energy technologies were investigated ex-post, i.e. they were not being taken into consideration for determining the capacity of renewable energy production. Taking into account increasing the re-use of materials and improving material efficiency TER concludes material scarcity to be an issue that can (and has to) be managed. In this regard, TER mentions material efficiency improvements in the sectors industry, buildings and transport, and also mentions consumers in relation to behavioural changes.

Summary of the Critical Materials for the Transition to a 100% Sustainable Energy Future Report[62]
This study specifically investigates the material supply bottlenecks which could occur in the transition to a fully sustainable energy system as represented in TER. The conclusion is that for most materials the TER will not pose material constraints.

The most critical bottlenecks in a transition to the TER energy system are the use of lithium and cobalt for batteries in electric vehicles. Current production capacities for both elements are not sufficient to meet the maximum annual demand for electric and hybrid electric vehicles in TER, which is expected to occur around 2030. For lithium, material demand for car batteries is expected to be around seven times the material production in 2011. For cobalt, material demand for car batteries is expected to be around twice as much as production in 2011. In addition, current reserves of lithium and cobalt are barely large enough to meet cumulative material demand of batteries until 2050. This does not yet take into account the additional demand for other purposes. In short, increased production of virgin material, recycling and additional research into alternative technologies is required to mitigate this bottleneck.

[60] Primes 2009 baseline, as published in EC DG Energy and Transport, European Energy and Transport—Trends to 2030 Update 2009, 2010.
[61] The small difference in the 2005 point is due to statistical differences.
[62] WWF, 2012. Critical Materials for Transition to a 100% Sustainable Energy Future, prepared by Ecofys, forth-coming.

Other materials, such as rare earths[63] for wind turbines and copper for wind and solar energy, energy efficient motors and a more elaborate electricity infrastructure, are less likely to become bottlenecks. Indium, gallium, tellurium (cells) and silver (pasting) are not considered important bottlenecks either, because their use in photovoltaics could be substituted by using technologies based on less critical materials, such as silicon (in the cells), respectively copper and/or aluminium (in the pasting). The use of indium and gallium for energy efficient lighting is very small compared to production in 2011 and reserves and resources.

4.3 Electricity imports for balancing

What assumptions has this report made on the role played by electricity imports from neighbouring countries and what impact have these assumptions had on WWF's target for RES in the EU's energy mix by 2030?

Electricity imports from outside the region are not included in the global TER model. We can however discuss whether electricity imports from neighbouring regions would benefit EU27.

As touched upon in Section 3.2, the RES share in electricity is expected to be 65% in 2030 and the share of supply driven sources in electricity is limited to ~43%, the rest being filled from demand-driven sources (see Appendix B). Analysis shows that the deployment potential of supply-driven RES electricity in Europe is larger than its use in 2030. Feeding RES electricity from demand -driven sources into the grid from elsewhere (in this case via imports) could potentially increase the EU27 RES share, but this would likely also require additional investment in transmission or additional interconnections (see also Appendix B). In an integrated power system this would require these regions to already deploy a higher share in RES than EU27, as the imported electricity would be a mix of the imported sources.

Countries or regions which are candidates to import electricity for balancing from are:

- Norway and Switzerland: can continue to play a role in grid stabilisation via hydropower pumped-storage (with limited opportunities to extend the production and storage capacities)[64].
- Northern Africa has large RES (notably solar) resources. For Africa the assumed deployment rates in TER global are becoming material only after 2020. In addition, local electricity demand is still growing as the region develops further. Currently Africa's own RES deployment is much lower than that of the EU and targets that have been set have not been reached.

[63] In this analysis it is assumed that neodymium in direct drive turbines will only be applied in offshore turbines, while conventional geared wind turbine generators will remain the technology of choice for wind turbines (which do not contain neodymium). Bottlenecks could arise if all wind future turbines will contain neodymium.
[64] For example, in Norway new hydro installations raise severe environmental concerns amongst Norwegian citizens and NGOs.

To conclude, the limiting factor for RES electricity in 2030 is RES deployment potential in Europe for demand-driven RES and the ability of the grid to cope with the large amount of supply driven RES. Interconnectors with countries outside the EU27 can help to reach a higher target when:

- Demand-driven RES electricity is used for cross-boundary balancing
- The grid is expanded, either with interconnections, or additional transmission lines to incorporate a higher share of supply driven RES sources

To fully investigate the potential of imports for balancing, a local grid/energy/resource model is needed.

4.4 Biomass

Which assumptions has this report made on the role played by biomass and what impact have these assumptions had on WWF's target for RES in the EU's energy mix by 2030?

In the global TER analysis biomass is treated as a last RES option after other RES resources have been used. This approach in itself limits the use of biomass to the minimum required to attain high RES supply shares. The actual amount of biomass used varies by sector, because demand and supply are matched at the sectoral level and depending on the type of energy needed (heat at different temperatures, fuel, and electricity). For example, in industry high temperature heat is needed which cannot easily be provided by solar heat. This heat demand will have to be provided by biomass, or by fossil fuels or nuclear, if no biomass is available. Buildings, which require low temperature heat, can use solar heat and will need less biomass for heating in the future.

In TER biomass is fully traded between regions, without penalising transport of biomass (though emissions from this transport are included in the carbon emissions estimate[65]). Globally, the full deployment potential of biomass is used in 2030.
Our analysis shows that the deployment potential of biomass in Europe exceeds its actual use in 2030. In addition, the overall balance masks imports and exports for individual sources. As can be seen in Table 7, not all biomass streams are in equal demand in Europe: The use of energy crops exceeds domestic supply in 2030 but other bioenergy streams (waste and residues, complementary fellings) are more readily available.[66]

In the global TER analysis much attention was paid to sustainable use of biomass worldwide and clear criteria were used to ensure its sustainability. Biomass sustainability criteria were analysed using the following categories (TER p.162):

- Land use and food security
- Agricultural and processing inputs

[65] See TER, Section 5.9, p. 190ff.
[66] It must be noted that the use of bio energy is not influenced by regional supply, but optimised globally. This means that in reality, more residues may be used in Europe than calculated in TER replacing some of the crops used.

- Complementary fellings
- Residues and waste

Table 7 European (not EU27) potential and use of sustainable biomass in the global TER model[67]

Type	European potential 2030 (EJ)	European use 2030 (EJ)
Bio crops	0.3	2.7
Other bioenergy	9.4	6.4

Since the publication of the global TER analysis, discussions on biomass sustainability and issues such as carbon debt and indirect land use change (ILUC), etc, have continued and are important to address for WWF in the European context. We look at three biomass sources separately[68]:

- A: all biomass options as in global TER
- B: residues and waste and complementary fellings
- C: waste and residues

In addition to waste and residues (C) and complementary fellings (B), A also includes traditional biomass, crops and algae (algae not in substantial amounts before 2030). For all of these uses of biomass the sustainability criteria on land use[69], food security and sustainable agriculture have been applied. A pre-requisite is that the mechanisms to guarantee sustainability have to be put in place globally.

Importing from outside Europe could raise more concerns on sustainability than using supplies from within the Union, since European legislation may have less control over sustainability of imported biomass. As was shown above, most imports will probably consist of biomass from crops, whereas other biomass streams (waste and residues, complementary fellings) have more potential in Europe than are used in 2030.

In Figure 13 the amount of energy supplied by biomass, non biomass RES and non RES (A) is shown. Biomass shares increase from 4% in 2000 to 19% of energy consumption in 2030 in EU27.

[67] For the full approach to the sustainability of biomass in TER, see TER (2011), Chapter 5, p.157ff.

[68] B and C are calculated back from the main scenario A. A is the basis for the results presented previously.

[69] The TER global analysis assumes that all bioenergy from crops is sourced entirely from available land[67]. The effective implementation of policy is required to ensure no indirect effects occur.

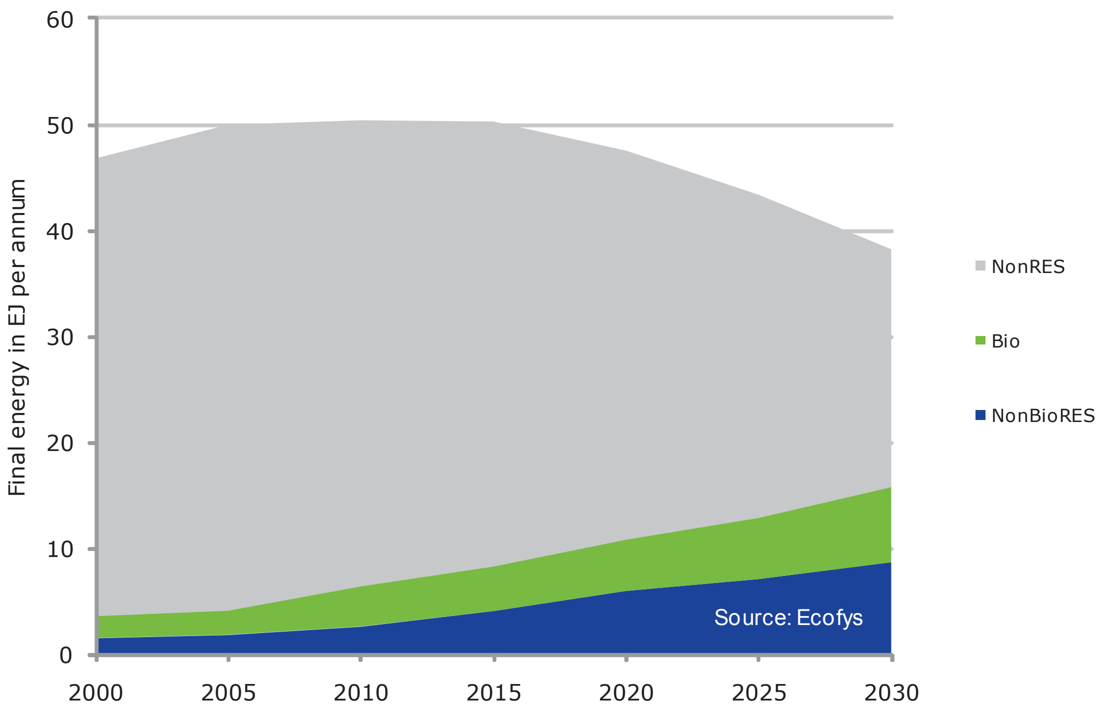

Figure 13 Energy supply from non biomass RES, biomass and not RES sources in TER analysis for EU 27 (A).

As can be seen in Table 8, the result of the TER analysis for EU27 is that biomass is primarily used in transport fuels, and to a lesser extent in industry fuels and heat, with almost no use occurring in electricity production. The use in transport fuels and industry is growing steadily until 2030 whereas use for heating buildings is decreasing.

Table 8 Share in types of use of biomass in 2030 in final energy

Biomass use	Share	Amount (EJ)
Bio: Electricity	4%	0.3
Bio: Heat buildings	14%	1.0
Bio: Heat industry	18%	1.3
Bio: Industry fuels	14%	1.0
Bio: Transport fuels	49%	3.5
Bio: total	**100%**	**7.2**[70]

[70] Due to rounding, the table adds up to 7.1

In Table 9 an overview is given of all sources separately. B includes residues, waste and complementary fellings; the share of biomass grows to 12% of energy consumption in 2030 in EU27. In C only residues and waste are used, the share of biomass grows to 8% of energy consumption in 2030 in EU27.

Table 9 Share of biomass sources in 2030 in final energy

2030 final energy	EJ	%
Renewable energy - non bio	**8.6**	**23%**
Renewable energy - bio - of which...	**7.2**	**19%**
... Bio: Residues and Waste	3.2	8%
... Bio: Traditional biomass	0.2	0%
... Bio: Complementary Fellings	1.6	4%
... Bio: Crops	2.2	6%
Non-renewable energy	**22.4**	**59%**
Total	**38.2**	**100%**

Less biomass in the energy system will, in the TER analysis and without changes in assumptions, lead to a higher use of fossil fuels, since biomass is only used when other RES sources cannot provide the energy needed. This is mostly the case with fuels and high temperature heat. To reduce the amount of biomass required without increasing the requirement for non-renewable sources would require a decrease in overall demand for fuel and heat.

4.5 Investments and savings

What amount of investment is likely to be needed to deliver WWF's target for RES in the EU's energy mix by 2030, where could this investment come from, and which economic benefits is it likely to return?

Investments and savings in Europe were assessed semi-quantitatively based on the global analysis in TER. The outcomes of the global TER study show that the required CapEx (capital expenditure) increases up to <3% of global GDP in 2030, decreasing again towards 2050.
We expect the overall picture to be similar for Europe, but with slightly higher net costs and a different split over sectors.
This is due to a variety of reasons (see Appendix C for details), examples include:

- The European building sector will continue to have a higher share of existing (pre-2005) stock whereas globally shares of new stock will be larger. Since renovations for old stock are more expensive than the surplus costs for new stock, more investment would be needed in Europe. This will have high savings but not as much as new stock so the net benefits will be lower in Europe.
- Fewer investments may be needed in the transport infrastructure and the grids sector since activity grows less fast in Europe and infrastructure is already well-established compared to other regions. This is offset by savings, so the Net Cost will be comparable.

5 Conclusion

We have derived an ambitious, yet feasible energy scenario for the EU27 for 2030 which is consistent with the global TER vision on a fully renewable global energy system by 2050.
From the analysis of TER for EU27 we envisage a RES share of 41%[71] in 2030. In Table 10 the sectoral RES shares are given.

Table 10 Envisaged renewable energy shares in the EU27 in 2030 overall and per demand sector[72]

Share of renewable energy in each sector in 2030 in our scenario	
Total	41%
Industry	40%
Buildings	50%
Transport	36%

The RES share in electricity is 65% and ~43% is provided from supply-driven sources in 2030. The feed-in of supply-driven sources is capped at 45% on average annually in 2030, under the assumption that the electricity grid cannot accept higher shares by then.

Energy savings on primary energy are estimated to be ~38% in this scenario, compared to the 2007 baseline. Energy related emission reductions compared to 1990 are estimated to be 50%.

Compared to other EU scenarios for 2030 analysed, the TER EU27 analysis has low final energy demand and a RES amount comparable to the other studies. The RES share is higher than those of the EU roadmap, but below the advanced scenario of EREC.

The overall RES share includes a biomass share of 19% of the total final energy demand. Biomass is, towards 2030, increasingly used in industry for high temperature heating and as a transport fuel and decreasingly used in buildings for space heating. The share of residues and waste in the EU27 energy mix is 8%, the share of complementary fellings is 5% and bioenergy crops 6%.

The investment / cost / benefit balance for EU27 will be comparable to results at the global level with slightly higher net costs (relative to global TER results). From the analysis in the global TER, it is clear that the largest investments up to 2030 would be required in efficiency measures and achieve modal shifts in the transport sector and high retrofit rates in the building sector.

[71] As mentioned before this is with heat pumps accounted for as efficiency measure, not RES.
[72] Sectors cover 96% of energy demand.

Appendix A Making TER more Europe specific

Scaling the results to EU27

TER is a global report, based on 10 world regions. The region 'Europe' in TER contains the countries of the EU27 plus additional countries within geographic Europe. We therefore apply a scaling factor to report results for EU27, based on the TER model results for geographic Europe.[73] This is not equivalent to running the model at EU27 level, but the difference is expected to be small[74].

Making the results more Europe-specific

Many assumptions used in the global TER analysis are made at global or OECD level only. In chapter 3 we give an overview of these assumptions. We have adapted several of them in this study to be more suitable for the European situation, producing a more accurate forecast, such as:

- Population forecast updated [source: World Energy Outlook 2011], resulting changes:
  - No major changes for Europe, but slightly higher energy demand in other regions
- GDP growth update[75], resulting changes:
  - In Europe the only adjustment was made for the period 2010-2020, where the annual growth rate is reduced from 2% to 1.5%.
  - Some changes for other regions due to higher growth of energy consumption (7–10% growth in WEO 2011 vs. 4–5% in the global TER analysis).
- Buildings:
  - Activity: we have updated the floor area forecast which is at most 10% higher in 2030 (total floor space)
  - Intensity:
    - no change in renovation assumptions from the global TER report
    - new stock: the global TER analysis assumes passive standards on heat demand are met by 2030, 2025 was found more realistic for Europe[76]
- Transport:
  - Activity: We have updated the activity forecast to the Primes 2009 forecast[77], which results in 10% higher passenger km in 2030 than used in the global TER analysis for the European region.

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[73] We scale historic results (2000, 2005, 2010) from Europe to EU27 using IEA statistics on final energy for these years. We scale the RES and non RES part of final energy separately. We do the same for future periods, using 2010 values from IEA.
Because Eurostat does not provide statistics for all countries in the Europe region in TER, we used IEA statistics for this comparison.

[74] This is because the difference in the structure of per capita energy consumption and production is not expected to be large between the average of EU27 and the average of the additional countries (Balkans, Iceland, Norway, Switzerland, Turkey), compared to other uncertainties in the forecasting approach..

[75] World Energy Outlook 2011

[76] 2025 was chosen for implementation of the passive house standard, which is expected to have lower energy use then the - to be adopted - EU policy for 2020.

- Intensity: no change required
- Industry:
  - Activity: no change required
  - Intensity: We have checked OECD numbers vs. Europe numbers and found, that Europe is comparable to average OECD assumptions made in TER since countries such as the US have higher intensity, and others like Japan have lower intensities[78]. We did, however, make one change in the cement sector where we increased the starting intensity of electricity to be in line with European current intensities. This is expected to slightly increase the savings potential in Cement, but the effect is small.
- Non biomass RE source potentials:
  - We have updated European historical growth figures to most recent data: This is especially pertinent for PV which has moved faster than assumed in the global TER analysis (see
  - Table 11). While this will affect the split of RES between, e.g. solar and wind, it will not affect the overall RES share as RES deployment is not limited by potential in the long-term (this was also the case in the global TER analysis).

Table 11 Comparison of assumptions on deployment potential for PV applied in The Energy Report and this report[79].

PV PJ/a	2000	2005	2010	2020	2030
TER	0	10	30	350	2,680
WWF 2030	0	10	60	2,830	8,270
Historic		7 - 12	86 - 150		

Comparing actual developments from 2005-2010 with TER

The global TER has 2005 as its base year. Rather than updating the model to a new baseline, we compare the discrepancy with reality in the last five years. In
Table 12 the TER EU results on RES share are compared to IEA and Eurostat statistics. The discrepancy in 2010 less than 1%-point compared to Eurostat.

Table 12 Comparing actual development from 2005-2010 with TER

	2000	2005	2010
RES share TER EU27 results	7%	8%	12%
historical RES share EU27 (IEA, 2012)[80]	8%	8%	12%
historical RES share EU27 (Eurostat)	7%	8%	13%

[77] EC DG Energy and Transport, European Energy and Transport—Trends to 2030 Update 2009, 2010.
[78] IEA, 2007. Tracking Industrial Energy Efficiency and CO2 Emissions. International Energy Agency, Paris
[79] Historic deployment is given in installed capacity (EPIA, 2011), a range is given to account for the uncertainty in full load hours.

[80] IEA (2012), Energy Balances of Non-OECD Countries. International Energy Agency (IEA), Paris.

Appendix B Electricity grid

As in the global TER model the feed-in of supply driven electricity in the transmission grid is limited. For Europe it is capped from 30% in 2000-2020 to 60% in 2050, as can be seen in Figure 14. These numbers are based on the grid study of Ireland[81] for the early period that showed that 20–30% of supply driven sources can be taken up in the grid without large investments. Several 2030 scenarios have ~35% of supply driven electricity in the power system[82]. From other studies it is expected that this figure can rise up till 60%[83,84] in 2050. This is however including re-design of the grid including investments to the grid incorporating demand side management, storage, smart grids. More investigation is needed.

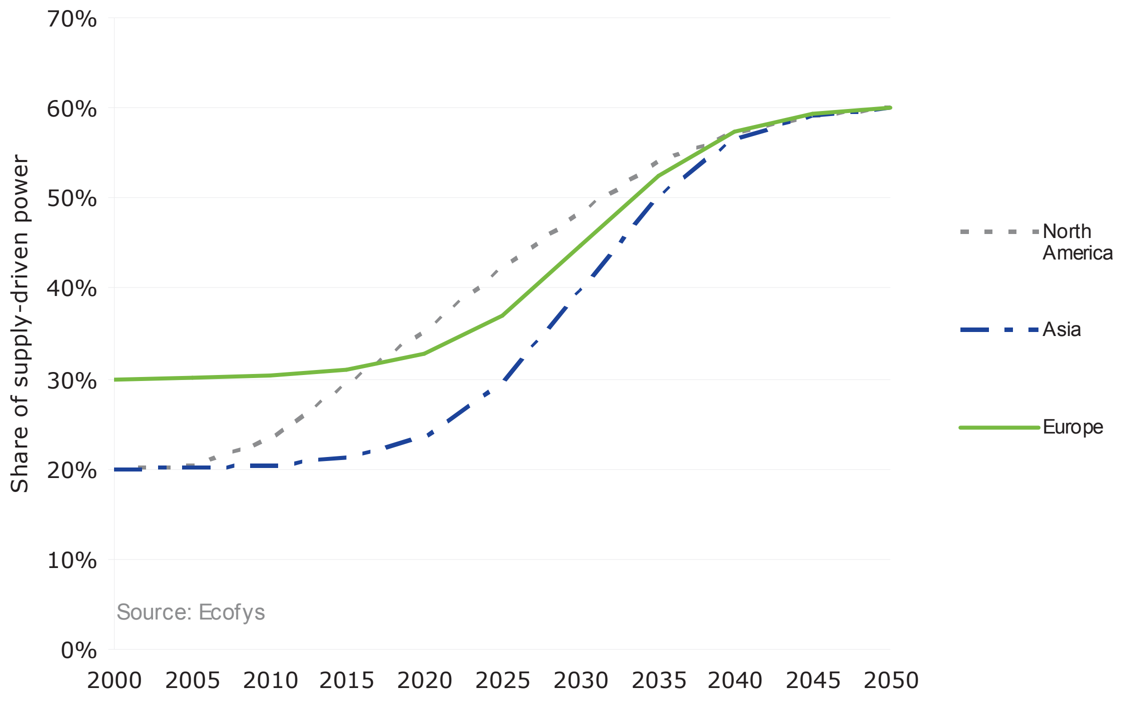


Figure 14 Share of supply driven electricity in power system

[81] C. Nabe, All grid Island study, Ecofys 2010
[82] The nuclear scenario in ECF Power perspectives 2030; and Greenpeace Advanced Energy [r]evolution scenario.
[83] K. Blok, A Renewable Energy System for the Netherlands, Proc. 5th International Solar Forum, DGS Sonnenenergie Verlags, München, 1984.
[84] B. Sørensen: Renewable Energy, Academic Press, 2004

Appendix C Investments and savings

What amount of investment is likely to be needed to deliver WWF's target for RES in the EU's energy mix by 2030, where could this investment come from, and which economic benefits is it likely to return?

Investments and savings for Europe in 2030 are derived from the global TER study. In this study investments and savings are calculated after the energy calculations. From the global study a comparison of cost results with global GDP is given in Figure 15.

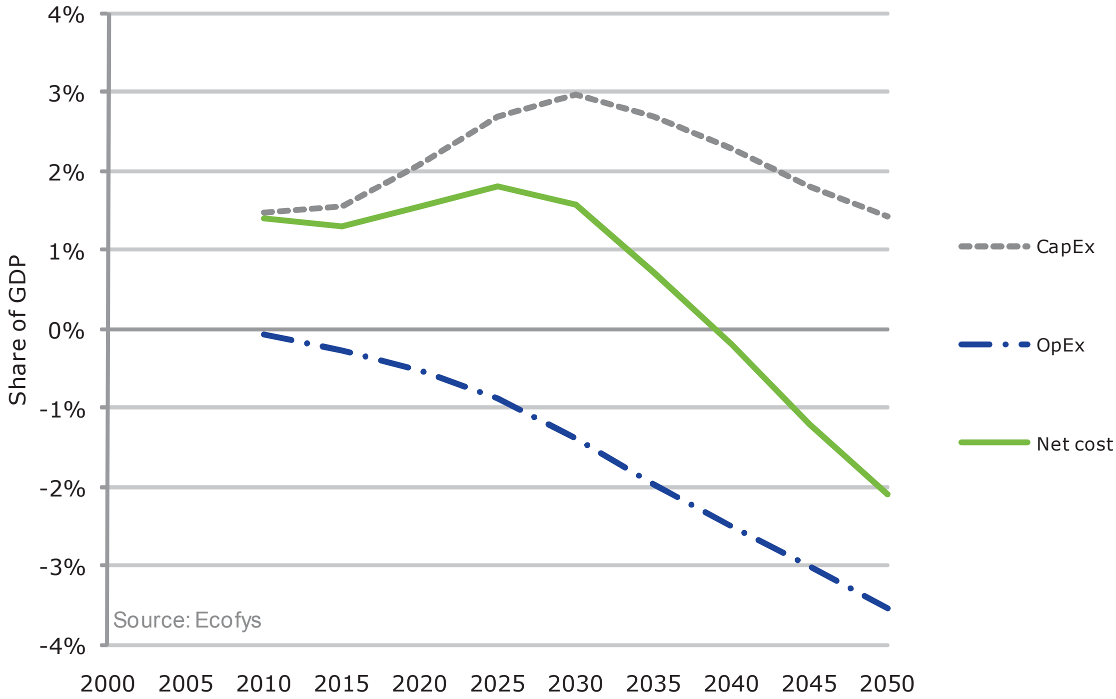


Figure 15 Comparison of cost results from the global TER analysis (TER 2011)

The outcomes of the global TER study show that the required CapEx (capital expenditure) is <3% of global GDP. This will increase up to 2030 and decrease again towards 2050. OpEx is dominated by savings, so OpEx decreases slowly to around -4%. This results in Net Costs peaking just below 2% around 2025 and decreasing to -2% in 2050.
In Table 13 we give indications on where to expect a higher or lower value for Europe.

Table 13 Indications for change from global cost/benefits to European level

	CapEx	OpEx	Net Costs
Investment cost level			
Investment cost level of PV			
Share of RES			
Industry			
Buildings			
Transport infrastructure			
Transport vehicles			
Type of RES			
Grids			

Indicators
Lower for EU
Same
Slightly higher for EU
Higher for EU

On a global level recent developments have shown higher decrease in investment costs than projected in TER, especially in PV. That means that for PV, the investment cost is overestimated in the global TER.

There are several reasons why the investment / cost / benefit balance may differ between the global and the European situation:

- European investment costs will be higher than the global average, due to higher cost of materials and labour. However, energy savings may not be commensurately higher, since energy prices for some fuels vary little across the globe. Therefore, the overall picture may show smaller net benefits for Europe.
- In 2030 Europe has a larger share of RES and degree of efficiency saving than the global average, i.e. it is still a 'frontrunner'. Thus, higher investments can be expected in Europe than for the global average.
- The mix of resources: in 2030 there is less PV and more wind offshore in Europe than globally. Since wind offshore is assumed to stay more expensive than PV, whereas PV has larger cost reductions, higher investments may be required in the RES part of the total cost.
- Structure of specific sectors:
    - The European building sector will continue to have a higher share of existing (pre-2005) stock whereas globally shares of new stock will be larger. Since renovations for old stock are more expensive than the surplus costs for new stock, more investment would be needed in Europe. This will have high savings but not as much as new stock so the net benefits will be lower in Europe.
    - Fewer investments may be needed in the transport infrastructure and the grids sector since activity grows less fast in Europe and infrastructure is already well-established compared to other regions. This is offset by savings, so the Net Cost will be

comparable. Vehicle technology is developed and traded globally so no differences are expected.

- Fewer investments will be needed in the grid since it is already well integrated across Europe compared to other regions. This will be balanced with smaller benefits.

In conclusion the balance will be comparable to results at the global level with slightly higher Net Costs.

From the analysis in the global TER, it is clear that the largest investments up to 2030 would be required in the transport and building sectors. In Table 14 the share of global investments in sections of a sector[85] in TER is shown. For some investments it is expected they will be higher in Europe compared to the rest of the world as was discussed above.

Table 14 Share of global investments in sections of a sector

Sector	Share in investments
Industry	1%
Buildings	35%
Transport infra	25%
Transport vehicles	25%
RES	14%
Grid	<1%
Total investments	**100%**

This analysis gives indications on investment and cost benefit levels in Europe only considering local investment and use. Cost sharing and co-financing of the energy transition needed in developing regions is not included. This could, however, be logical to include in a larger framework of global emission reduction financing and finding cost optimal solutions.

Co-financing schemes can also be thought of for electricity imports with a sharing of benefits between regions.

[85] For sectors industry, buildings and transport vehicles these investments cover the energy efficiency measurements and fuel shifts, transport infra covers modal shifts, RES the renewable energy technologies and grid the investment in the electricity grid.

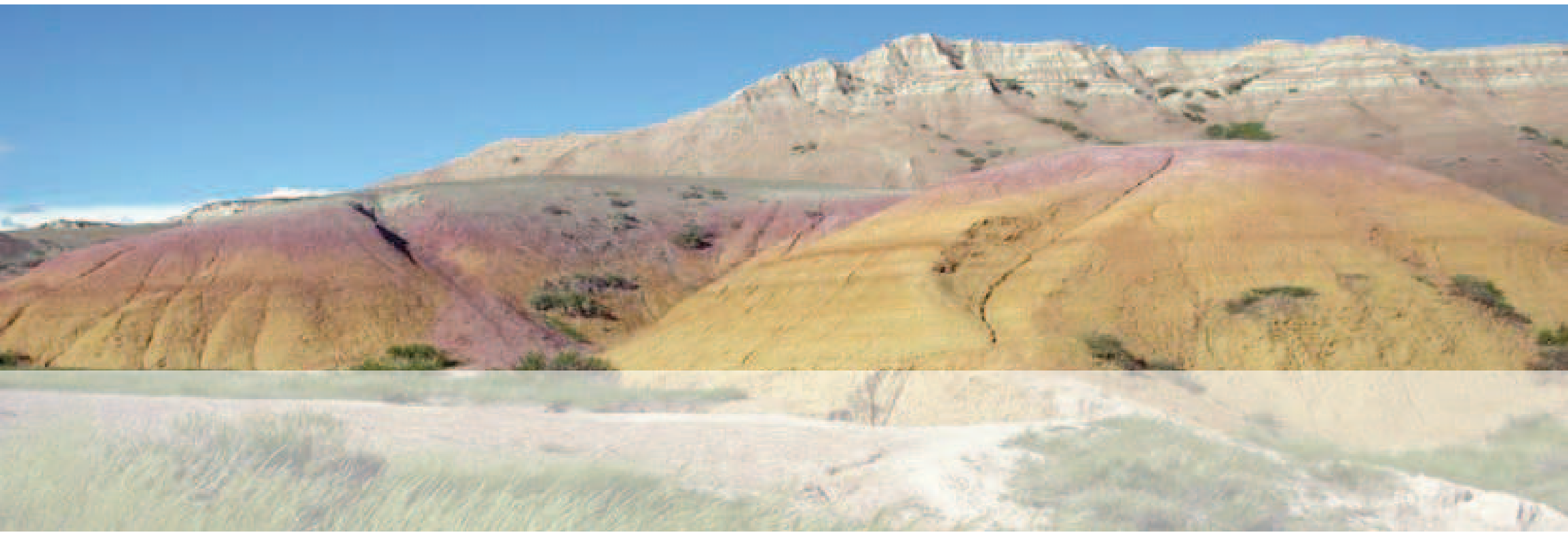
Appendix D The Energy Report 4-page summary

ECOFYS

sustainable energy for everyone

A FULLY RENEWABLE ENERGY SYSTEM GLOBALLY BY 2050

The Energy Report shows that a global energy system based on renewable energy is possible by 2050



A fully sustainable and renewable global energy system is possible by 2050. For the first time, the feasibility of such a system is demonstrated by The Energy Report, published by Ecofys and WWF. With emphasis on detailed developments and practical application, the report illustrates how almost 100% of all energy carriers, all regions and all sectors of the global energy system can be renewable, by 2050.

For several reasons, the world needs an adapted energy system to accommodate its growing population: Climate change, depletion of natural resources and a growing dependence on only a few energy suppliers are a threat to our current system. Renewable energy sources are therefore necessary for a sustainable balance.

The Energy Report is unique. Never before has a renewable energy scenario been so ambitious and so broad in scope, incorporating all aspects of sustainability. By utilising today's technologies alone, 95% of all energy can be renewable by 2050, comfortable lifestyles can be developed and sustained and long-term benefits can outweigh short-term costs. To make this transition, we must abandon the convention of meeting energy demand with fossil fuels. Systems and energy markets must change and hard choices must be made. The Energy Report charts the elements needed for this transition.

Approach

The Energy Report asks the fundamental question: "Is a fully sustainable global energy system possible by 2050?" Ecofys, with over 25 years of experience in the field of renewable energy and energy efficiency, investigated the technical, social and economical developments of the future world, by:

> forecasting the future level of energy-consuming activities (e.g. tonnes of steel produced)

> deriving the minimum level of energy necessary for these activities

> defining the most sustainable sources of that energy.

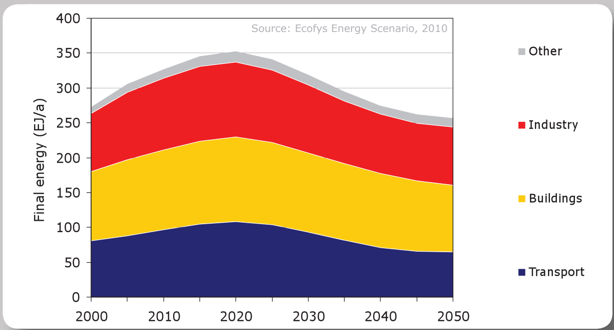
Activity and energy demand

First, The Energy Report makes an estimate of future energy demand. This demand is based on a detailed assessment of activities in ten global regions and in all energy-using sectors: industry, buildings and services, and transport.
An important condition in assessing demand is the rate of development towards a sustainable standard of living, based on increasing equity between different regions in the world. This part of the Report leads to a development of demand differentiated into the three main energy carriers: electricity, heat and fuels.

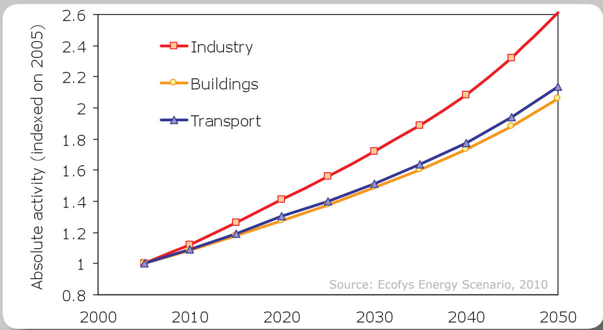
Step one: maximise conservation of energy and material

A very different energy system

The energy system in 2050 will look quite different from the system of today. All sectors and sub-sectors will use energy and materials as efficiently as possible; the recycling and recovering of base materials will be elemental to all industrial processes. By substantially increasing efficiency globally, the final energy consumption in 2050 will fall below the annual consumption of 2000, while global activity, and the associated increase in living standards, will more than double. Only with this significant reduction in energy demand is it possible to supply this energy from renewable sources.

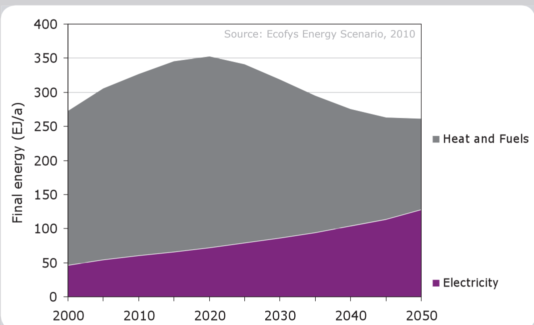


The stabilisation and contraction of overall energy demand (left) is mostly due to ambitious energy efficiency improvement since activity levels continue to increase (right) in all sectors.



Energy supply

This energy demand profile is then matched with different energy supply options that rely entirely on existing technologies. These options are arranged in order of sustainability. The utilisation of energy from the sun, from wind, water and heat from the earth's crust are prioritised. Only once these options are exhausted is bio-energy deployed. Within the bio-energy category, The Energy Report also applies a ranking of sources by sustainability and excludes non-sustainable use. Through this method, demand and supply are matched using renewable resources and proven technologies.

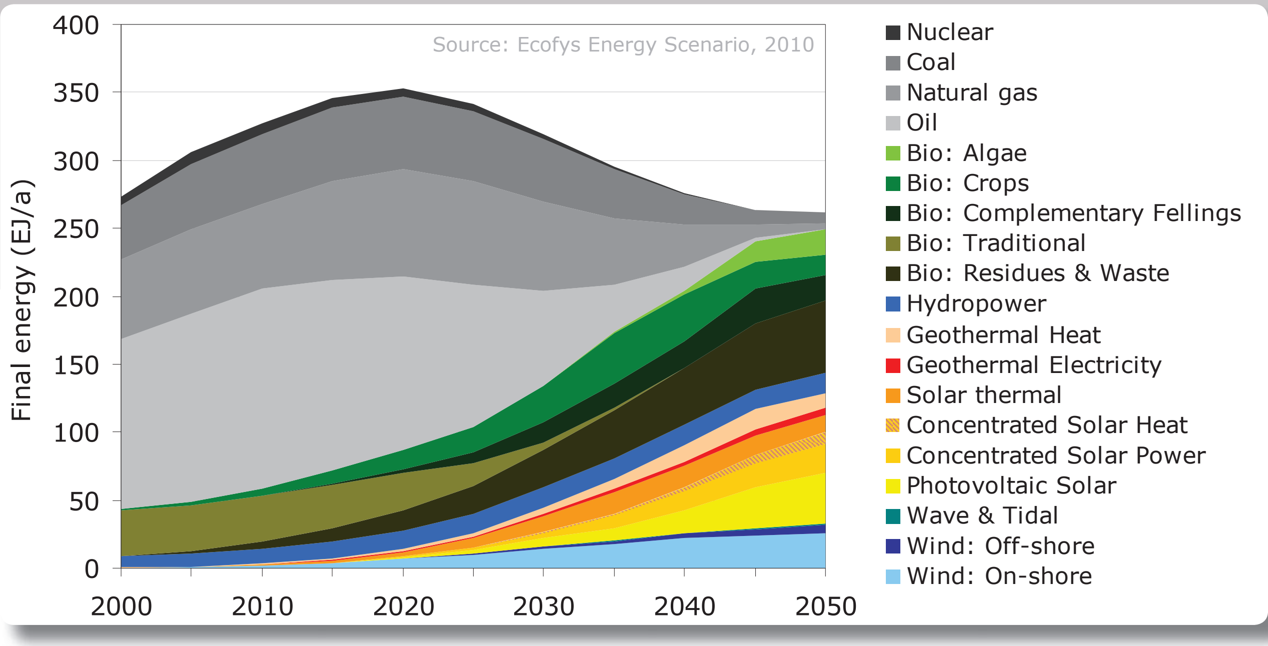


Ambitious electrification ensures a maximum share of renewable supply options.

Step two: scale up currently available renewable energy options

Approximately 60% of the low energy demand will be sourced from the sun, wind, hydropower and geothermal energy. An accelerating and sustained utilisation of these energy sources is essential to the realisation of The Energy Report's energy system. Most of these sources will contribute to a further electrification of our society. The renewable sources mentioned here are particularly suitable for producing electricity, more so than they are for offering heat or fuel solutions. This is reflected by an increasing share of electric power in the overall energy supply to end-users, from around 20% to almost 50%, in 2050.

Overall energy supply in The Energy Report.



Sustainable bio-energy

Not all transport fuels and industrial heat and fuel supply can be substituted with electricity however and by 2050 a substantial contribution from bio-fuels will also be needed. Air and freight transport, for example, will require large quantities of bio-fuels to maintain current and future high levels of activity.

More so than other sources, bio-energy requires a careful consideration of sustainability conditions. The Energy Report ascertains that sufficient source options and conversion technologies for bio-energy are available; source options that meet stringent sustainability criteria for biodiversity, non-degradation of land systems and effects on food production. Following this approach, energy from organic residues and waste will contribute the largest proportion of bio-energy to the 2050 energy supply, followed by the sustainable use of fellings from forestry and, to a lesser extent, energy from crops and algae.

Limitations

Certain manufacturing processes (e.g. steel, cement) need specific properties of their fuels that cannot yet be substituted by renewable fuels. This leads to a residual fossil energy use of 5% in 2050 for which substantially new technologies or alternative products would need to be developed. Renewable energy, as a source, is not the limiting factor; the technical potential of renewable sources is much higher than that used in the scenario.

Grid constraints are another reason why the renewable energy sources are not used to their full potential. New and renovated grids are necessary to accommodate the evolving balance between 'supply-driven' power (solar and wind) and 'demand-driven' sources (biomass or hydropower). With an increase in transmission range and capacity, a share of 20–30% 'supply-driven' power can be achieved. To accommodate higher shares of up to 60%, The Energy Report postulates a re-design of our grids, making full use of demand side management and storage.

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Initial investments will yield returns by 2050

Investments, savings and benefits

Large additional upfront investments are required in the early decades but a considerable share of these will be recouped before 2050 through additional savings. The investments will be approximately 1–2% of the global Gross Domestic Product (GDP); comparable to the value that the world currently invests in clean air and water. There are significant economic gains stemming from a large decrease in material and energy use and by 2035 these annual gains can be higher than the annual investments. The net profit will reach approximately 2% of the global GDP by 2050 from the energy system alone. The Energy Report does not account for additional economic benefits from reduced pollution.

Acting now will secure benefits later

The Energy Report creates questions such as:

> Who will invest?
> Which policies are needed?
> How will tasks be divided between public and private actors?
> How will benefits be distributed?
> What are implications at regional or sectoral level?
> What are the consequences for businesses, organisations, individuals?

The Energy Report concludes that a substantial concerted effort is required in every sector and region of the world's economy over the next four decades and a particularly dynamic effort over the next 10 years. The current level of action is not substantial enough to realise the scenario in The Energy Report. It requires resolute and rapid action. Familiar excuses for inaction no longer apply; conserving energy is compatible with increasing living standards, sufficient renewable energy options are available today and the transition is affordable, even profitable, in the long-term.

The Energy Report provides a concrete direction to a new horizon; a horizon that is technically possible and economically viable for the entire global society. By providing a clear route to achieving this possible scenario, The Energy Report is intended as a source of inspiration for governments, companies and citizens.

WWF is one of the world's largest and most experienced independent conservation organizations, with over 5 million supporters and a global network active in more than 100 countries. WWF's mission is to stop the degradation of the earth's natural environment and to build a future in which humans live in harmony with nature.

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Ecofys – Experts in Energy

Established in 1984 with the vision of achieving "sustainable energy for everyone", Ecofys has become the leading expert in renewable energy, energy & carbon efficiency, energy systems & markets as well as energy & climate policies. The unique synergy between those areas of expertise is the key to its success. Ecofys creates smart, effective, practical and sustainable solutions for and with public and corporate clients all over the world. With offices in the Netherlands, Germany, the United Kingdom, China and the US, Ecofys employs over 250 experts dedicated to solving energy and climate challenges.

Please visit our website: **www.ecofys.com** for the download of the full report.

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