RE-thinking 2050

A 100% Renewable Energy Vision for the European Union

EREC

EUROPEAN RENEWABLE ENERGY COUNCIL

WHO IS EREC

EREC, the European Renewable Energy Council, is the umbrella organisation of the major European renewable energy industry, trade and research associations active in the field of photovoltaics, small hydropower, solar thermal, bioenergy, ocean & marine, geothermal, wind energy, and solar thermal electricity. It represents an industry with an annual turnover of more than €70 billion and with more than 550,000 employees.

EREC shares its offices with its member associations in the Renewable Energy House in Brussels, a model showcase for integration of energy efficiency and renewable energy technologies in a historic building.

EREC' members:

AEBIOM (European Biomass Association)
EGEC (European Geothermal Energy Council)
EPIA (European Photovoltaic Industry Association)
EREF (European Renewable Energies Federation)
ESHA (European Small Hydropower Association)
ESTELA (European Solar Thermal Electricity Association)
ESTIF (European Solar Thermal Industry Federation)
EUBIA (European Biomass Industry Association)
EU-OEA (European Ocean Energy Association)
EUREC Agency (European Association of Renewable Energy Research Centres)
EWEA (European Wind Energy Association)

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Foreword

Europe's current energy system is confronted with a number of uncertainties: unpredictable and highly volatile fossil fuel prices and the resulting economic challenges, geopolitical risks related to import dependency, and the harmful environmental consequences of fossil fuel based energy generation. However, what remains certain, is that if we continue on the energy pathway of the last few decades, climate change will have a more and more unpredictable and disastrous impact on our lives, our energy import dependency will rise, and fossil fuels will become scarcer and concentrated in a few countries around the world.

Inertia is not a solution in the face of these challenges. The answer to these challenges is not beyond our reach, the solution, in fact, lies in our hands and with it our ability to change the future. By switching from fossil fuel, greenhouse gas intensive sources of energy to renewable sources of energy, Europe is able to fully grasp its sustainable potential - in economic, ecologic and social terms.

Significantly increasing energy efficiency and deploying renewable energy technologies is the most promising effort we can make to mitigate man-made climate change and reduce hazardous pollution, enhance local and regional energy independence, stimulate world-class high-tech industries and create thousands of new jobs, not least in rural and remote areas.

Today's energy decisions will shape Europe's supply system for at least the next 50 years, thereby determining the future level of greenhouse gas emissions, fossil fuel dependency and the competitiveness of European economies. In view of the fundamental transformation needed to ensure a sustainable Europe by the middle of the 21st century, a fundamental structural change is needed. As investments in the energy sector are of a long-term nature, the decisions we take today will have an impact on the energy system of tomorrow.

For all these reasons, Europe must prepare the ground for a 100% renewable energy future, starting today. *RE-thinking 2050* outlines a pathway towards a 100% renewable energy supply system by 2050 and clearly shows that it is not a matter of technology, but rather a matter of making the right choices today to shape tomorrow. The challenge ahead of us is huge, but we have no choice if we want to act responsibly towards future generations. "We do not inherit the Earth from our ancestors: we borrow it from our children".[1]

Prof. Arthouros Zervos
President
European Renewable Energy Council (EREC)

1 Native American proverb, likely coined by 20th century environmentalist David Brower

The EREC report *RE-thinking 2050* sets out an ambitious vision for a 100% renewable energy system for the European Union. The report provides a comprehensive estimate of the economic, environmental, and social benefits associated with such a move. It also particularly focuses on the policy recommendations considered necessary to tackle the non-technical barriers to achieving such a vision, tackling all three of the important sectors – electricity, heating and cooling and transport. While the vision may probably be more ambitious than the level likely to be achieved in practice, we very much welcome this important work that thoroughly explores the issues associated with a major expansion in the contribution from renewable energy.

In the IEA's view, the use of renewable energy must be increased in order to improve energy security and reduce climate change. The IEA's Energy Technology Perspective included a Blue Scenario, which envisages reducing global CO_2 emissions by 50% compared with 2005 levels by 2050. When combined with deep cuts in other greenhouse gas emissions, this scenario is consistent with a temperature rise limited to 2-3°C. In this scenario renewable energy will be a key contributor to CO_2 abatement, contributing 21% of the required reductions. Electricity will be the most important sector, with the proportion from renewables rising from the current 18 to 46%. Since total electricity production doubles during this period, this implies a four-fold increase in renewable power production. Currently a more ambitious renewables scenario is under development, in which 75% of global electricity production comes from renewable sources.

Realising these ambitious goals will be difficult. Technical challenges will need to be overcome. The technologies also need to become progressively more cost competitive. To ensure large scale investment and deployment in the electricity, heating and cooling and transport sectors, the required policy framework needs to be developed and implemented, including appropriate financial incentives and measures to tackle the other non economic barriers. Furthermore, the physical infrastructure will need to be adapted.

RE-thinking 2050 makes a valuable contribution to the reflections on the features of the policy framework which will be needed to meet any ambitious renewable energy target in the future.

Didier Houssin
Director of Energy Markets and Security Directorate
International Energy Agency (IEA)

Introduction

Europe's demand for energy is increasing in an environment of high and unstable energy prices. Greenhouse gas emissions are rising and the energy sector is one of the main emitters of greenhouse gases. Natural reserves of fossil fuels such as oil and gas are concentrated in just a few supplier countries around the world. Climate change along with an increasing dependency on energy imports are only a few of the risks the European economy is facing today. The energy sector is the fuel of Europe´s economic engine, hence having the right approach is important.

In order to counteract these tendencies and ensure a sustainable energy and economic future for the European Union (EU), we need to act now in order to deliver sustainable, secure and competitive energy. The interrelated challenges of climate change, security of energy supply and competitiveness are multifaceted and require a profound change in the way Europe produces, delivers and consumes energy. Harnessing the EU´s energy efficiency potential and fully deploying its sustainable, indigenous renewable energy resources are therefore vital and the only way to go forward.

Simultaneously mitigating climate change and securing energy supply by renewable energy sources constitutes an important factor for mid- to long-term economic growth. Fully grasping and enabling the growth opportunities of tomorrow requires fostering comprehensive action from EU policies, industry and society. Renewable energy is a stimulus for economic growth. Moreover, a strong emphasis on "sustainable development" must lie at the heart of any economic, environmental and social activity.

With the agreement in 2009 on the Energy and Climate Package which contains the European Directive on the promotion of the use of energy from renewable sources with its binding target of at least 20% renewable energy in final energy consumption by 2020, the EU has made a strong and ambitious commitment towards renewable energy. The direction Europe has started to take is the right one however we need to continue and speed-up the needed transformation of our energy system through continuous and stable commitments and policy frameworks, especially in economically challenging times.

Europe should lead the way with a clear commitment to a 100% renewable energy future by 2050. Analyses by the European renewable energy industry and by many renowned scientific institutions show that this is not only technologically feasible, but also the only truly sustainable alternative both in economic terms, and in social and environmental terms.[1]

The challenges of transforming Europe's energy system remain urgent and daunting: the EU currently imports approx. 55% of its energy[2] – and might reach 70% in the next 20 to 30 years.[3] In 2030 the EU will be importing 84% of its gas, 59% of its coal and 94% of its oil. In these circumstances, it is obvious that the challenge to satisfy our energy needs is big.

Europe has to break the cycle of increasing energy consumption, increasing imports, and increasing outflow of wealth created in the EU to pay energy producers. At 2008 energy prices, every EU citizen is paying around €700 per year for the external control of their energy supply.[4] By increasing the share of renewable energy and thereby decreasing the energy import bills, significant savings can be made, which can then be used for building the renewable energy based infrastructure that Europe needs, not only boosting the EU's indigenous energy supply, but also strengthening the competitiveness of our economy as well as creating sustainable jobs and sustainable economic growth.

RE-thinking 2050 presents a pathway towards a 100% renewable energy system for the EU, examining the effects on Europe's energy supply system and on CO_2 emissions, while at the same time portraying the economic, environmental and social benefits of such a system. Moreover, the report provides policy recommendations for what is needed to fully exploit the EU's vast renewable energy potential.

Reinventing the EU´s energy system on a sustainable energy model is one of the critical challenges of the 21st century. Renewable energy can become the backbone of Europe's energy and economic system within this century. The challenge ahead of us is an enormous one, but tackling it will open up a far reaching sea of opportunities.

1 Christopher Jones: "A zero carbon energy policy for Europe: the only viable solution", in: EU Energy Law, Volume III, Book Three: ***The European Renewable Energy Yearbook***. 2010. Page 51f. and 81f.**;** Hulme, M., Neufeldt, H., Colyer, H.: *Adaptation and Mitigation Strategies: Supporting European climate policy. The final report from the ADAM project.* 2009; ECF: *Roadmap 2050: a practical guide to a prosperous, low-carbon Europe*. April 2010; SRU: *Setting the Course for a Sustainable Electricity System*. Full report forthcoming October 2010.

2 European Commission (Eurostat): *Sustainable development in the European Union. 2009 monitoring report of the EU sustainable development strategy.* 2009. Page 83.

3 European Commission: *A European Strategy for Sustainable, Competitive and Secure Energy*. 2006.

4 European Commission(COM(2008) 781 final): *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Second Strategic Energy Review. An EU Energy Security and Solidarity Action Plan*. 2008.

01

Objective

The objective of the following report, *RE-thinking 2050*, is to set a long-term vision for the energy system in the European Union (EU), one which is entirely based on renewable energy sources. The report outlines a way towards 2030 and presents a vision for 2050. In addition, it analyses the economic, environmental and social benefits likely to accompany such a transition and points out the necessary framework conditions to make this vision become reality.

Determining a long-term vision over 40 years is, by nature, a difficult task and the resulting outlook should by no means be seen as an exact prediction of what the future has in store for us. Projections of economic growth rates, fossil fuel prices and of the overall energy demand are of course assumptions and do by no means represent concrete prognoses. Long-term scenarios are to be considered as analytical tools for reflection, highlighting choices and opportunities, rather than predicting the future. However, looking at the energy system of tomorrow can provide valuable insight into what has to be done today to achieve the desired situation in the EU in 2050.

Source: EC

02

Renewable Energy Sources and Technologies

When talking about renewable energy, we refer to an abundant range of technologies that can provide energy services in the form of electricity, heating and cooling as well as transport solutions. The questions to be addressed to the renewable energy sector should not concentrate solely on whether it is desirable to have a centralised or decentralised energy system or on which source of renewable energy will dominate in the world of tomorrow. The two concepts and all types of energy harnessing the forces of nature must be considered as interdependent if energy supply, climate mitigation and competitiveness are to be secured and increased in a sustainable manner.

The following renewable energy technologies are included in this report (Table 1): bioenergy, wind, hydro-power, all solar technologies as well as geothermal and ocean energy.

Table 1 Renewable Energy Sources and Technologies

	Electricity	Heating and Cooling	Transport
Wind	Onshore Offshore		
Hydro	Small Hydropower (<10MW) Large Hydropower (>10MW)		
Solar	Photovoltaics (PV) Concentrated Solar Power (CSP)	Solar Thermal	
Ocean	Wave; Tidal; Thermal; Osmotic		
Geothermal	Conventional Geothermal Electricity (hydrothermal); Electricity ORC and Kalina Cycle; Enhanced goethermal systems (EGS); Supercritical fluids	Direct Use Ground Source Heat Pumps	
Bioenergy	Biomass Biogas	Biomass Biogas	Bioethanol Biodiesel Biogas

The terms used in this report for the various renewable energy sources (RES) as well as for gross final energy consumption ("final energy demand") are in accordance with the definitions applied in the European Directive on the promotion of the use of energy from renewable sources ("Renewable Energy Directive")[1].

1 See Article 2 of *Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*.

03

Current Status of Renewable Energy in the EU

EU Market Overview

Hardly anyone could imagine how fast the renewable energy sector has developed over the past few years. All forecasts on the expansion of renewable energy have consistently been surpassed.

Within just two decades, renewable energy has developed from an alternative energy source in a niche market to one of the most important energy sources worlwide and a driving force for a sustainable 21st century economy. Renewable energy is currently on its way to becoming the mainstream source of Europe's energy system in the conceivable future.

By the end of 2009 the renewable energy sector secured more than 10% of Europe's final energy consumption, provided one-quarter of the EU's binding 20% greenhouse gas reduction target (or 7% CO_2 reduction against 1990 emissions), over 550,000 high quality jobs, and had an annual turnover exceeding €70 billion (Table 2).

Table 2 RES Market Overview (2004-2010)

	2004	2006	2008	2010
Jobs	200,000	300,000	400,000	550,000
Turnover (€bn)	10	15	35	70
RES share (%)	8.2	9.2	10.5	12

Source: EREC

These are not mere figures, this is the competitive strength of Europe. The European Renewable Energy Industry is the leader on world markets and a real growth factor for a sustainable 21st century economy.

In other words, the renewable energy sector is not only making a significant contribution to a more sustainable supply system and to improving security of energy supply, but is also manufacturing equipment, exporting technology and creating added value.

Moreover, the renewable energy industry will create new jobs and bring about market opportunities. EREC believes that by 2020 renewable energy could offer jobs to more than two million citizens in Europe[1] and provide a leading market with a turnover of several hundred billion Euros.

By looking closer into the RES development of recent years it is becoming obvious that the renewable energy industry is on a promising track to making Europe's Energy Future a Renewable Energy Future. In 2007, renewable energy reached a share of 9.9% of the EU´s final energy consumption. As can be seen in Table 3, from 2005 to 2007 the RES share increased by 1.3 percentage points (0.65%-points per year).

Table 3 RES Development (2005-2007)

	2005		2006		2007		AGR 2005-2007
TYPE OF ENERGY	Mtoe	%	Mtoe	%	Mtoe	%	%
Final Energy Consumption*	1,211.2	100	1,213	100	1,194.9	100	-0.7
1. Electricity**	42.45	3.5	44.26	3.7	46.69	3.9	4.9
2. Heating and Cooling	59.44	4.9	62.17	5.1	62.98	5.3	2.9
3. Transport Biofuels	3.15	0.3	5.38	0.4	7.88	0.7	51.6
Total Renewable Energy	105.0	8.6	111.8	9.2	118	9.9	5.9

Source: EREC based on EUROSTAT data
*Including electricity and steam transmission/distribution losses and own consumption
**Normalised for hydro and wind

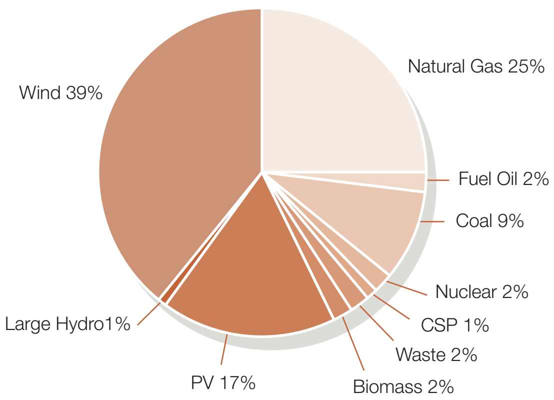
1 See section *"Social Benefits"* of chapter 7. For further reading see as well a study conducted by Frauenhofer-ISI for the European Commission on the employment effect of deploying renewable energy technologies "EmployRES".

If the EU follows this increase of 0.65%-points per year in the next decade, it will already reach a share of 18.35% renewable energy in its final energy consumption by 2020 (following business as usual). However, it has to be noted that the progress in the development of renewable energy in Europe up to 2010 is mainly driven by a few EU countries and is accompanied by the European Directive on electricity from renewable sources[2] and the Directive on biofuels[3], both setting indicative targets.

It is clear that the European Commission took on an ambitious political project when it proposed a binding 20% target for renewable energy in Europe, and succeeded in so doing. However, given past trends and technological developments, EREC believes that the Renewable Energy Directive[4], including its binding targets for each of the EU-27 Members States, will in fact enable Europe to reach a much higher share of renewable energy than the minimum binding target of at least 20% by 2020.

The rapid development of the renewable energy industry is underlined by another historical fact. In 2008 more new renewable energy capacity was installed in the field of electricity than any conventional source of electricity. Renewable energy made up 57% of the overall 23.8 GW installed in 2008.[5] This figure was topped in 2009, where, as can be seen in **Figure1**, 62% of all new installed electricity capacity was in renewable energy, clearly led by wind, PV and biomass.[6] Hence, in two successive years neither gas, nor coal nor nuclear power reached by far the amount of newly installed renewable electricity generation capacity. Both in 2008 and 2009 RES power was investors' first choice.

Figure 1 Installed Capacity in 2009

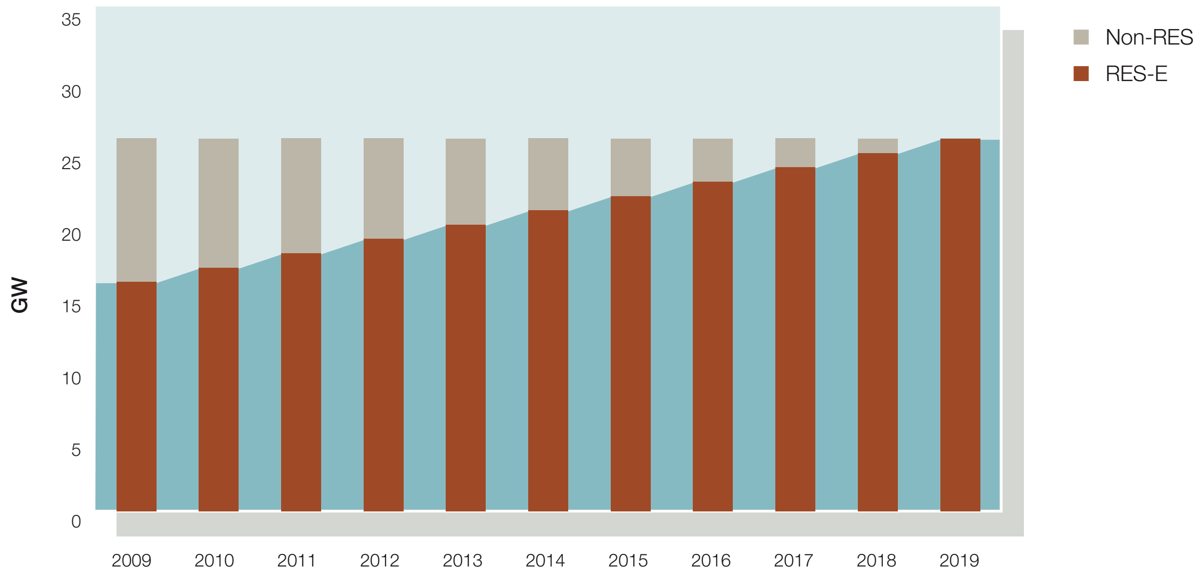


Source: EWEA, EPIA, ESTELA, EU-OEA and Platts Powervision

A pure extrapolation of this trend would mean that if Europe were to continue in this trend of newly installed RES power capacity of 5%-points per annum over the years to come, then this would result in Europe not needing to build a single new conventional power plant after 2020. Obviously, this is a simplification of complex investment decisions and market developments, and one which implies that the total newly installed electricity capacity remains constant on an annual basis (26 GW per annum). However, as can be seen in **Figure 2**, this assumption clearly underlines the fact that RES electricity generation does have the potential to replace fossil and conventional power generating capacity.

2 European Union: *Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market*. 2001.
3 European Union: *Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport*. 2003.
4 Directive 2009/28/EC.
5 European Wind Energy Association (EWEA): *Wind Map 2008.* 2009
6 European Wind Energy Association (EWEA): *Wind in power. 2009 European statistics.* 2010. Page 6.

Figure 2 **BAU RES-E Capacity Increase vs. Constant Total Newly Installed Electricity Capacity**



Source: EREC

CO_2 Reduction from Renewable Energy Sources

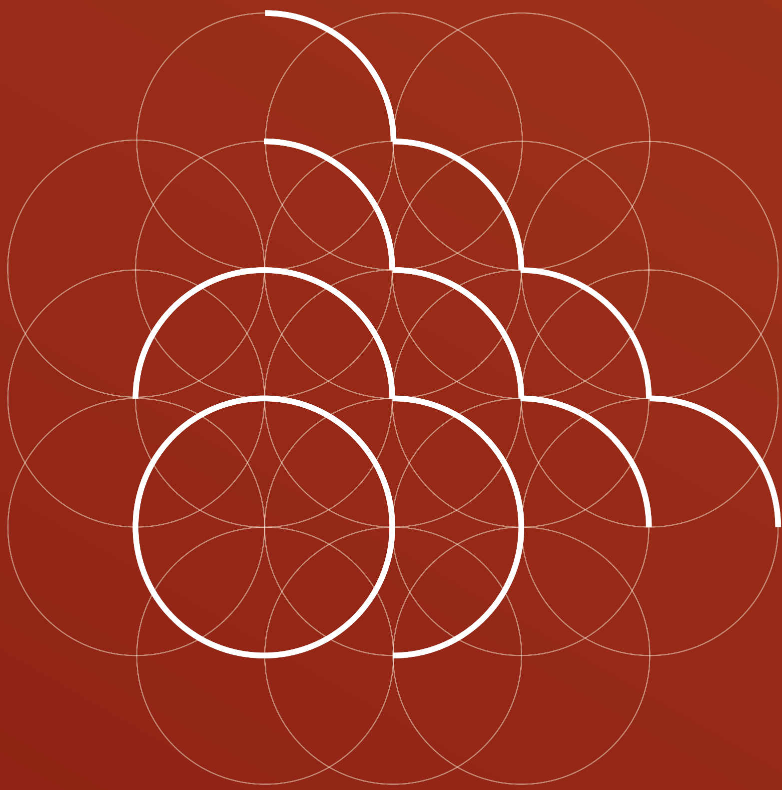
Wind, solar, hydropower, ocean and geothermal energy do not contain any fossil carbon atoms to form climate-damaging CO_2 during combustion. In principle, biomass is stored solar energy; it is CO_2-neutral as it absorbs the same amount of CO_2 during growth period as it emits during use.

Hence, renewable energy is not only resource compatible, but also climate compatible. In 2009 alone, CO_2 emissions were reduced by about 340 million tonnes or 7% against 1990 levels in the EU through the use of renewable energy sources.[7] Given a carbon price of about €15/t in 2009 this emission reduction benefit equals about €51 billion.

6 See section *"Environmental Benefits"* of chapter 7 for a detailed explanation of the methodology..

04

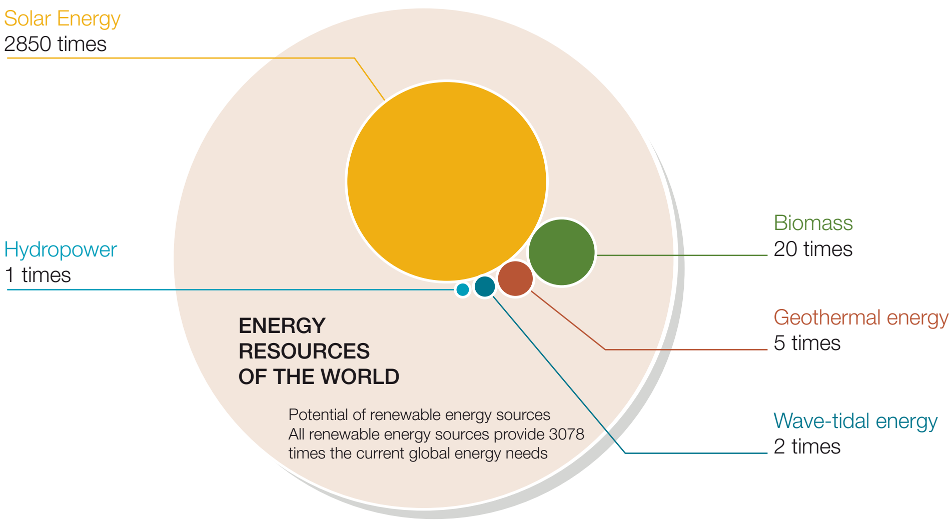
General Approach and Definition of Potentials



Nature offers a broad range of renewable energy sources: ocean energy, geo- and solar thermal, photovoltaics, bioenergy, wind, hydropower and solar thermal electricity. They all stem in some way or another from the constant flow of energy that hits the surface of the earth from the sun, and from the continuous heat flux coming from the earth. These constant flows of energy amount to about 3,000 times the total present day energy consumption of the whole of mankind. In one day, the sunlight which reaches the earth produces enough energy to meet the current global power needs for eight years.[1] For many centuries industrialised societies have not been able to grasp this incredibly rich source of energy. We have lacked the technology to reach out and make use of this vast source of energy, thereby letting it pass us by for many years. Today, we have the technology to largely harvest these resources and satisfy a planet hungry for energy.

However, when outlining the availability of renewable energy sources, it is important to define the type of potential that is considered. There is no one single definition of the different types of potentials. *RE-thinking 2050* distinguishes and defines three types of potentials: theoretical, technical and economic potential.

Figure 3 **Energy Resources of the World**



Source: WBGU 2008 (Greenpeace/EREC 2008)

Theoretical Potential

The highest level of potential is the theoretical potential. In order to derive the theoretical potential, general physical parameters must be taken into account (e.g. based on the determined energy flow resulting from a certain energy resource within the investigated region). Hence, the theoretical potential identifies the upper limit of what can be produced from a certain energy resource from a theoretical point of view, of course, based on current scientific knowledge.

Technical Potential

The technical potential takes into account technical boundary conditions, i.e. the conversion efficiency of technologies, overall technical limitations such as the land area that is available for energy generation as well as the availability of raw material. For most resources the technical potential must be considered in a dynamic context – e.g. with increased research and development (R&D), conversion technologies may be improved and, hence, the technical potential increase.

1 Greenpeace International/EREC: *energy [r]evolution – a sustainable global energy outlook*. 2008. Page 122.

Economic Potential

The economic potential is the proportion of the technical potential that can be realised economically. Hence, the economic potential takes into account cost levels which are considered to be competitive.

In this report, calculations are based on a CO_2 price of 41 €/t CO_2 in 2020, 45 €/t CO_2 in 2030 and 100 €/t CO_2 in 2050 and on oil prices of $100 per barrel in 2020 and $120 in 2030 rising to $200 per barrel in 2050.[2]

This report focuses on the economic potential of renewable energy. In addition, the capital investments of each technology for 2020, 2030 and 2050 are analysed. The costs are expressed in €/unit installed.

2 For further details see the following chapter 5 (Overall assumptions and scenarios).

05

Overall Assumptions and Scenarios

In order to be able to simulate and comprehend the assumptions given in the ***RE-thinking 2050*** report, it is important to provide the scenarios that were used to assess the total share of renewable energy for the years ahead. As mentioned in chapter 1 (Objective), scenarios are tools for reflection, not concrete prognoses of the future. In this sense, different scenarios were taken or developed on the future energy system in Europe in order to analyse the contribution of the different renewable technologies and renewable energy in general in 2020, 2030 and in 2050.

Both the demand and the supply side assumptions are limited to the EU-27 and do not include third countries. For bioenergy, however, a volume of about 10% of imports of raw material from outside the EU is included in the case of the higher demand scenarios. Hence, increased energy efficiency and savings would result in a decreasing share of bioenergy imports.

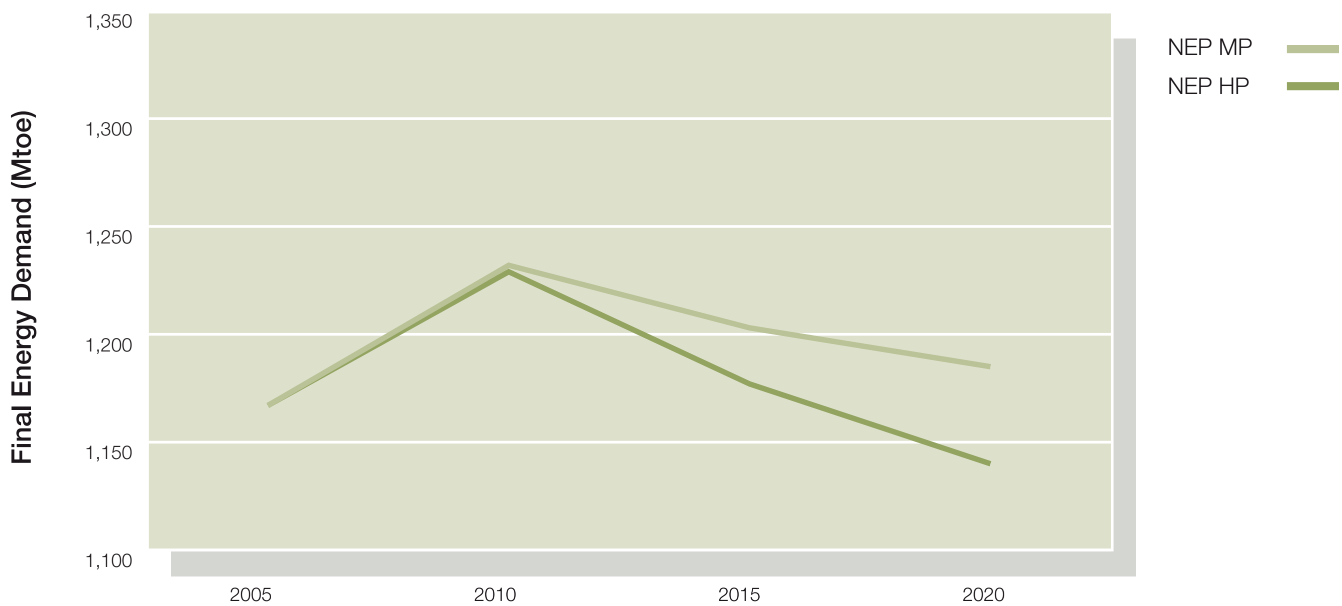
Demand Side Assumptions

Assumptions for 2020 on final electricity, heat and cooling as well as transport demand are based on the Commission´s "New Energy Policy" (NEP) scenario with both a moderate and high price environment as outlined in the Second Strategic Energy Review.[1]

The NEP scenarios assume full implementation of new policies to make substantial progress on energy efficiency. The 20% renewable energy and greenhouse gas targets for 2020 are assumptions used for the NEP.

In the New Energy Policy, the price of CO_2 is equal to 41 €/t and is determined endogenously in order to reach the 20% emission reduction target with moderate energy prices. The moderate price (MP) environment means an oil price of $61/barrel in 2020[2]. The high price (HP) environment would comprise an oil price of $100/barrel in 2020[3]. As can be seen in **Figure 4** this would result in a reduction of energy demand of 4% compared to the $61/barrel scenario.

Figure 4 Consumption Assumptions (2005-2020)



	2005	2010	2015	2020
NEP MP	1,167	1,232	1,203	1,185
NEP HP	1,167	1,229	1,177	1,140

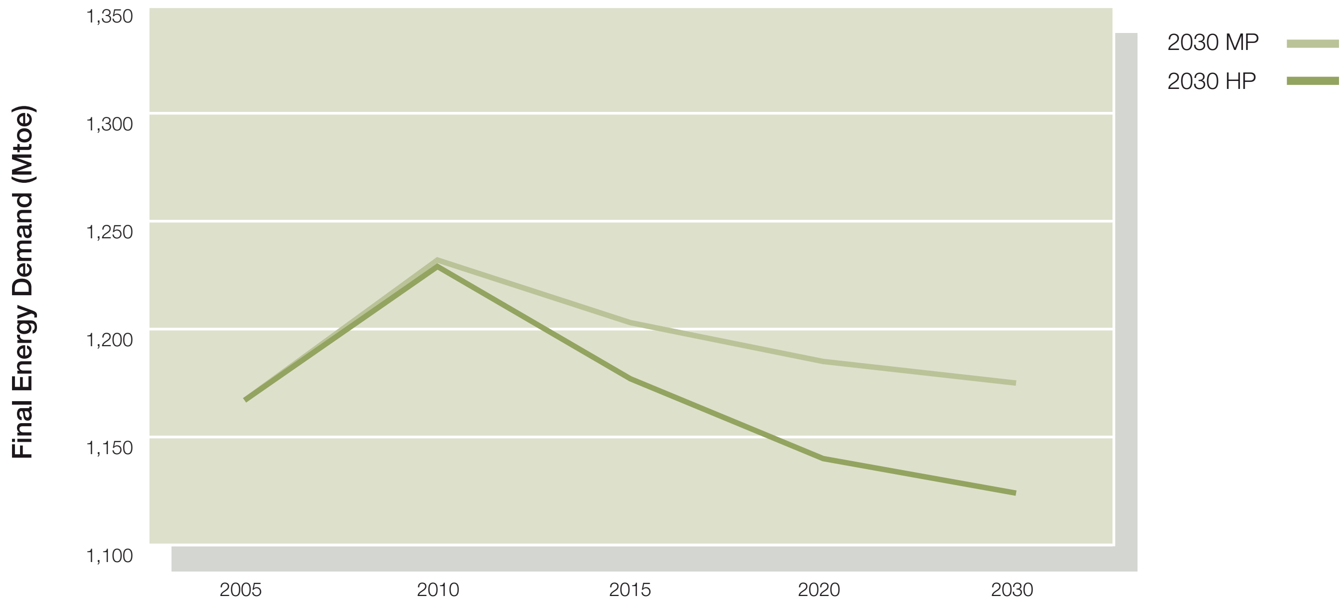
Source: EREC based on "Second Strategic Energy Review", European Commission 2008

1 European Commission(COM(2008) 781 final): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Second Strategic Energy Review. An EU Energy Security and Solidarity Action Plan. 2008.
2 This price equates to a nominal price of 84 $/barrel in 2020 provided that the ECB reaches its target to keep inflation from now on below 2% pa.
3 This price equates to nominally 137 $/barrel with future inflation of just under 2% pa.

The total share of renewable energy in the EU's energy demand in 2030 is examined through two different scenarios. EREC has projected demand in 2030 following a moderate price scenario assuming $63/barrel and a high price scenario, which assumes $120/barrel in 2030.[4] Figure 5 shows that the trend of decreasing energy demand would continue in both scenarios.

Apart from the assumptions on the price of CO_2, which is assumed to be 45€/t, all other assumptions such as population or GDP were calculated by EREC following the same parameters as given in the Commission's NEP for 2020.

Figure 5 Consumption Assumptions (2005-2030)



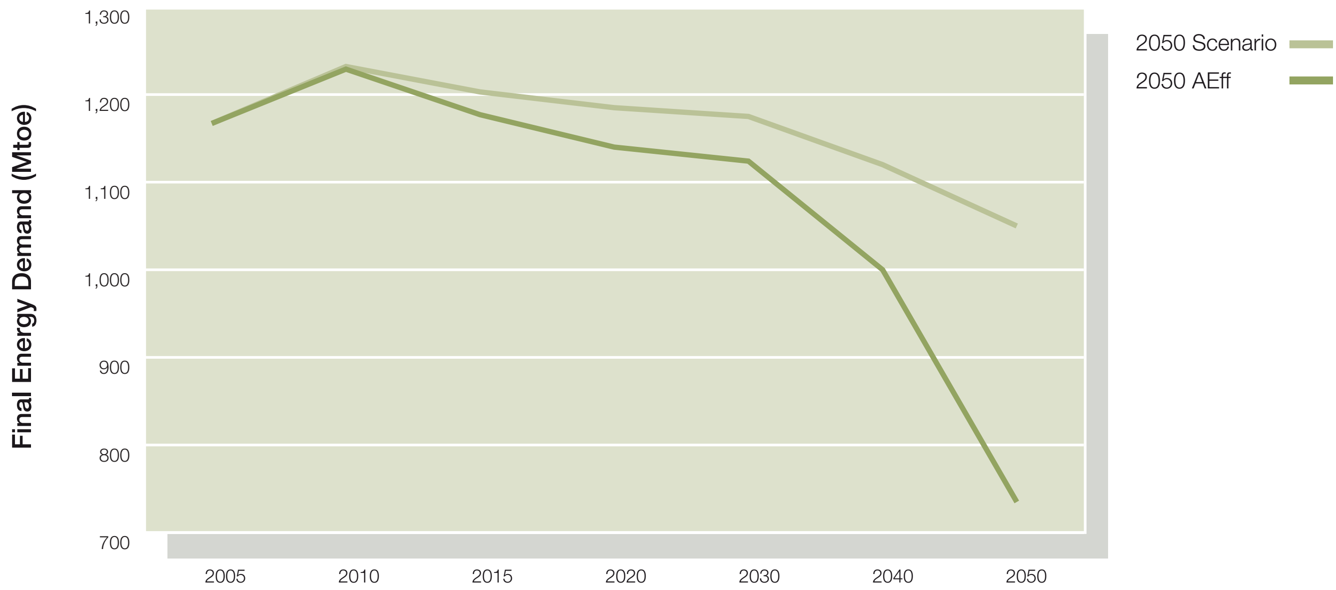
	2005	2010	2015	2020	2030
2030 MP	1,167	1,232	1,203	1,185	1,175
2030 HP	1,167	1,229	1,177	1,140	1,124

Source: EREC

4 The European Commission assumes in its ***European Energy and Transport – Trends to 2030*** (update 2007) an oil price of $66/barrel, while the International Energy Agency assumes $115/barrel (World Energy Outlook 2009).

According to **Figure 6**, final energy consumption in the EU-27 by 2050 will be 1050 Mtoe, an assumption that EREC considers within reason and in line with other modelling scenarios.[5] The lower line indicates what might be possible in 2050 on the basis of an aggressive efficiency and savings approach. It assumes that overall energy demand can be reduced by 30% against the consumption assumption for 2050 – this equals an energy saving of about 38% compared to today.

Figure 6 Consumption Assumptions (2005-2050)



	2005	2010	2015	2020	2030	2040	2050
2050 Scenario	1,167	1,232	1,203	1,185	1,175	1,120	1,050
2050 AEff	1,167	1,229	1,177	1,140	1,124	1,000	735

Source: EREC

Supply Side Assumptions

Supply side figures for each RES technology are projections by EREC's member associations in accordance with the underlying assumptions of the respective scenarios. Given that 2050 is four decades away, the precise mix of renewable energy technologies is not forecasted but rather seen as a prognosis, within which a wide range of options exist. Hence, the aim is not to discriminate between the various RES technologies, but rather to keep a focus on remaining on the overall 100% RES pathway, showing that both in technical and economic terms, it is feasible to get to a fully sustainable energy system based on renewable energy in the EU by 2050.

5 See for instance: Christopher Jones: „A zero carbon energy policy for Europe: the only viable solution"; In: EU Energy Law, Volume III, Book Three: *The European Renewable Energy Yearbook*. 2010. Page 51f. and 81f.**;** Eurelectric: *Power Choices – Pathways to carbon-neutral electricity in Europe by 2050*. 2009; Hulme, M., Neufeldt, H., Colyer, H.: *Adaptation and Mitigation Strategies: Supporting European climate policy. The final report from the ADAM project.* 2009.

06

Renewable Energy Sources' Contribution to Final Energy Consumption

The following chapter gives the outlook of the RES industry on how the different renewable energy technologies can contribute to a 100% renewable energy supply by 2050. *RE-thinking 2050* outlines a pathway towards a fully sustainable energy system in the EU given that strong political, public and economic support for all renewable energy technologies is provided.[1] However, due to the long-term framework of *RE-thinking 2050*, the exact technology mix is of an indicative nature.

Renewable Electricity up to 2050

One can observe today the characteristics of the past, in particular in the EU´s power sector, a centralised, nationally organised electricity supply system with ageing technologies and underdeveloped power markets. Still, more than 20 years after the Single European Act was signed (in 1986), the EU is lacking a well-functioning internal market for electricity. However, in order to meet its 2020 climate and energy targets, the EU has to accelerate its ambition to create a single European power market, based on renewable electricity (RES-E), an EU Super Grid as well as a Smart Grid in order to facilitate an intelligently and efficiently interconnected electricity system of both centralised and decentralised renewable energy installations.

Especially in the period leading up to 2020, Europe has to invest in new energy production capacity to replace ageing plants while meeting future demand. Approximately 330 GW of new power capacity needs to be built by 2020, which represents 42% of the current EU capacity.[2] The EU must use such an opportunity created by this up-coming large turnover in capacity to construct a new, modern renewable energy power supply and grid system capable of meeting the energy and climate challenges of the 21st century, while enhancing Europe's competitiveness and creating hundreds of thousands of jobs. The new power system must be supported by a well functioning internal market in electricity in which investors, rather than consumers, are exposed to carbon and fuel price risk.

As can be seen in Table 4, with an average annual growth rate of renewable electricity capacity of 14% between 2007 and 2020, the EU will have an installed renewable power capacity of about 520 GW in 2020, which means that an extra 336 GW will be built in that time. Hence, renewable energy has a crucial role to play, as it can thus provide the 336 GW of new electricity capacity mentioned above that needs to be built over the coming years to replace ageing power plants and meet the expected increase in demand.

Table 4 Renewable Electricity Installed Capacity (GW)

	2007	2020	2030	2050
Wind	56	180	288.5	462
Hydro[1]	102	120	148	194
PV	4.9	150	397	962
Biomass	20.5	50	58	100
Geothermal	1.4	4	21.7	77
CSP	0.011	15	43.4	96
Ocean	-	2.5	8.6	65
Total RES-E capacity (GW)	185	521.5	965.2	1,956

Source: EREC
1 The capacity of pumped storage plants is not included

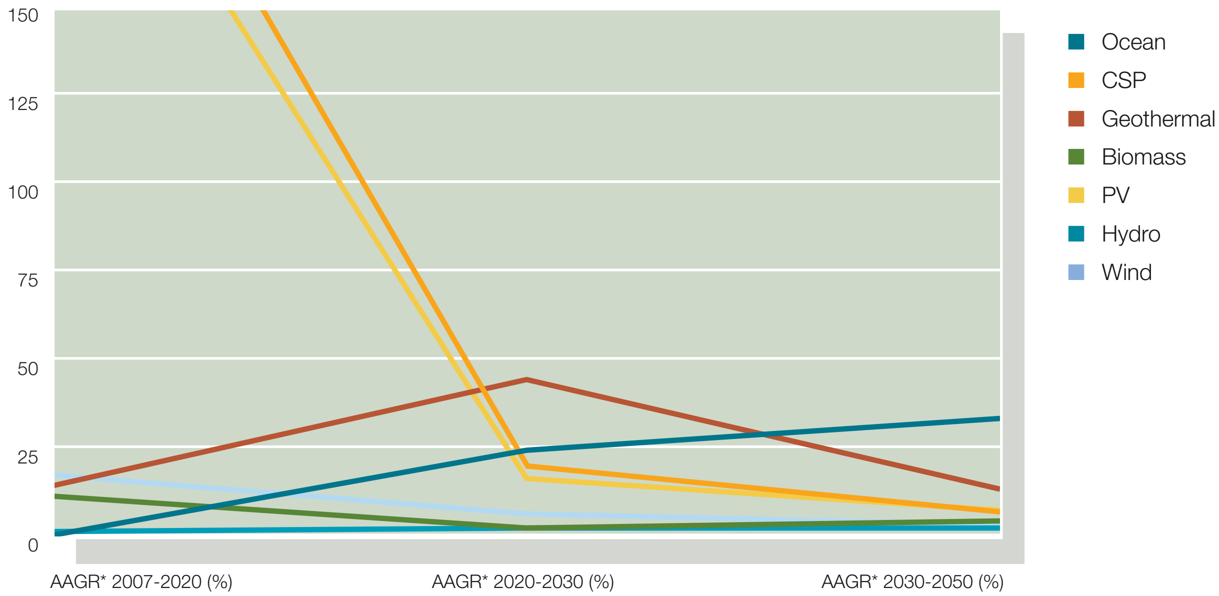
1 For policy recommendations see chapter 8.

2 European Wind Energy Association (EWEA): *Pure Power – Wind energy targets for 2020 and 2030.* 2009. Page 6.

Between 2020 and 2030, geothermal electricity is predicted to see an average annual growth rate of installed capacity of about 44%, followed by ocean energy with about 24% and CSP with about 19% (Figure 7). This is closely followed by 16% for PV, 6% for wind, 2% for hydropower and biomass with about 2%. By 2030, total RES-E installed capacity amounts to 965.2 GW, dominated in absolute terms by PV, wind and hydropower. Between 2020 and 2030, total installed RES-E capacity will see an increase of about 46% with an average annual growth rate of 8.5%.

As can be seen in Table 4 this trend of a steep increase of RES-E installed capacity continues after 2030 leading to almost 2,000 GW of installed capacity by 2050.

Figure 7 Average Annual Growth Rates of Renewable Electricity Technologies



* Average Annual Growth Rates (AAGR) under "ceteris paribus" conditions

As mentioned previously, the Renewable Energy Directive sets an overall target of a share of at least 20% renewable energy by 2020. As far as electricity is concerned, the European Commission expects that the share of renewable energy will need to increase to 34%.[3] According to Table 5, by 2020, all RES-E technologies will contribute to about 39% of the total electricity consumption. The RES contribution to power demand increases further in 2030, where the share of renewable electricity will account for 65-67%. By 2050 renewable electricity will provide for 100% of the EU´s power demand and certainly top it in the "aggressive efficiency" scenario.

Table 5 Contribution of Renewable Electricity Technologies to Electricity Consumption (TWh)

		2007	2020	2030	2050
Wind		104	477	833	1552
Hydro[1]		325	384	398	448
PV		5.4	180	556	1347
Biomass		102	250	292	496
Geothermal		5.8	31	169	601
CSP		0.8	43	141	385
Ocean		-	5	18	158
Total RES-E (TWh)		543	1,370	2,407	4,987
Total Gross Electricity Consumption					
Eurostat		3,362			
NEP	Moderate Price High Price		3,443 3,493		
2030	Moderate Price High Price			3,616 3,702	
2050	Scenario Aggressive Efficiency				4,987* 3,491**
Total Share of RES-E (%)		16%	39.2 – 39.8%	65% - 67%	100% - 143%

Source: EREC

1 The capacity of pumped storage plants is not included

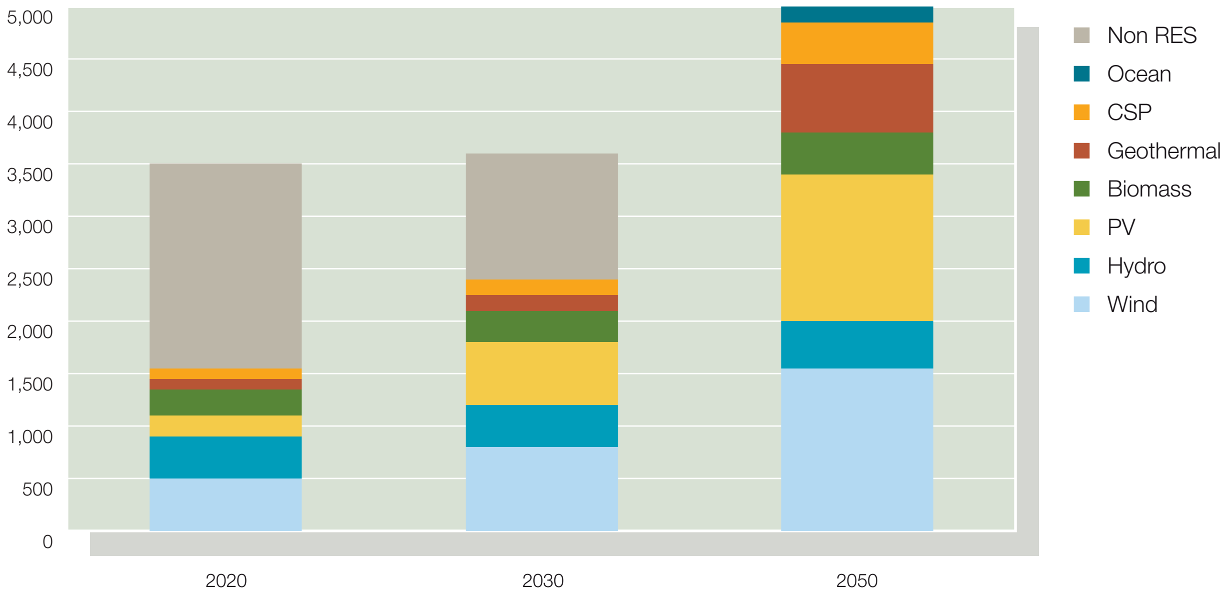
* the strong increase of electricity demand is mainly due to a modal shift and the electrification of the road transport sector as well as an increase in heat pumps usage.

** setting an energy efficiency target of about 30% against the 2050 Scenario

3 European Commission (COM(2006) 848 final): *Communication from the Commission to the European Parliament. Renewable Energy Road Map. Renewable energies in the 21st century: building a more sustainable future*. 2007. Page 11.

As can be seen, a significant increase of electricity demand is expected between 2030 and 2050 (Table 4). This is mainly due to two factors: an increase in heat pumps usage and a modal shift of both passenger and freight transport to less energy intensive public transport such as bus and rail as well as a shift of fuel usage towards the electrification of road transport. The overall magnitude of the impact of electric vehicles (EVs) on the power sector depends on the penetration rate, on yearly mileage, and on battery efficiency. However, as outlined in more detail further on in this chapter, *RE-thinking 2050* assumes a slow uptake of EVs after 2020 and a steep increase after 2030, with a view to the electrification of road transport by 2050.[4]

Figure 8 Contribution of Renewable Electricity Technologies to Electricity Consumption (TWh)



Source: EREC

Figure 8 shows that by 2020 the largest contribution to RES-E will come from wind, hydropower and biomass. By 2030, this picture changes slightly and wind will be closely followed by PV (556 TWh) and hydropower (398 TWh). Wind and PV continue being the largest contributors up to 2050, but geothermal electricity will see the biggest increase in absolute terms between 2030 and 2050 (+72%). While the increase of CSP and ocean energy between 2020 and 2030 remains moderate, both technologies will see a significant increase towards 2050 accounting for about 8% and 3.2% respectively of the EU´s total electricity demand.

4 The typical lifetime of an average car is 10 to 20 years.

Renewable Heating and Cooling up to 2050

The heating and cooling demand accounts for 49% of the overall final energy demand in the EU and will most likely remain a high share of the final energy demand in the future to come. Without a major shift towards heating and cooling from renewable energy, the EU will continue to import an ever larger share of fossil fuels, while damaging the environment and putting the health of its citizens at risk. To meet the overall target of at least 20% by 2020, the share of renewable heating and cooling (RES-H&C) could almost triple compared to the current share of about 10%. Most of the growth could be provided by biomass. However, and as can be seen in Table 6, by 2030 solar thermal will make up a share of about 20% of total RES heat contribution, while geothermal will increase to about 10%. By 2050, biomass could contribute 214.5 Mtoe, while geothermal could account for 136.1 Mtoe and solar thermal for 122 Mtoe.

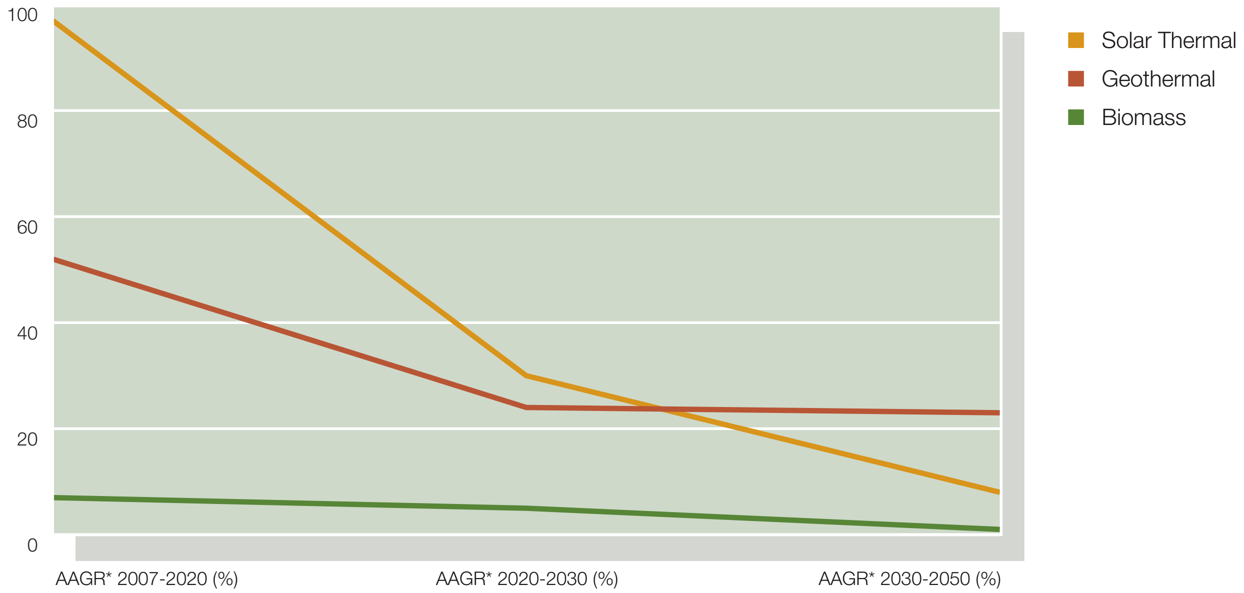
Table 6 Renewable Heating and Cooling Consumption (Mtoe)

	2007	2020	2030	2050
Biomass	61.2	120	175	214.5
Solar Thermal	0.88	12	48	122
Geothermal	0.9	7	24	136.1

Source: EREC

The largest average annual growth rate for each of the renewable energy heating and cooling technologies will be seen between 2007 and 2020, while towards 2030 and 2050 these rates will go down to 23% for geothermal, 8% for solar thermal and 1% for biomass (Figure 9).

Figure 9 Average Annual Growth Rates of Renewable Heating and Cooling Technologies



* Average Annual Growth Rates (AAGR) under "ceteris paribus" conditions

According to **Table 7**, between 2020 and 2050, RES-H&C will see an increase of about 30% amounting to around 470 Mtoe in 2050. RES-H&C will reach a share of almost 30% of total heat consumption by 2020 and cover more than half of the EU´s heat demand by 2030. By 2050 renewable heating and cooling will provide 100% of the consumption assumed in the "2050 Scenario".

Table 7 Contribution of Renewable Heating and Cooling Technologies to Heat Consumption (Mtoe)

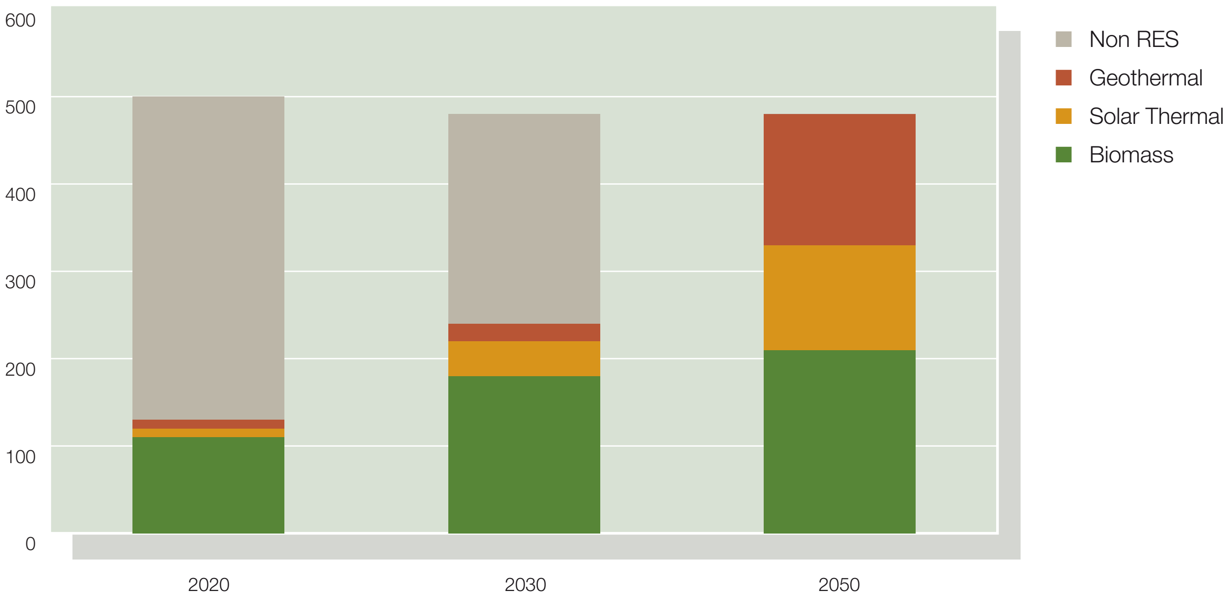
		2007	2020	2030	2050
Biomass		61.2	120	175	214.5
Solar Thermal		0.88	12	48	122
Geothermal		0.9	7	24	136.1
Total RES-H&C (Mtoe)		62.98	139	247	472.6
Total Heat Consumption					
Eurostat		554			
NEP	Moderate Price High Price		499 465.7		
2030	Moderate Price High Price			474.1 436.7	
2050	Scenario Aggressive Efficiency				472.6 330.8*
Total Share of RES-H&C (%)		11.4%	28% - 29%	52% - 57%	100% - 143%

Source: EREC

* setting an energy efficiency target of about 30% against the "2050 Scenario"

Figure 10 shows that biomass will remain the main source of renewable heat supply in 2020, 2030 and up to 2050. However, in 2030, solar thermal comes second with a contribution of 48 Mtoe and geothermal third with 24 Mtoe. By 2050, geothermal is expected to provide about 140 Mtoe of the heat demand, while solar thermal follows closely behind with more than 120 Mtoe, supplying about 26% of the EU´s total heat consumption.

Figure 10 Contribution of Renewable Heating and Cooling Technologies to Heat Consumption (Mtoe)



Source: EREC

Renewable Transport up to 2050

Today, the transport sector relies on an unbroken and relatively cheap supply of oil for its survival. There is no other sector which shows such a high level of dependence on one single source of energy. The EU transport sector has an oil dependency of 98%, the vast majority of which is imported. Transport patterns as well as road, rail, sea faring or air infrastructure were mainly developed during an era of relatively cheap fossil fuel transport. However, energy intensive pathways are no longer sustainable. In the EU, compared to 1990 levels, in no other sector has the growth rate of greenhouse gas (GHG) emissions been as high as in transport.[5] Between 1990 and 2007, total GHG emissions from transport (excluding international aviation and maritime transport) in the EU-27 increased by 26% while emissions from non transport sectors decreased over the same period. Road transport dominates with 94% of total transport GHG in 2007.[6]

The need for a "transportation reform" is more urgent now than ever. To meet the Commission´s ambition to "end oil dependence in the transport sector"[7], measures to improve efficiency, expand the use of biofuels and biomethane as well as the promotion of the uptake of new vehicle technologies such as electric, renewable hydrogen and hybrid cars are needed in order to significantly reduce oil demand.

Biofuels will play a key role in making the transport sector sustainable. The EU is the world's leading region for both production and consumption of biodiesel which accounts for 63% of biofuel supply in the EU in 2007. On the other hand, bioethanol is the most important biofuel at a global level, with the EU covering about 10% of its supply.

Table 8 Biofuels Consumption (Mtoe)

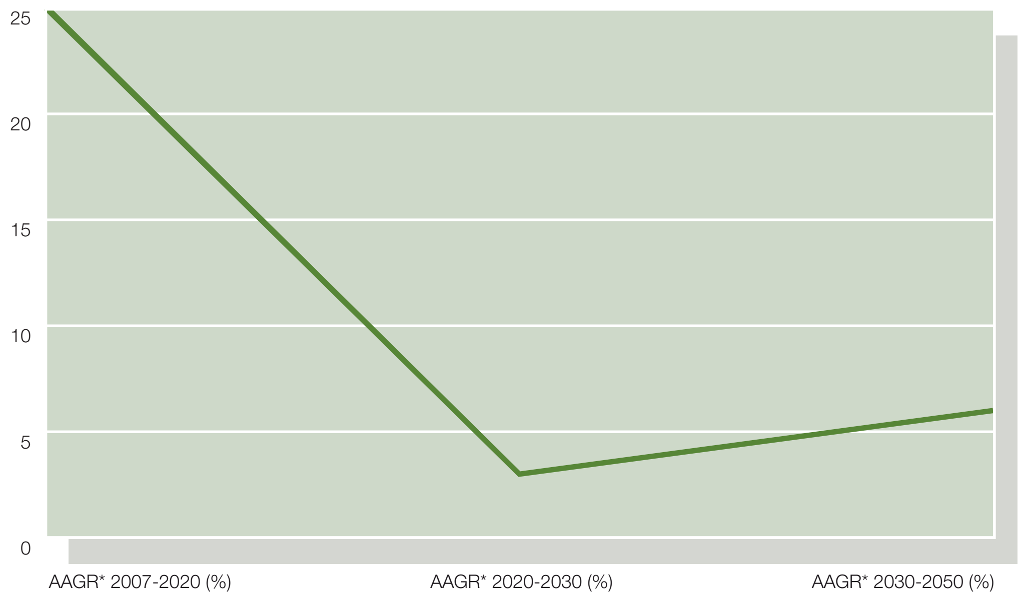
	2007	2020	2030	2050
Biofuels	7.88	34	44.5	102

Source: EREC

As shown in Table 8, biofuels production increases from 34 Mtoe in 2020 to 102 Mtoe in 2050. The Renewable Energy Directive sets a binding target for the share of renewable energy in transport of at least 10% by 2020[8], whereby the majority of that will certainly be met by biofuels. However, in the long-run, biofuels may well be reserved for those applications where high energy density liquid fuels will remain predominant in the foreseeable future such as heavy duty vehicles (HDVs).

5 DG TREN: ***EU energy and transport in figures***. Statistical pocketbook. 2009.
6 European Commission (Eurostat): ***Sustainable development in the European Union. 2009 monitoring report of the EU sustainable development strategy.*** 2009. Page 94.
7 European Commission(COM(2008) 781 final): *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Second Strategic Energy Review. An EU Energy Security and Solidarity Action Plan.* 2008. Page 16
8 Article 3, paragraph 4 of Directive 2009/28/EC.

Figure 11 Average Annual Growth Rate of Biofuels



* Average Annual Growth Rates (AAGR) under "ceteris paribus" conditions

By 2020, 9% of the transport fuel demand will be met by biofuels (Table 9). However, it has to be noted that this scenario compares biofuels production to the total transport fuel demand, while the target setting in the Renewable Energy Directive is based on the demand for diesel and gasoline. According to the NEP scenario for 2020, diesel and gasoline consumption makes up about 300 Mtoe in both NEP price scenarios. Hence, 9% of total transport fuel demand would correspond to 11% of the demand for diesel and gasoline in 2020, thereby exceeding the binding target of at least 10% renewable energy share in road transport with biofuels alone. In 2030, diesel and gasoline consumption makes up about 315-360 Mtoe. Hence, the 11.4% to 12% would correspond to 12% to 14% of the demand for diesel and gasoline.

Table 9 Contribution of Biofuels to Transport Fuel Demand (Mtoe)

		2007	2020	2030	2050
Biofuels production		7.88	34	44.5	102
Total Transport Fuel Demand					
Eurostat		377			
NEP	Moderate Price High Price		390 374		
2030	Moderate Price High Price			390 369	
2050	Scenario Aggressive Efficiency				148.6* 104**
Total Share of RES-T		2%	8.7% - 9%	11.4% - 12%	68.6% - 98%

Source: EREC

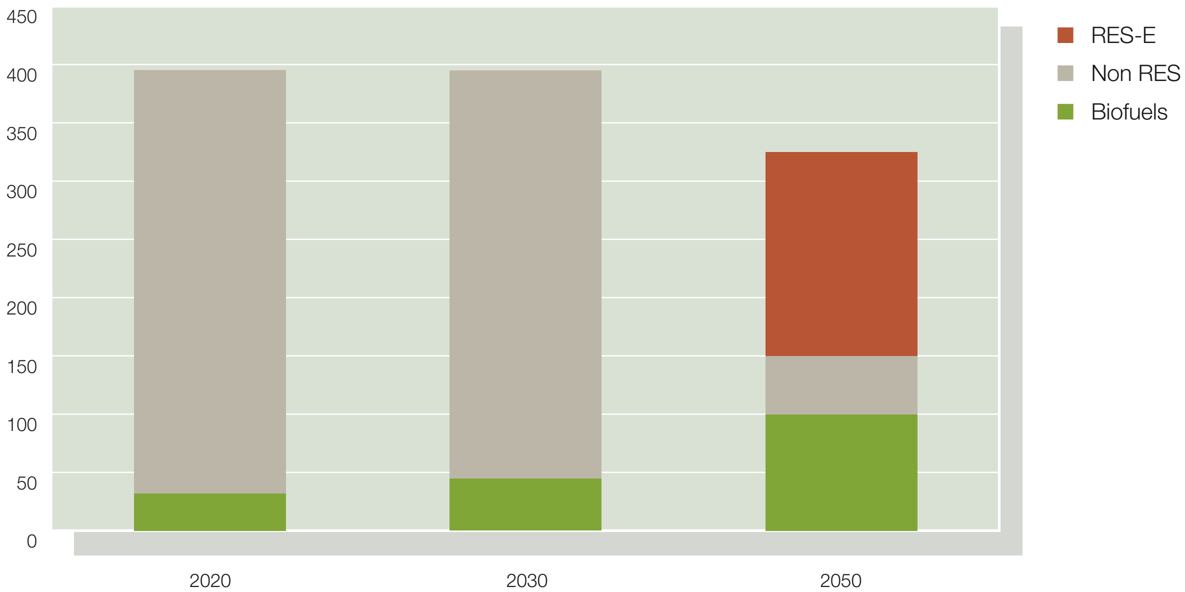
* the strong decrease of fuel demand in the transport sector is due to the shift of transport fuel usage towards electrification.

** setting an energy efficiency target of about 30% against the "2050 Scenario"

A steep decrease of transport fuel demand between 2030 and 2050 can be seen in Table 9. This is due to a modal shift of both passenger and freight transport to less energy intensive public transport, such as bus and rail, as well as the electrification of the road transport sector.

Conservatively assuming that an average electric vehicle (EV) consumes 0.20 kWh/km[9] and has an average annual mileage of 10,000 kilometres per car, an EV would consume 2,000 kWh annually. Therefore, knowing that there were about 230 million cars in Europe in 2007,[10] a figure which is expected to increase to about 385 million by 2050[11], about 770 TWh would be needed in order to power all light duty vehicles (LDVs) and medium duty vehicles (MDVs). Due to the fact that electric engines are considered to be more efficient than combustion technologies there is an additional efficiency gain with the shift from current diesel and gasoline usage to EVs. Conservatively and in line with the Renewable Energy Directive, the electricity consumed by electric road vehicles is considered to be 2.5 times the energy content of the electricity input.[12] Hence, about 166 Mtoe of assumed overall transport fuel demand would be replaced by renewable electricity in 2050[13], reducing the total fuel demand to about 150 Mtoe (Figure 12).

Figure 12 Contribution of Biofuels to Transport Fuel Demand (Mtoe)



Source: EREC

Uncertainties remain, however, with regard to heavy duty vehicles (HDV), aviation and inland navigation. In this report it is assumed that about 50 Mtoe of fossil fuels are likely to go into those transport modes in 2050. No assumptions are made in this publication on the use of biofuels in shipping or aircrafts, although they are already contributing at a pilot stage today.

Nevertheless, the analyses provided in this chapter give a clear indication that even in the "2050 Scenario" the total transport fuel demand in 2050 can largely be met by biofuels and renewable electricity. With additional efficiency and energy savings measures RES could provide for 100% of the EU´s 2050 transport fuel demand (Table 9).

9 See for instance: CE Delft: *Green Power for Electric Cars*. 2010. Page 16; or EEA: *Environmental impacts and impact on the electricity market of a large-scale introduction of electric cars in Europe*. 2009 *Forthcoming.*

10 DG TREN: ***EU energy and transport in figures***. Statistical pocketbook. 2009. Page 156.

11 Extrapolation of data from European Commission „Energy and Transport – Trends to 2030 (update 2007)" in TREMOVE (www.tremove.org); for further information see: "EU Transport: Routes to 2050" (www.eutransportghg2050.eu)

12 Article 3, paragraph 4 of Directive 2009/28/EC.

13 Applying the 2.5 efficiency factor leads to an electricity demand of 1,925TWh, which equals about 166 Mtoe.

Renewable Energy up to 2050

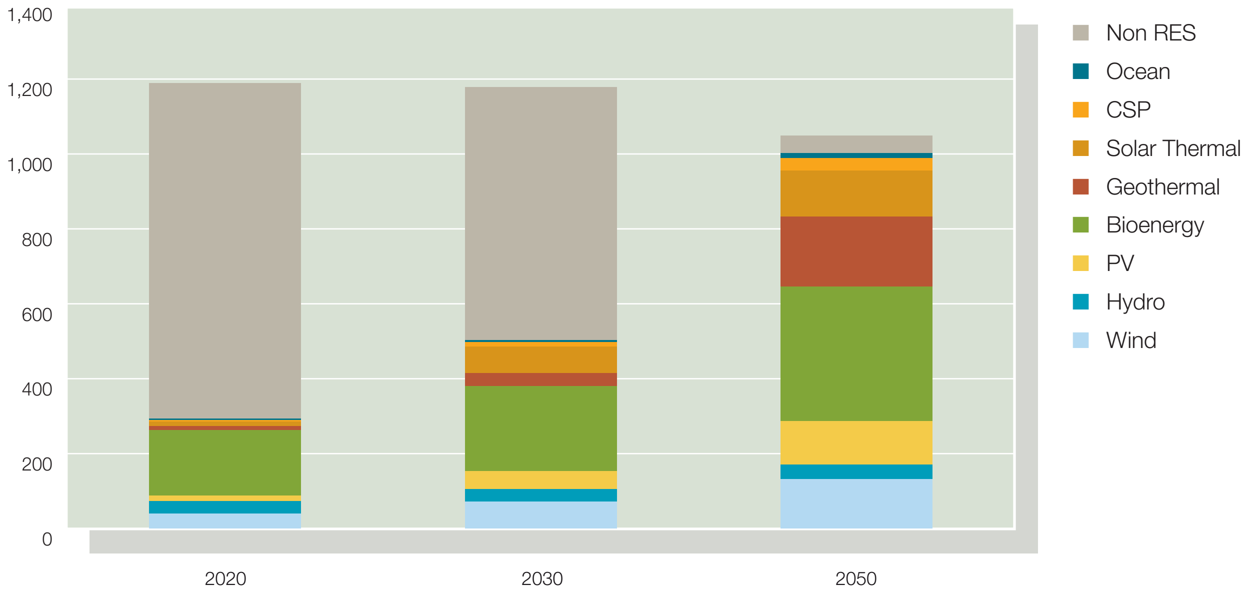
As indicated in Table 10 from about 118 Mtoe at present, the EU will see a rise to roughly 1,000 Mtoe of renewable energy by 2050, an increase of more than 88% of current renewable energy deployment within 40 years.

Table 10 Contribution of Renewable Energy to Final Energy Consumption (Mtoe)

RES Type		2007	2020	2030	2050
Wind		8.9	41	72	133.5
Hydro[1]		27.9	33	34.2	38.5
PV		0.5	15.5	48	116
Bioenergy		77.8	175.5	226	359.1
Geothermal (Electricity and H&C)		1.4	9.7	35.5	188
Solar Thermal		0.9	12	70	122
CSP		0.1	3.7	12.1	33.1
Ocean		-	0.4	1.5	14
TOTAL RES (Mtoe)		118	290.8	499.3	1,004.2
Final Energy Consumption					
Eurostat		1,194.9			
NEP	Moderate Price High Price		1,185 1,140		
2030	Moderate Price High Price			1,175 1,124	
2050 2050	Scenario Aggressive Efficiency				1,050 735*
Total Share of RES (%)			24.5 – 25.5%	42.4% - 44.4%	96% - 137%

Source: EREC
1 – The capacity of pumped storage plants is not included
* assuming an energy efficiency target of about 30% against the “2050 Scenario”

Figure 13 Contribution of Renewable Energy Technologies to Final Energy Consumption (Mtoe)



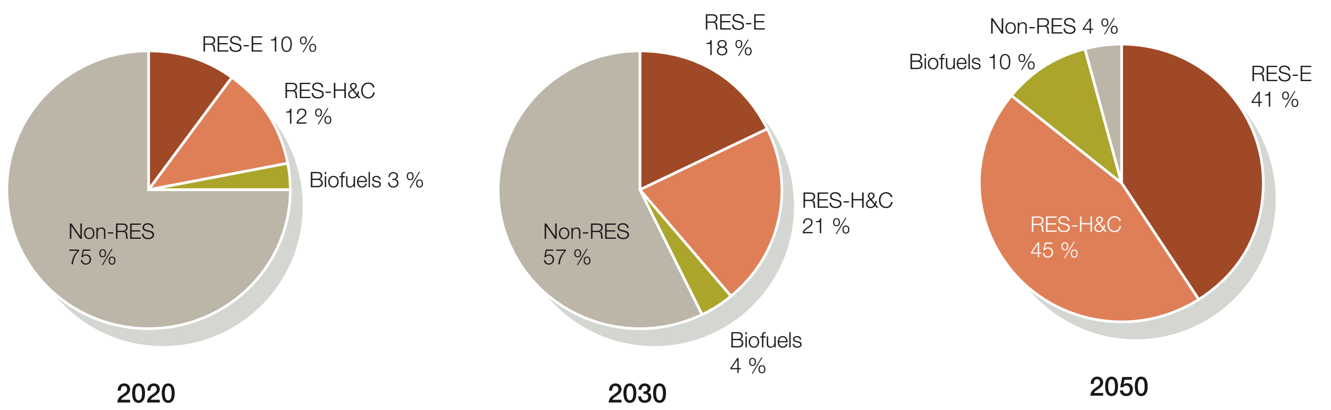
Source: EREC

The largest increase towards 2050 both in terms of energy output and contribution to final energy is projected for renewable electricity, in particular for pure power options such as wind and PV (**Table 10**). The share of renewable electricity of total final energy demand increases from 10% in 2020 to 18% in 2030 and finally 41% by 2050 (**Figure 14**).

As a sector, heating and cooling remains the largest contributor to final energy demand. The renewable heating and cooling market comprising residential and industrial biomass as well as solar thermal and geothermal applications, is predicted to take off fast. Together, they hold a share of about 21% and 45% of total final energy consumption in 2030 and 2050 respectively (**Figure 14**).

In terms of growth rate, renewable energy in the transport sector can look forward to a significant increase, especially in the post-2020 years when advanced conversion technologies such as lignocellulosic bioethanol are ready to enter the market at a significant scale. As can be seen in **Figure 14** the share of renewable transport fuels in overall final energy consumption increases from 3% by 2020 to 4% by 2030. In 2050 their share is likely to account for 10%.

Figure 14 Contribution of Renewable Energy to Final Energy Consumption by Sector (Mtoe)



Source: EREC

07

Economic, Environmental and Social Benefits

Sustainability encompasses not only ecological but also economic and social aspects, which must always be considered collectively and in their interactions.[1]

A 2009 study by HSBC concluded that the three most promising sectors in terms of social return, job creation and relevance to the recovery of the global economy are renewable energy, building efficiency and sustainable vehicles.[2] The following chapter analyses the economic benefits, including security of supply and RES investment, the environmental benefits by looking into avoided CO_2 emissions and the related carbon costs which are avoided and finally the social benefits for European citizens.

Economic Benefits

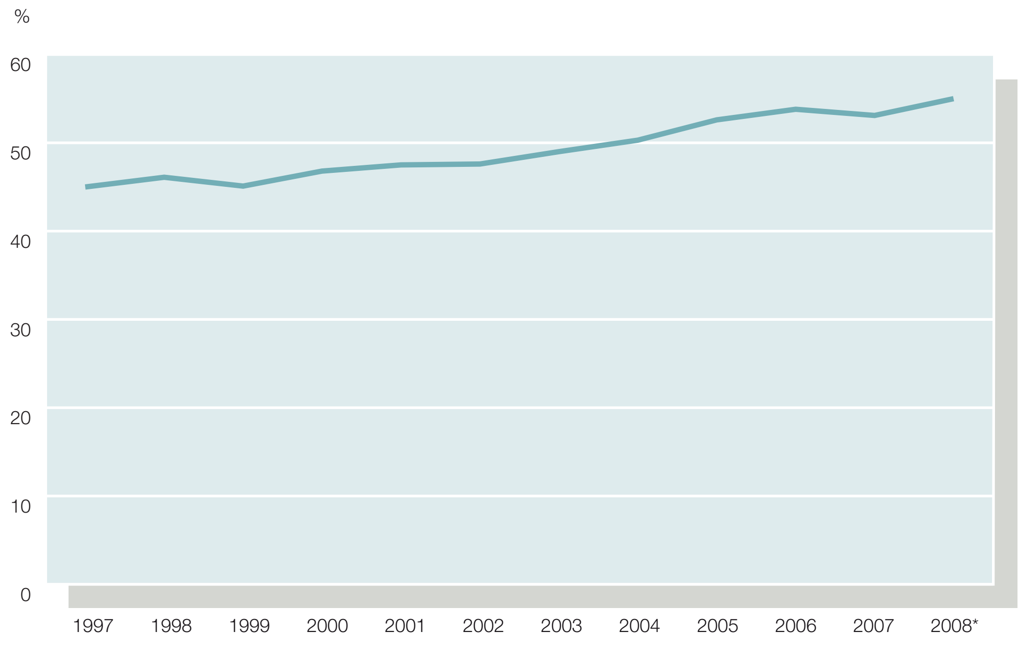
When outlining the economic impacts of deploying renewable energy technologies two aspects have to be considered: 1) security of energy supply and related avoided fuel costs; and 2) the capital requirements involved.

Security of Energy Supply and Avoided Fuel Costs

Security of energy supply was the main driver of EU energy policy in the mid-1990s in the move towards renewable energy.[3] This concern has further increased as has the EU´s import dependency from 45% in 1997 to about 55% in 2008[4] (Figure 15). Certainly, this dependency turns into a price risk as fossil fuels are globally traded commodities. According to the European Commission, these energy imports represent an estimated €350 billion, which is equal to around €700 annually for each and every EU citizen.[5]

With its large and increasing dependency on imported fossil fuels the EU is highly vulnerable to any disruption in supply, both politically and socio-economically. Recent history has shown that these risks are real.

Figure 15 EU-27 Import Dependency (1997-2008)



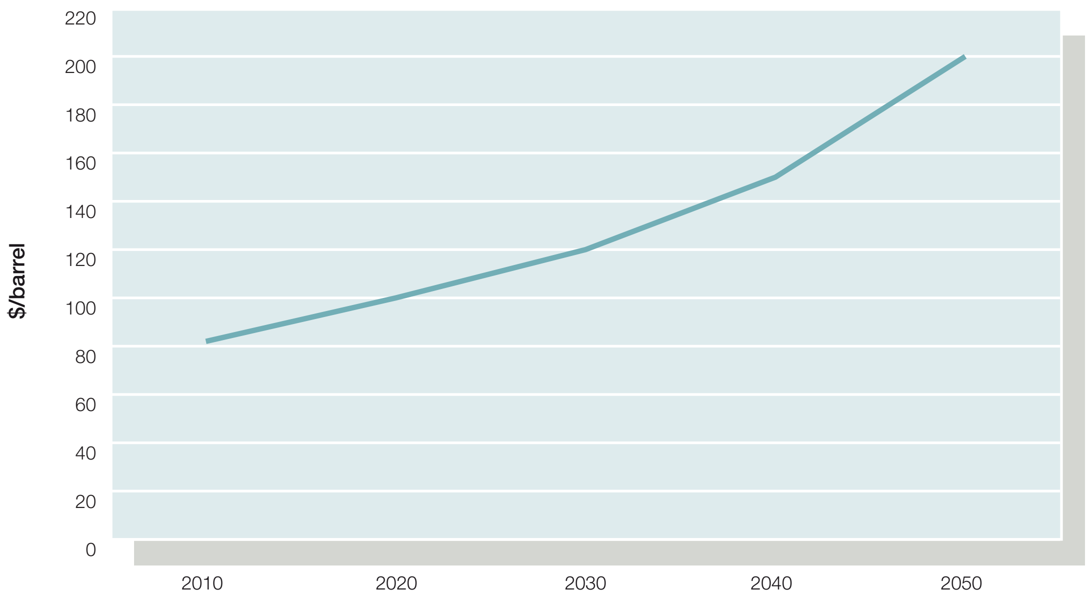
Source: EREC based on Eurostat
* 2008 based on Eurostat´s 2009 *monitoring report of the EU sustainable development strategy*

1 A comprehensive definition of "sustainability" was first formulated by the Brundtland Commission, adopted by the Rio Conference in 1992: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
2 HSBC: *A Climate for Recovery.* 25th February 2009.
3 European Commission (COM(1997) 599 final): *Communication for the Commission. Energy for the future: Renewable sources of energy. White Paper for a Community Strategy and Action Plan*. 1997.
4 European Commission (Eurostat): *Sustainable development in the European Union. 2009 monitoring report of the EU sustainable development strategy.* 2009. Page 83.
5 European Commission(COM(2008) 781 final): *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Second Strategic Energy Review. An EU Energy Security and Solidarity Action Plan.* 2008. Page 2.

Relying on natural sources for their "fuel", one of the most attractive facts about renewable energy technologies is that their increased use is contributing to enhanced security of supply by decreasing fossil fuel dependency from third countries and diversifying fuel consumption within the EU. The use of biofuels for example replaced 1,593 million litres of gasoline and 7,730 million litres of diesel in the EU in 2007. This is almost 3% of the total EU fuel consumption in road transport.[6] In addition, renewable energy saves significant amounts of fuel costs in the form of fossil and nuclear energy. Hence, renewable energy clearly forms an important part in reducing the EU´s vulnerability.

The amount of avoided fossil fuels and related fossil fuel expenses due to increased renewable energy production are obviously very sensitive to the energy prices assumed. Today, oil and gas prices are very closely linked, as is coal – to a lesser extent –, and follow the price of oil. Therefore, the fuel costs avoided due to increased renewable energy production by 2020 can be calculated on the basis of the European Commission's fuel price assumptions in its NEP scenario. For 2030 and 2050, the oil price is assumed to increase as outlined in chapter 5 (Overall assumptions and scenarios) to $120 and $200 per barrel, respectively, with a linear variation in the intermediate years (**Figure 16**).

Figure 16 Oil Price Assumption (2010-2050)



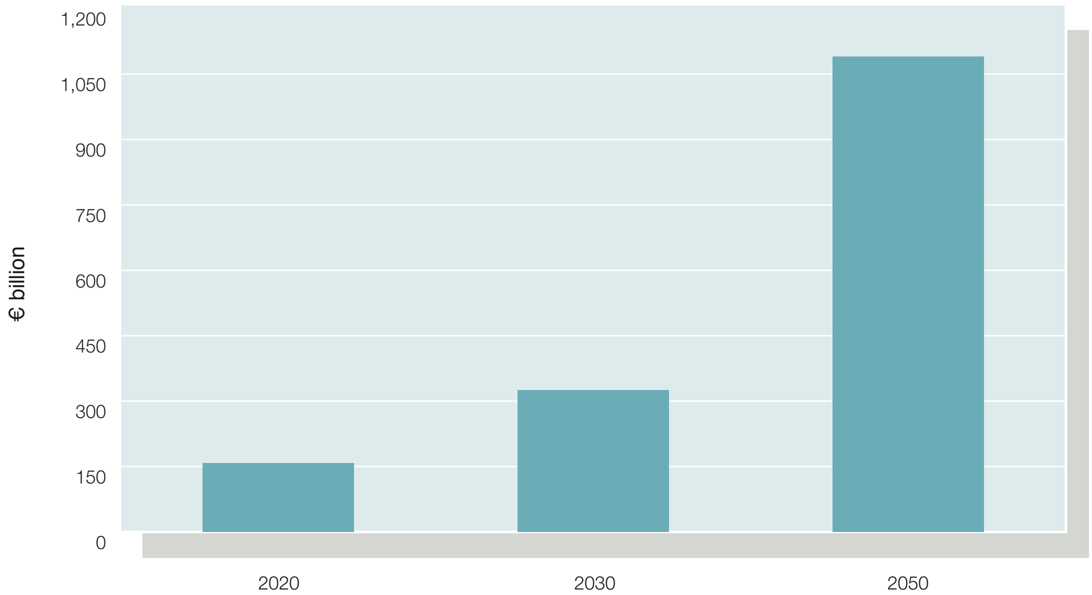
	2010	2020	2030	2040	2050
Oil price assumption*	82	100	120	150	200

Source: EREC
* 2010: European Commission, Market Observatory;
2020: NEP High Price scenario;
remaining based on EREC assumptions

By 2020, the EU can reduce its annual fossil fuel demand by over 290 Mtoe, reaching almost 500 Mtoe by 2030 and more than 1,000 Mtoe by 2050.[7] Hence, renewable energy will avoid fossil fuel costs of about €158 billion in 2020, €325 billion in 2030 and about €1,090 billion (or more than €1 trillion) in 2050 (**Figure 17**).[8] The calculation is based on an exchange rate of $1.35/€.

6 European Commission (COM(2009) 192 final): *Communication from the Commission to the Council and the European Parliament. The Renewable Energy Progress Report.* 2009. page 7.
7 As calculations on the overall contribution of RES are expressed in million tonne of oil equivalent (Mtoe) it is assumed that one Mtoe of renewable energy replaces one Mtoe of fossil fuel.
8 Using a conversion factor of 1 tonne of oil equivalent (toe) = 7.33 barrels. Hence, with an oil price of $100, for instance, one toe costs $733.

Figure 17 **Avoided Fuel Costs from RES Deployment (2020-2030-2050)**



Source: EREC

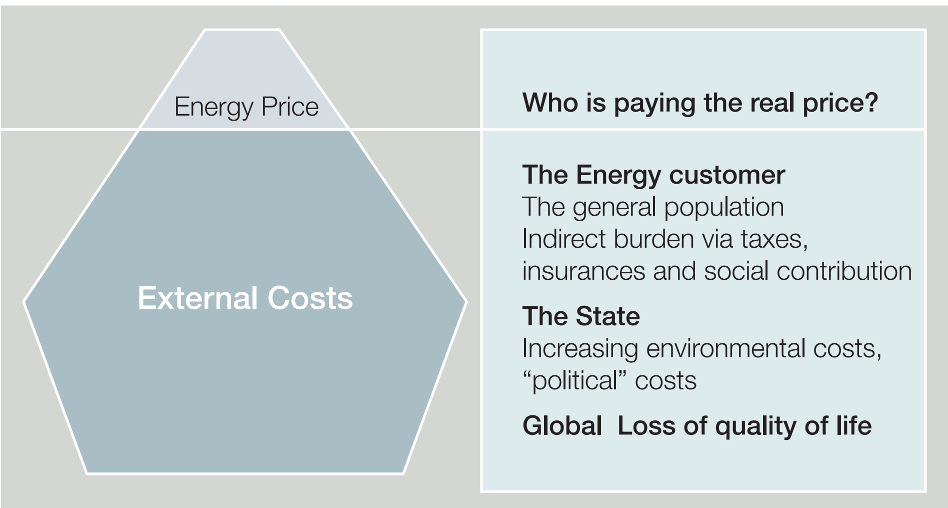
Certainly, every Euro spent on renewable energy and energy efficiency is a spending on Europe's energy independency and the clear enhancement of every citizen's energy security.

Capital Investments

The costs of producing energy and its value are still largely disconnected entities in the current business environment. The price we pay in our energy bill today simply does not include all the costs incurred to society: air pollution and subsequent health costs and the disruption of the natural environment.

Energy market price signals remain distorted in favour of fossil and nuclear energy sources[9], in particular due to the continued failure to systematically internalise the mentioned external costs (Figure 18). Although external costs are partially internalised through the EU´s Emission Trading System (ETS), fiscal instruments or support schemes for renewable energy sources, current market prices are still far from reflecting true cost.[10]

Figure 18 **External Costs**



9 European Commission (COM(2006) 851 final): *Communication from the Commission. Inquiry pursuant to Article 17 of Regulation (EC) No 1/2003 into the European gas and electricity sectors (Final Report).* 2007.

10 For further reading see: European Commission: *ExternE. Externalities of Energy*. 2005.

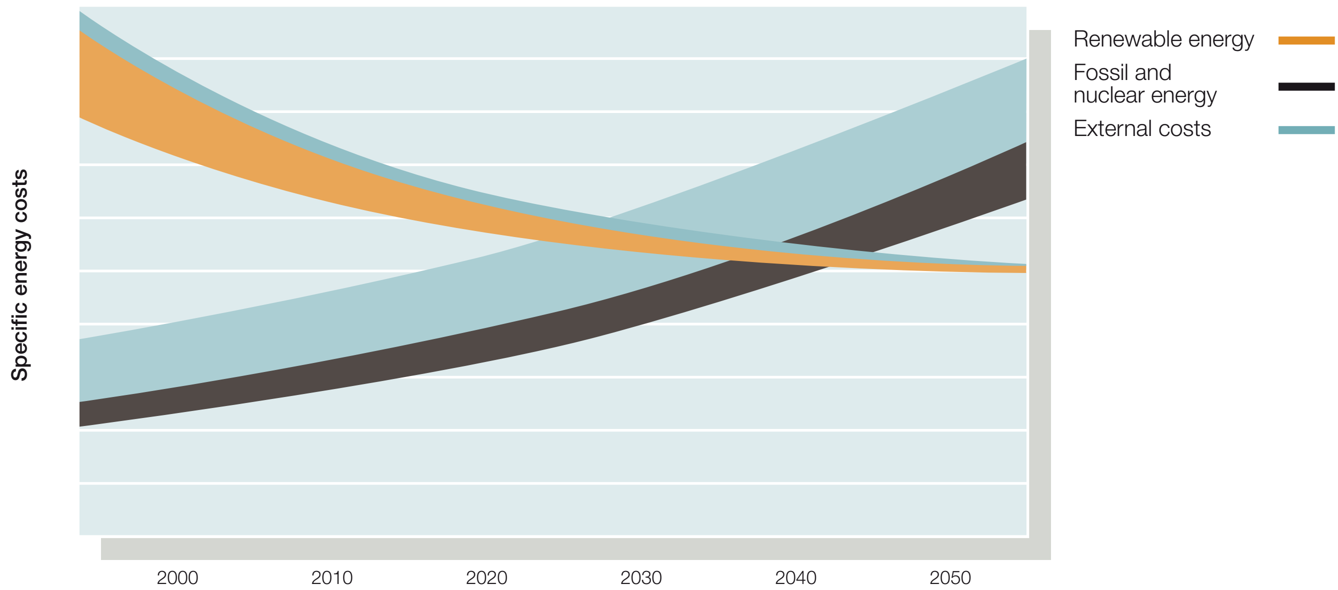
Hence, the "real costs" must always be judged in relation to the environmental and social "qualities" of the service provided, including the external costs and damage avoided that would result from the use of fossil or nuclear energy systems.[11]

RE-thinking 2050 explains that although many of the renewable technologies employed at the present time are at a relatively early stage of market development, i.e. as a result, the costs of electricity, heat and fuel production tend to be higher than those of conventional energy systems, these costs will be cut over time, as technical advances, manufacturing improvements and large-scale production take place.

Moreover, the currently broad range of costs of several renewable energy technologies reflect variations in resources (e.g. for photovoltaic or wind energy) or demand-specific conditions (e.g. full load hours in the case of heating).

However, and in contrast to conventional energy sources, there has been a continued and significant reduction in the cost of renewable energy over the last 20 years (Figure 19).

Figure 19 Development of Costs for Renewable and Conventional Energy Sources



Source: DLR

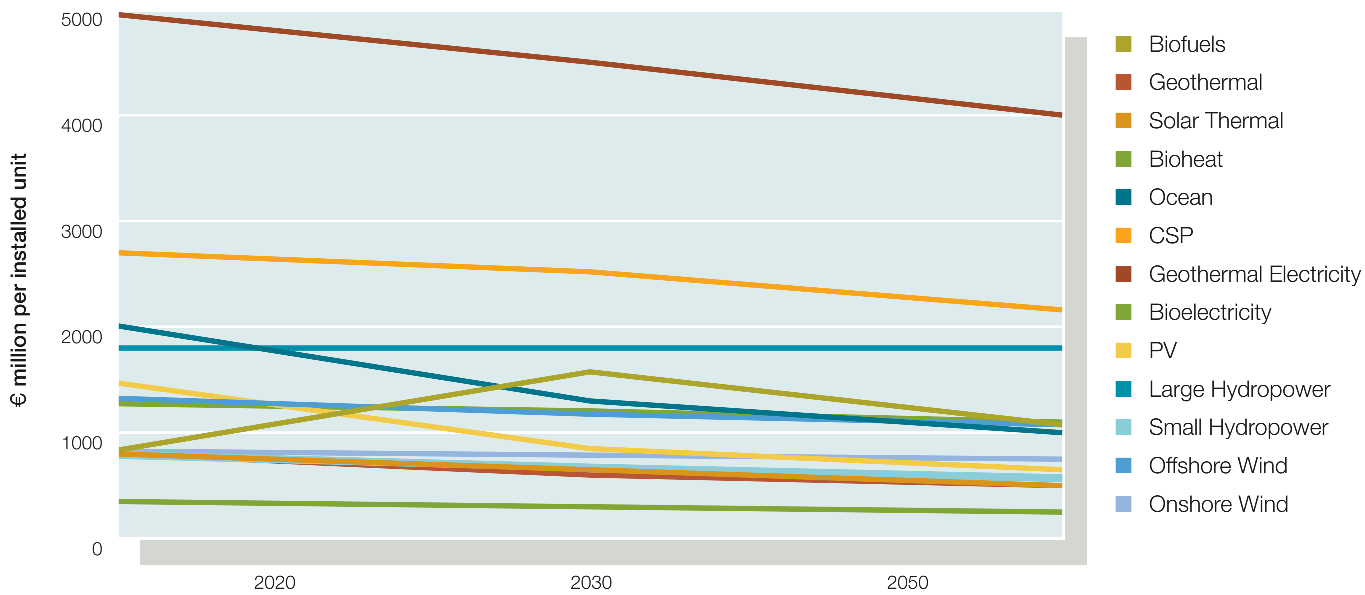
11 See section "*Environmental Benefits*" of chapter 7 for avoided CO_2 emissions and related avoided carbon costs through the use of RES..

Nonetheless, reaching a share of 100% renewable energy in the EU by 2050 will certainly require additional investments. The size of such investments will depend on the implementation of energy saving and energy efficiency measures, the technology choices, decommissioning rates and the degree of competition in the energy sector as such.

In any case, cost outputs for specific technologies as well as for technology pathways have to be considered in the light of high uncertainties in cost development over the next 40 years. When developing long-term scenarios spanning periods of several decades, the dynamic trend of cost developments over time, as mentioned before, plays a crucial role in identifying strategies. To analyse the long-term capital investment needs up to 2050, learning rates for each technology have been applied which reflect the correlation between cumulative production volumes of a certain technology and a reduction in its costs.[12]

Figure 20 shows the development of average capital investment costs per unit installed of the various renewable energy technologies up to 2050. It has to be noted that specific technology investment costs within one technology sector may vary significantly.[13] Therefore, the investment costs per unit installed of renewable energy technologies in Figure 20 are average costs. The costs of infrastructure improvements and extensions as well as operation costs are not addressed.

Figure 20 Capital Costs of Renewable Energy Technologies Per Unit Installed (2020-2050)



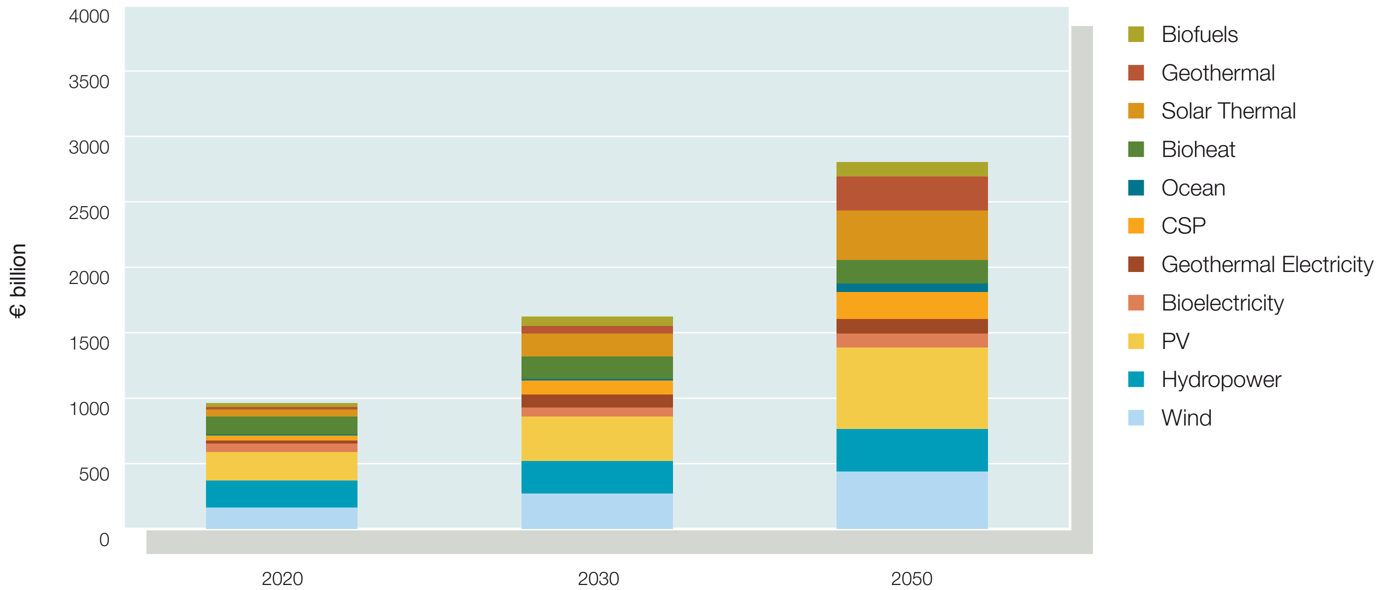
Source: EREC

12 For Onshore Wind, for instance, a learning rate of 10% per year has been applied up to 2050. For Offshore Wind, however, a learning rate of 5% up to 2020 and of 7% up to 2050 has been used. Ocean Energy projects a learning rate of its technologies of 10%.

13 In the case of bioelectricity, for instance, the projected investment cost per unit installed ranges from €150/kW for co-firing to about €2,500/kW for advanced combustion by 2020.

Based on EREC´s assumptions for the installation of the different technologies up to 2050 and the specific capital costs per unit installed shown above, Figure 21 shows expected total cumulative investments in 2020, 2030 and 2050.

Figure 21 Total Cumulative Investments (2020-2030-2050)



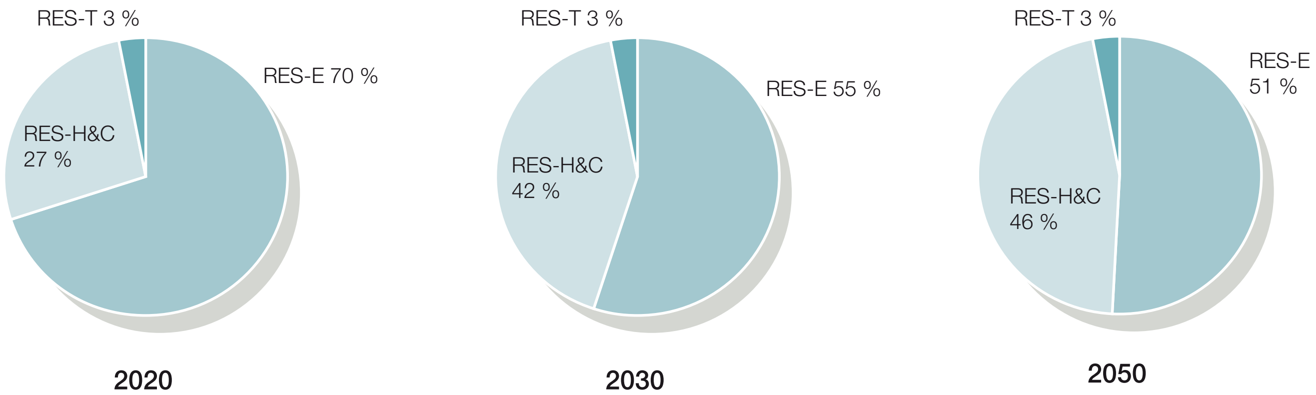
Source: EREC

By 2020, total cumulative renewable energy investments will be €963 billion going up to about €1,620 billion by 2030. By 2050, total cumulative renewable energy investments will reach more than €2,800 billion. These cumulative investment costs would already be off-set by the avoided CO_2 costs alone.[14]

Certainly, the mentioned cumulative investments do not all take place at the same time, rather they will be spread over the respective periods, between 2020 and 2030 and between 2030 and 2050. The resulting average annual renewable energy investments in the decade between 2020 and 2030 are about €162 billion and €140 billion between 2030 and 2050.

It is important to note that the investments made before 2020 and then up to 2030 will have an impact on later years as a renewable energy unit installed in a given year will obviously deliver beyond the year it is installed. Hence, expressed in additional cumulative capital requirements, these will increase from about €660 billion in 2030 to more than €1,180 billion in 2050.

Figure 22 Cumulative RES Investments by Sector (2020-2030-2050)



Source: EREC

14 See section "*Environmental Benefits*" of chapter 7 for a detailed analysis.

Considered by sector (**Figure 22**), most investments in 2020 can be seen in the renewable electricity sector (70%), followed by heating and cooling (27%) and biofuels (3%). By 2030, the cumulative heating and cooling market reaches 42% of total cumulative renewable energy investments, while the renewable electricity sector holds 55% and biofuels 3%. The cumulative biofuels market share will remain at 3% in 2050, increasing in absolute terms however from about €70 billion cumulative investments in 2030 to €110 billion by 2050. The renewable heating and cooling market will further increase to 46%, while the renewable electricity market will account for 51% of the total cumulative renewable energy investments in 2050, with about €1,850 billion and more than €2,077 billion respectively.

Environmental Benefits

There is wide scientific consensus that emissions of greenhouse gases (GHG), of which the biggest share is CO_2, are responsible for global warming, with potentially dramatic economic, social and environmental consequences. Therefore, the EU has put forward its "Climate and Energy Package", comprising, amongst other commitments, the binding 20% target for renewable energy in 2020 and a binding 20% GHG reduction target by the same year.[15]

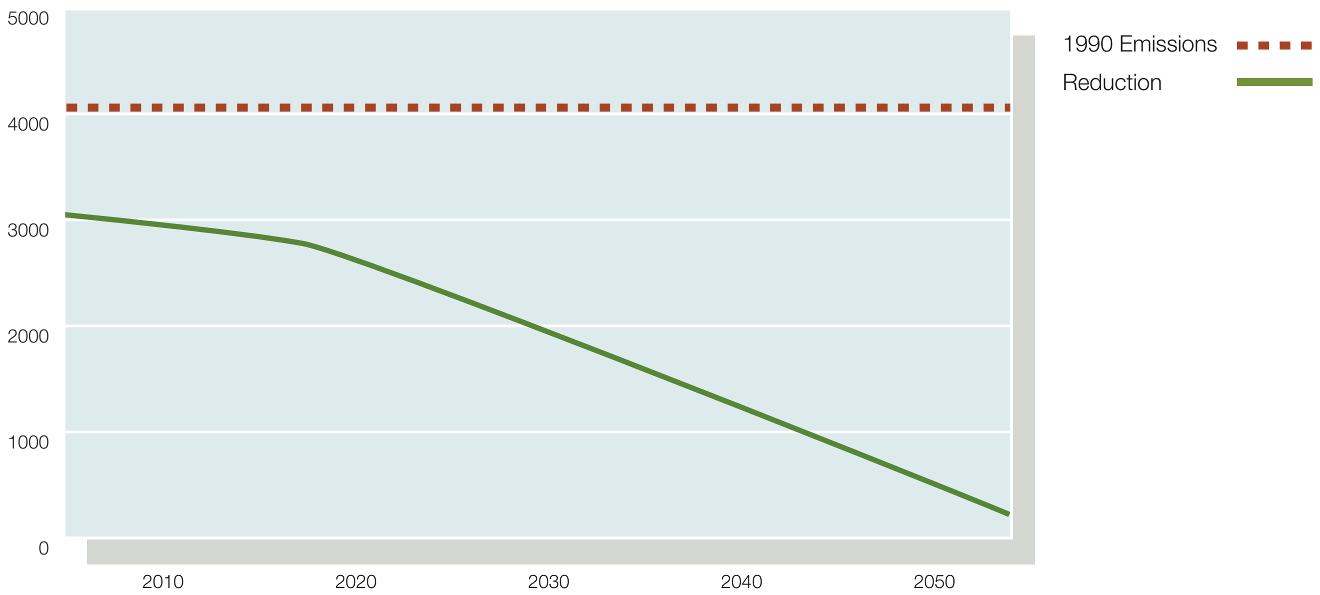
Renewable energy has a significant role to play in mitigating climate change. Increasing the share of renewable energy in the EU fuel mix will result in significantly lower greenhouse gas emissions.

According to the "Fourth Assessment Report" (2007) of the Intergovernmental Panel on Climate Change (IPCC), the increase in average global temperature has to be limited to 2.0 to 2.4°C above pre-industrial levels in order to avoid the most severe consequences of climate change.[16] In this context, the EU has underlined its intention to set as an EU objective an emission reduction target of 80-95% by 2050 compared to 1990 levels.[17]

The amount of CO_2 emissions that can be avoided through the exploitation of the EU´s potential of renewable energy strongly depends on the way in which the renewable source is converted into heat, electricity or transport fuels, and which fossil fuels are replaced.

The emissions avoided via the use of renewable energy sources are calculated on the basis of specific CO_2 emissions for all conversion technologies, including assumed efficiency gains. In addition, it includes that a system must be constructed, operated and dismantled at the end of its lifetime.[18]

Figure 23 CO_2 Avoidance (2020-2050)



Source: EREC

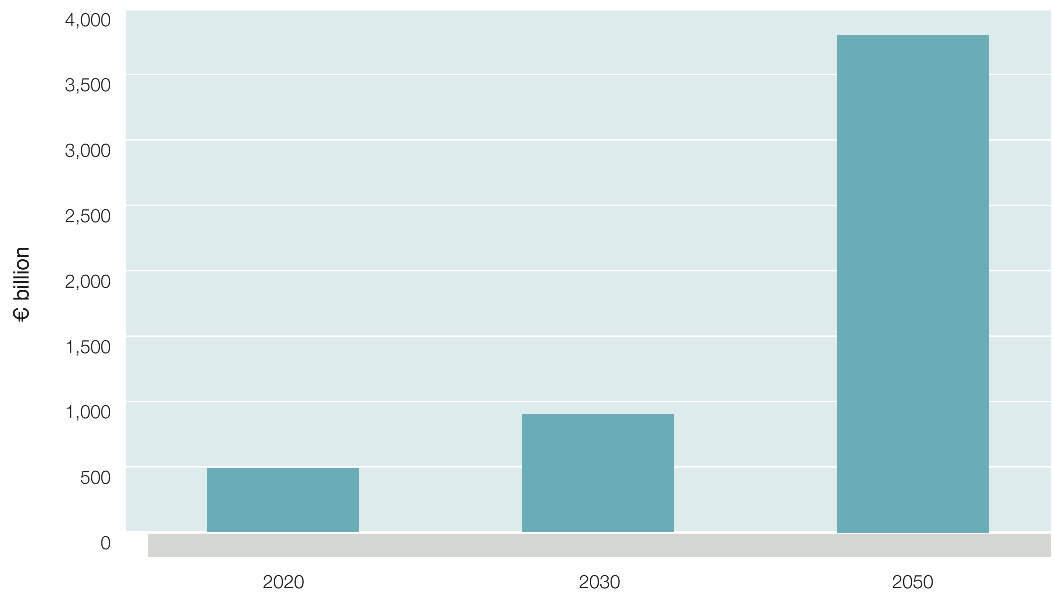
15 In the event of an international agreement on climate change the GHG reduction target will be increased to 30%; see for instance: Council of the European Union: *Presidency conclusions of the Brussels European Council 8/9 March 2007.* 2007.
16 IPCC: *Fourth Assessment Report on the mitigation of climate change for researchers, students and policymakers.* 2008.
17 Council of the European Union: *Presidency Conclusions of the Brussels European Council 29/30 October 2009.* 2009. Paragraph 7.
18 Calculations are based on the GEMIS-model (Global Emission Model for Integrated Systems): http://www.oeko.de/service/gemis/en/

Renewable energy deployment by 2020 will reduce annual energy related CO_2 emissions by about 1,200 Mt against 1990 emissions, and further by about 2,000 Mt in 2030 and 3,800 Mt in 2050. This equals a CO_2 reduction per annum of 30% in 2020 and about 50% in 2030. By 2050 the EU would be able to reduce its energy related CO_2 emissions by more than 90% against 1990 emissions.[19] As can be seen in Figure 23, CO_2 emissions compared to 1990 levels would decrease significantly in the journey up to 2050 due to the progress towards a 100% renewable energy system.

The long-term climate protection goal of reducing the EU´s emissions by at least 80% domestically should be achieved as efficiently as possible, i.e. at the lowest possible cost. The CO_2 costs avoided due to the use of a particular technology are often consulted to gauge the efficiency of reduction measures.

Considering a CO_2–price of €41/t in 2020, the additional total CO_2 benefit can be calculated as being about €492 billion (Figure 24). By 2030, assuming a CO_2–price of €45/t, the benefit would account already for €900 billion, culminating in 2050 at €3,800 billion (or €3.8 trillion), considering a carbon price per tonne of €100.

Figure 24 CO_2 Costs Avoided (2020-2030-2050)



Source: EREC

Hence, the CO_2 costs avoided in 2050 due to the deployment of renewable energy technologies already outweigh the cumulative investment of €2,800 billion needed to reach 100% renewable energy in 2050. The economic benefit of investing in renewable energy would therefore amount to €1,000 billion (or 1 trillion). When taking into account the avoided fossil fuel costs the economic benefit would increase to €2090 billion in 2050. Therefore, higher upfront investment needs do certainly pay off in the long-run, and for society at large.

19 By 1990, EU-27 CO_2 emissions were in the order of 4,047Mt, excluding international bunkers and LULUCF (Land-Use, Land-Use Change and Forestry).

Social Benefits

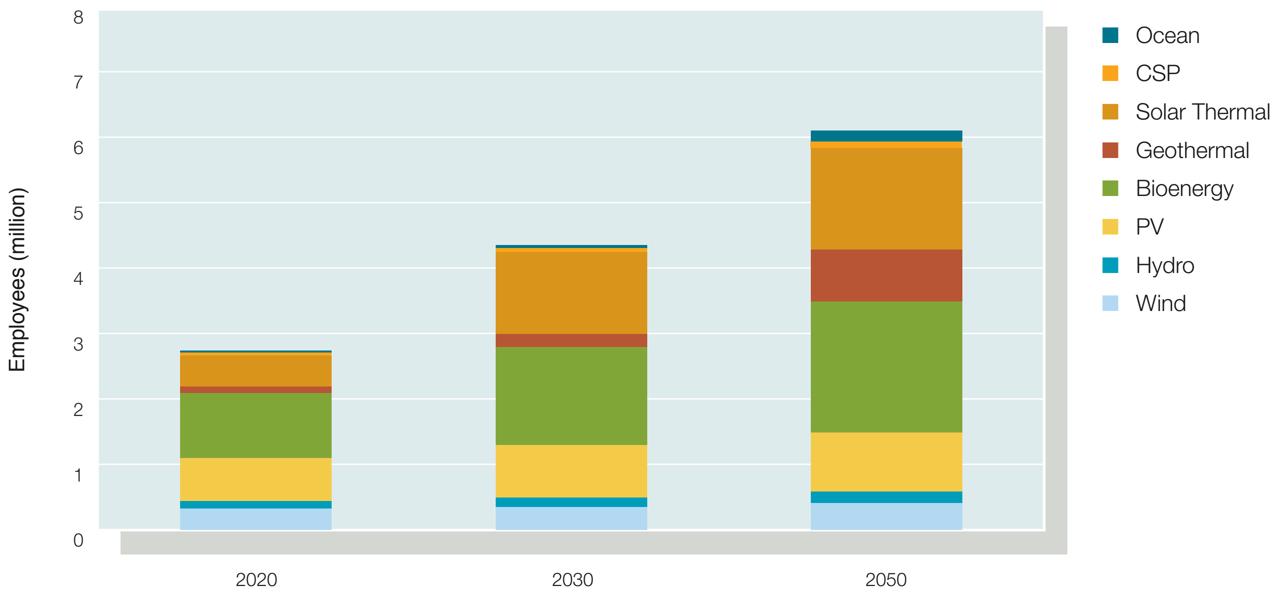
Nothing is simple, not least changing our energy system. As the social impact is a core element of moving towards a fully sustainable energy system, strong collaboration between the renewable energy industry and governments as well as local authorities and civil society is needed. Acceptance by society at large and public support are of the utmost importance. In the 2007 Special Eurobarometer on energy technologies EU citizens were asked about their attitudes towards different energy sources. The survey clearly states that EU citizens are most in favour of renewable energy sources, while the use of fossil and in particular nuclear energy is opposed by many.[20]

Certainly, it would be a mistake to assume that as a natural result of the heightened interest in climate change issues public support for renewable energy can be taken for granted. Public acceptance always has to be thoroughly addressed if energy policies are to be implemented successfully.

One of the core benefits inherent to an increased deployment of renewable energy technologies is the effect on employment. Renewable energy has a crucial role to play for a sustainable 21st century economy through job creation. The renewed Lisbon Strategy, the Commission Communication "Europe 2020", clearly states that the objectives of innovation, sustainable competitiveness and high-employment are strongly interrelated and that meeting the EU´s binding 20% renewable energy target plays a crucial role in this regard.[21] From a societal perspective, the renewable energy industry offers a variety of high-quality jobs in very different technologies, bringing an immeasurable benefit by encouraging a motivated workforce.

By the end of 2009, the renewable energy industry employed over 550,000 people in the European Union. Considering that the pathway set out in *RE-thinking 2050* is followed, the renewable energy sector will employ a total of more than 2.7 million people in 2020 and about 4.4 million in 2030 in the EU. This constitutes an average annual increase of gross employment of 36% and 30% respectively compared to 2009. By 2050, employment in the renewable energy sector is expected to exceed the mark of six million, bringing 6.1 million people into work (Figure 25).

Figure 25 Gross Employment in the Renewable Energy Sector (2020-2030-2050)



Source: EREC

20 80% support the use of solar energy, 71% wind energy, 65% hydropower, 60% ocean energy and 55% biomass energy, while for instance 37% express their opposition to nuclear energy. See: European Commission (Special Eurobarometer): *Energy Technologies – Knowledge, Perception, Measures.* 2007. Page 27.

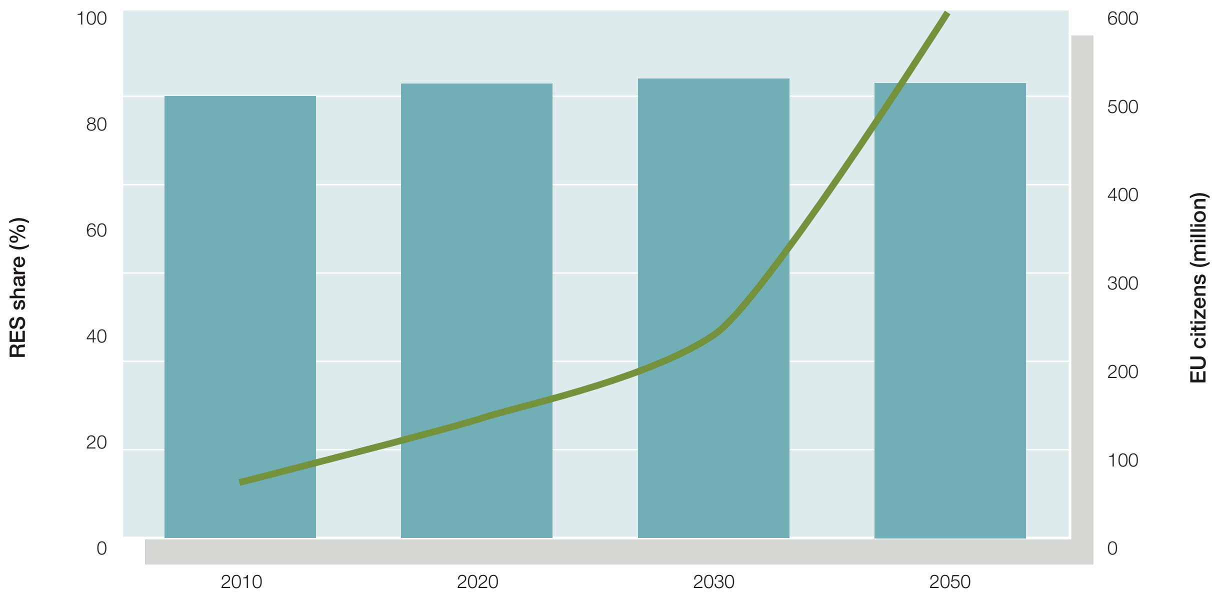
21 European Commission (COM(2010)2020): *Communication from the Commission. Europe 2020.* 2010.

The development of renewable energy also causes an important structural-policy side effect, with jobs being created in those regions where they are particularly needed. Coastal regions or rural areas benefit from the construction and utilisation of renewable energy technologies. Former coal regions, for instance, see a revitalisation of their industrial areas and new local economic cycles and resulting employment. Hence, as renewable energy is a domestic energy carrier, a large proportion of its added value has the potential to stay in the region. In such a way, the funds that have been benefiting the countries which export oil, natural gas, uranium, and coal will transform step by step into domestic added value for the benefit of all EU citizens.

Renewable energy presents a benefit that can also be expressed through the number of EU citizens provided by renewable energy. According to Eurostat, the number of citizens in the EU-27 will rise from 500 million today to 514 million in 2020, reaching approximately 520 million in 2030 before gradually declining to reach about 515 million in 2050.[22]

Consequently, by the end of 2009, RES provided the equivalent amount of energy consumption of 50 million Europeans, a number which increases to about 130 million in 2020 and over 218 million in 2030. In line with the two different 2050 scenarios analysed in *RE-thinking 2050*, all EU citizens will be provided with renewable energy at the latest by 2050 (**Figure 26**).

Figure 26 Number of EU Citizens Provided With RES (2010-2050)



Source: EREC

22 Konstantinos Giannakouris: "Population and social conditions", In: European Commission (Eurostat): *Statistics in focus 72/2008*. 2008. Page 6.

08

Policy Recommendations – Inventing Tomorrow Today

Continuing on today's energy path without any change in policies would not only mean that the pressing issue of climate change is not addressed, but also that our dependency on fossil fuels is set to increase. We would be bound to unpredictable energy prices, all of which would result in detrimental impacts on Europe's economy and in energy insecurity. According to the European Commission, if no action is taken, the EU's energy dependency is predicted to climb from 55% in 2008 to 70% in 2030.[1] Such a development would not only mean that Europe is geopolitically in a fragile position, relying on politically unstable regions, but also very vulnerable to uncontrollable fossil fuel price increases, and therefore economically unstable.

The only way to avoid the ever increasing energy dependence of the European Union is to develop the abundant renewable energy potential of all EU Member States. With the binding renewable energy target of 20% of final energy consumption by 2020, Europe has embarked on a sustainable pathway. However, we need to continue on our path and speed-up the transformation of our energy system. This will only happen through continuous and stable commitments and favourable policy frameworks, especially in economically challenging times. A successful programme for sustainable economic recovery lies in the promotion of energy savings, energy efficiency and renewable energy.

Europe should lead the way with a clear commitment to a 100% renewable energy future by 2050. Certainly, this is challenging. But it is the only true sustainable alternative to the energy system we currently have, in environmental, social and economic terms.

Households and businesses are largely responsible for making the required investments, but governments hold the key to changing the mix of energy investment. Policy and regulatory frameworks at local, regional, national and EU level will determine whether investment and consumption decisions are steered towards an energy-efficient, renewable energy based economy, or not.

This decade is the decade of decisions. The decisions taken today will have an impact on the forty years to come. It is now time to decide whether to continue the polluting energy pathway of the past or to progress to one based on clean, sustainable and locally available renewable energy sources.

As *RE-thinking 2050* clearly outlines, it is not a matter of availability of technologies. Renewable energy technologies are available, reliable and capable of providing all energy services from transport solutions to heating and cooling as well as electricity generation. It is a matter of political will and of setting the course today for a sustainable energy future tomorrow.

A 100% renewable energy supply for Europe will require paramount changes both in terms of energy production and consumption as well as concerted efforts at all levels – local, regional, national and European. Apart from the manifold social, economic and environmental benefits of such a paradigm shift, renewable energy can become the driving force and uniting element of the European ambition. As much as the coal and steel production provided the common foundation necessary for the federation of European states in 1957, a new energy policy, one of 100% renewable energy in 2050, would be the new federating pillar of the European Union in the 21st century.

The following pages briefly outline the policy recommendations for a 100% renewable energy supply for the European Union in 2050. Only a clear-cut and consistent mix of these measures will give Europe the truly sustainable energy future it deserves.

1 European Commission: *A European Strategy for Sustainable, Competitive and Secure Energy*. 2006.

Enabling Policy Measures

Supporting the Transition Towards a 100% Renewable Energy Economy through all EU Policy Areas

The commitment towards a 100% renewable energy system for the European Union needs to be established as the guiding principle for all European policies in the fields of:

- energy,
- climate,
- R&D,
- industry,
- regional development and
- international cooperation.

Less is More – An Ambitious Framework for Europe's Energy Demand

The accelerated increase in energy efficiency, which is a crucial prerequisite for achieving a 100% renewable energy based system, is beneficial not only for the environment but also for Europe's economic system. The mobilisation of the cost-effective energy saving and energy efficiency potential will directly lead to a reduction in costs. A dedicated energy efficiency strategy thus also helps to compensate in part for the additional costs required during the market introduction phase of renewable energy sources. Therefore, binding energy efficiency targets as well as an ambitious roadmap on how to reduce energy demand are essential elements to a sustainable European energy system.

Effective and Full Implementation of the New RES Directive (2009) in all EU-27 Member States

Every journey begins with a first step. With its adoption of a binding 20% renewable energy target, the European Union has, for the first time, made a binding commitment to reach one fifth of its energy consumption from renewable energy by 2020. It is of the utmost importance that this commitment is put into practice in all 27 Member States and that the right framework conditions are set to enable a strong growth of renewable energy in all energy sectors: transport, heating and cooling as well as electricity. This commitment to 20% renewable energy lays the basis for a higher renewable energy penetration. By supporting all renewable energy technologies Europe will ensure the technological and market leadership of the European renewable energy industry, which will thus become the motor for sustainable economic development in the 21st century.

Binding Renewable Energy Targets for 2030

As investment decisions in the energy sector are of a long-term nature and as 2020 is at our doorstep, the European Union should quickly proceed with fixing binding renewable energy targets for 2030, continuing its commitment towards developing this prosperous economic sector. A political discussion should start soon between all 27 EU Member States on the 2030 horizon in order to set the right framework towards a 100% renewable energy supply by 2050.

Full Liberalisation of the Energy Market

Europe's gas and electricity market is still lagging behind in terms of liberalisation and a well-functioning interconnected system. To fully enable Europe to address pressing climate and energy challenges and reach a fully integrated European market with multiple suppliers of renewable energy, the EU needs to improve its network and move towards a pan-European smart grid. The development of Network Codes and specific additional international standards by CEN/CENELEC to be implemented through relevant legislation should be fostered together with continued R&D efforts.

The regulatory framework on smart grids and balancing power should put forward a number of ideas for incentives that will make it economically attractive to build flexibility into the system (through renewable electricity production) as well as ideas of disincentives (e.g. negative pricing) for adding inflexible capacity to the grid. Until the EU has a fully functioning liberalised internal electricity market renewable energy sources must have priority access to the grid.

Phasing Out all Subsidies for Fossil and Nuclear Energy and Introducing an EU-wide Carbon Tax

The real cost of energy production by conventional energy includes expenses absorbed by society, such as health costs and local and regional environmental degradation - from mercury pollution to acid rain – as well as the global negative impacts of climate change.

Environmental damage should be rectified at the source. Translated into energy generation that would mean that the production of energy should not pollute and that it should therefore be the energy producers' responsibility to prevent pollution. In order to speed up the transition towards a fully sustainable energy generation system, the polluting energy producers should pay an amount equal to the damage the production causes to society as a whole; defining and quantifying such damage is the challenge.

The European project ExternE has tried to quantify the true costs, including the environmental costs, of energy generation.[2] As outlined in chapter 7 of this report, if those environmental costs were levied on energy generation according to their impact, many renewable energy sources would not need any support. If, at the same time, direct and indirect subsidies to fossil fuels and nuclear power were removed, the need to support renewable electricity generation would seriously diminish or cease to exist.

One way to internalise these external costs would be the introduction of an EU-wide carbon tax. The taxing of the burning of fossil fuels —coal, petroleum products such as gasoline and aviation fuel, and natural gas— in proportion to their carbon content, will immediately increase the competitiveness of renewable energy technologies.

2 European Commission: *ExternE. Externalities of Energy*. 2005.

Enabling Infrastructure Measures

Electricity Infrastructure – Moving Towards SuperSmartGrids

There is a clear need for an integrated European infrastructure perspective for 2050. Whereas today's power grids are designed to transport electricity from centralised power stations to consumers, the future power system has to be more versatile and allow for a combined approach of both centralised and decentralised power generation. On the one hand, large power centres such as offshore wind, concentrated solar power or ocean energy will feed electricity into the high-voltage grid, while, on the other, decentralised systems such as biomass, onshore wind or solar power systems will deliver electricity to the low and medium voltage grid. Technologies such as geothermal have more than 90% availability (8000 h/year) and will help to manage the grid, for matching the load.

Two concepts "Smart Grid" and "Super Grid" should be merged, though they represent different orders of magnitude. First, the idea of a Super Grid is to connect wind farms off the coast of the UK for instance with solar panels in Germany, CSP plants in Spain and hydropower in Scandinavia. A network of thousands of kilometres of highly efficient undersea cables will be required. The Super Grid will store electricity when energy demand is low. A European Super Grid would consist of three main rings: the North Sea offshore grid, the Mediterranean energy ring and the Baltic Interconnection Plan.

Second, when it comes to the "Smart Grid", the main challenge at distribution level is to modernise the networks so as to adapt to electricity generation closer to demand and improve end-user participation and massive demand-side response. Furthermore, technical innovations are enabling the creation of micro grids which under certain critical circumstances (for example during a serious fault at transmission level) will be able to disconnect from transmission network and still satisfy consumer demand in a reliable way. Smart distribution networks must, evidently, go hand in hand with the introduction of smart metering. Storage, industry, residential and transport demand need to be considered and interactions with non-electric energy uses, such as heating provided by district heating grids, should not be excluded.

End-user participation in modernised networks is essential, as a more active participation of the user is not only a goal in itself, but a possible means to integrate renewable energy sources of energy in the electrical network. Furthermore, EVs will serve as a form of energy storage on distribution level. Car fleets will be run on electricity generated from renewable sources in a Vehicle to Grid system (V2G). In the long run electric vehicles will not only be electricity consumers, but can also be integrated into the electricity system for storage purposes and as a source of balancing power.

Consumers will play a much more active role in the operation of the electricity system, meaning that there will be a real need for network companies to develop a much more user-centric approach, explaining the role individual consumers and households play and proactively engage with their network users. They will also have to be increasingly involved with supply companies and providers of energy services so as to find optimum efficient solutions.

Hybrid Energy Solutions and Virtual Power Plants

In order for the full potential of all renewable energy sources to be unravelled, further research needs to be carried out in order to develop the concept of hybrid energy solutions as well as Virtual Power Plants (VPP). A 100% renewable energy future will intelligently combine variable renewable energy sources, with renewables providing continuous energy supply. VPPs consist of real power plants of different nature and energy storage devices all interconnected and distributed into the power system through information and communication technology (ICT).

Heating and Cooling – Measures to Awaken the Sleeping Giant

Over the last decade, energy policy in the EU has predominantly focused on the liberalisation of the electricity markets. Citizens and the media often portray energy and electricity as one and the same thing. Most people, including some decision makers, underestimate the share of energy used for heating purposes. In fact, the EU's final energy demand for heating is higher than for electricity or for transport.

The heating sector is a neglected sleeping giant, and RES-H&C has so far received too little political attention. Another reason may be that RES-H&C products are substantially sold by small and medium sized enterprises (SMEs), which do not yet have a strong impact on EU energy markets.

Solar water heating, biomass for industrial and domestic heating, deep geothermal heat and shallow geothermal heat pumps are amongst the lowest cost options for reducing both CO_2 emissions and fossil fuel dependency. In many circumstances these technologies offer net savings when compared to conventional heating systems in terms of life-cycle costs.

Renewable heating and cooling technologies will provide heating services for individual houses as well as for large residential and tertiary buildings. In addition to this, thermally-driven cooling technologies will play a major role in the future, thereby helping to reduce electricity peaks in summer. In addition, over the next 40 years, RES-H&C technologies will provide the heat needed for industrial processes such as food production and drying, desalination of drinking water, industrial laundries etc.

Additional policy support for district heating infrastructure and combined heat and power (CHP) systems based on renewable energy sources is needed to unfold the full potential of this sector. New policy initiatives in this field need to address the key barriers to growth, including often high upfront investment costs. RES-H&C, especially solar thermal and geothermal energy, enjoy very low running costs (as the energy source is free), but a higher investment cost than fossil fuel or electrical heaters. This can be a key barrier, particularly for households. Part of such policy initiatives should also be to overcome the "owner-tenant dilemma": in many buildings, both residential and tertiary, those who pay the bill are not systematically the same people who decide on infrastructure investments. Owners have to be encouraged to make the necessary investments and to be able to benefit from the measures implemented.

New Transport Solutions

The current inefficiencies and individualistic structures of Europe's transportation system leave much room for improvement. In the short run, a change in car usage and driving behaviour will heavily reduce transportation fuel consumption. The impact of replacing the car fleet with fuel efficient, cleaner and lighter vehicles is effective in the medium and long term. In the long run, electric cars will become the solution for individual transport.

Transportation energy growth could be systematically mitigated through a change in modal shift to higher shares of public transportation such as the underground and rail. If combined with a change in land use and urban planning, such a transformation will make Europe's urban development more sustainable in the long run. This modal shift will require investment in new infrastructure and in the rehabilitation of existing infrastructure.

As outlined in chapter 6 of this report, ending oil dependence in the transport sector means a clear shift to electric vehicles and vehicles powered by biofuels. Measures such as tax breaks and other incentives are needed, e.g. encouraging earlier retirement for older more polluting vehicles; shifting all government and local authority vehicles to biofuel-fuelled and electric cars; smart-pricing systems etc. Investment in new sustainable transport infrastructure including "alternative fuelling" infrastructure is also necessary.

Enabling Energy Consumers - Think Global, Act Local

Smart-Energy Cities 2050

It is within the power of local governments to influence the energy choices of their citizens. Since the beginning of this decade, and for the first time ever, over 50% of the world's population now live in urban environments[3]. This proportion will continue to grow over the next few decades. The energy infrastructure that every city and town depends on will therefore need to be continually adapted and upgraded if it is to meet the ever-increasing demands for energy services. This provides the opportunity for local government leaders to encourage the increased deployment of energy efficiency appliances and renewable energy systems in their cities and hence capitalise the multi-benefits they offer.

Smart-Energy Cities in 2050 will use energy more efficiently and generate heat, fuel and electricity from renewable sources of energy. They will provide space for urban green areas and larger connected parks. They will offer affordable Smart-Energy buildings and more efficient public transport, including biofuels or electric-powered buses. The number of electrically-assisted battery pushbikes will increase significantly and renewable energy recharging stations where bikes may refresh their batteries will emerge around cities.

Several leading and progressive cities and towns have already taken innovative decisions to enhance the deployment and use of renewable energy resources within their geographic boundaries.[4] The evolution of decentralised energy systems will vary by location, and according to existing energy infrastructure, renewable energy resources available, and energy business ownership status. Local governments will take a leading role by developing policies that will help support the transition of the current conventional energy sector to a decentralised system fully reliant on renewable energy.

Smart-Energy Buildings 2050 – Constructing a Better Climate

The building sector is among the "lowest-hanging fruit" when it comes to making our energy system more sustainable. It is the sector where progress towards sustainability is cheapest to reach and where the impact would be tremendous. Buildings in the EU account for 40% of primary energy and more than two-third of the electricity consumed. Energy efficiency strategies can reduce a building's energy consumption by 50% to 70%. Renewable energy technologies must be used to reach the goal of a net-zero energy building. A combined approach on both the demand and the supply side is required.

Indeed, business as usual will not be sufficient to achieve the EU's binding climate targets and to mitigate climate change. The annual construction rate of new buildings is in the order of 1% of the building stock, the demolition rate about 0.5% and retrofit about 1.8%. At these rates it will take a very long time to improve the energy performance of the building sector, unless a large-scale mobilisation of actors is achieved. Governments, businesses and individuals must transform the building sector through a multitude of actions, which include increasing energy awareness.

Building on its commitment to make nearly-zero energy buildings the norm for all new buildings by 2020, the European Union must develop a strategy that ensures that all existing buildings after 2030 and all buildings (existing and new constructions) become net-zero and positive energy buildings as of 2040. A comprehensive investment today in Europe's new and existing building stock will reduce the EU's import dependency and carbon footprint in the sector tomorrow.

3 International Energy Agency*: Cities, Towns and Renewable Energy - Yes In My Front Yard,* 2009.
4 Covenant of Mayors: www.eumayors.eu

09

Glossary

Terms and Abbreviations

Glossary

Terms and abbreviations

Mt – Million tonnes
Mtoe – million tonne of oil equivalent
GW – Gigawatt
TWh – Terawatt hour
GHG – greenhouse gas
CO_2 – carbon dioxide
EV – electric vehicle
HDV – heavy duty vehicle
LDV – light duty vehicle
MDV – medium duty vehicle
€ – Euros
$ - US Dollar

Conversion Coefficients

		kJ (NCV/PCI)	Kgoe (NCV)/kgep (PCI)
Derived heat	1 MJ (GCV)	1000	0.024
Electrical energy	1 kWh	3600	0.086

10

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Annex
EREC Members´ Technology-specific Visions up to 2050

Wind Vision up to 2050

Introduction

"The extent of wind energy resources in Europe is very considerable." That is the key finding of the European Environment Agency's 2009 report, 'Europe's onshore and offshore wind energy potential'.[1] The report highlights wind power's potential in 2020 as three times greater than Europe's expected electricity demand, rising to a factor of seven by 2030. "The fact that the competitive potential even in a relative short time horizon is much bigger than the electricity demand means that the key need for policy makers should be on facilitating the integration of wind energy into the energy system," concludes the report. The EEA clearly recognises that wind power will be key to Europe's energy future.

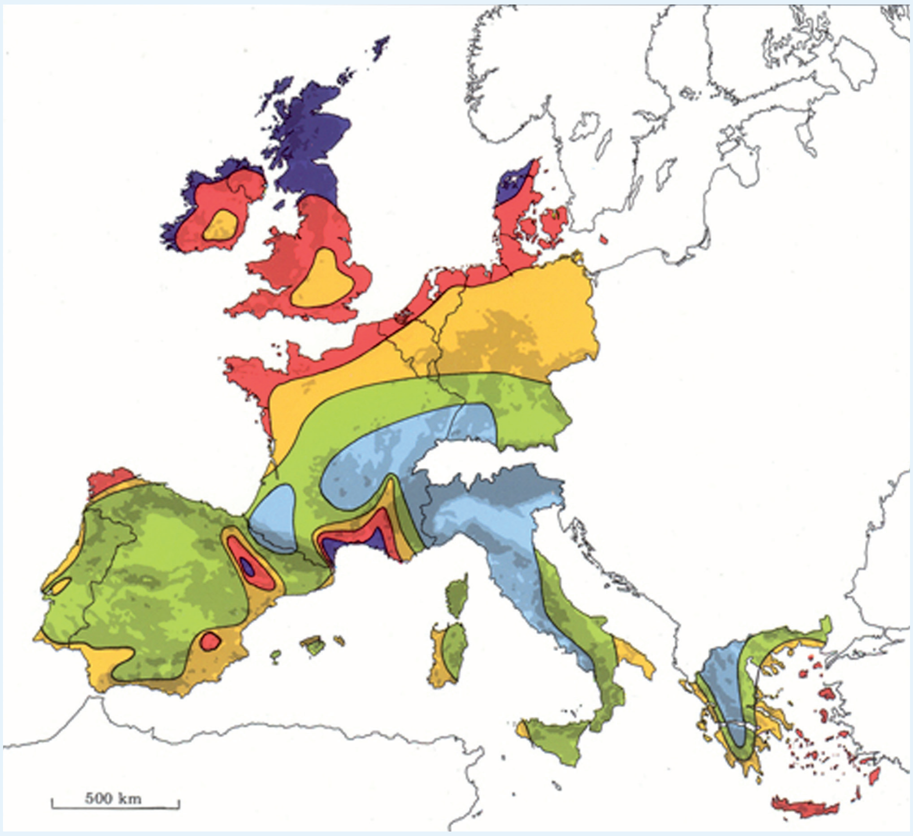


Table 1 Wind Resources at 50 Metres Above Ground Level for Five Different Topographic Conditions

	Sheltered terrain		Open plain		At a sea coast		Open sea		Hills and ridges	
	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}	ms^{-1}	Wm^{-2}
■ (purple)	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
■ (red)	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
■ (yellow)	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
■ (green)	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0-8.5	400-700
■ (blue)	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

Source: European Wind Atlas, Onshore, Source, Risø National Laboratory, Denmark.

1 EEA (European Environment Agency), 2009. 'Europe's onshore and offshore wind energy potential'. Technical report No 6/2009.

Technology Today

At the end of 2009 wind energy had increased its share of total power capacity in the EU to 9.1%, with a total installed capacity of 74,767 GW, which would, in a normal wind year, produce 4.8% of the EU's electricity demand. But it is wind's contribution to new generation capacity that is even more striking. 39% of all power capacity installed in 2009 was wind power, amounting to 10,163 MW of new installations. 2009 was the second year running that more new wind power capacity was installed than any other generating technology.

Technology Outlook[2]

The medium term outlook for the wind industry looks strong. On 7 October 2009, the European Commission published its Communication on "Investing in the Development of Low Carbon Technologies (SET-Plan)" – COM (2009) 519, in which it is estimated that €6 billion of investment in wind energy research is needed in Europe over the next 10 years. According to the European Commission's Communication, "The return would be fully competitive wind power generation capable of contributing up to 20% of EU electricity by 2020 and as much as 33% by 2030. More than 250,000 skilled jobs could be created." EWEA (European Wind Energy Association) agrees with the Commission's assessment, highlighting that additional research and significant progress in building grid infrastructure are key to the sector's success. Meeting the European Commission's ambitions for wind energy would require 265 GW of wind power capacity, including 55 GW of offshore wind by 2020. The Commission's 2030 target of 33% of EU power from wind energy can be reached by meeting EWEA's 2030 installed capacity target of 400 GW wind. A total of 600 GW of wind energy would be needed in 2050 to meet 50% of the EU's electricity demand: 250 GW would be onshore and 350 GW offshore. With a higher proportion of offshore wind energy, wind energy could produce more than the 2,015 TWh.

Technology-specific Recommendations

- **Building a European offshore power grid**
  Electrical grids are no longer simply national infrastructure and they should become European corridors for electricity trade. A future European offshore grid would contribute to building a well-functioning single European electricity market that will benefit consumers, with the North Sea, the Baltic Sea and the Mediterranean Sea leading the way. It would provide grid access to offshore wind farms, smooth the variability of their output and improve the ability to trade electricity within Europe, thereby contributing dramatically to Europe's energy security.

- **Improved competition in the Internal Electricity Market**
  A single European grid and effective competition in the European power markets would help to ensure affordable electricity prices, security of supply, and for reducing carbon price risk and fuel price risk.

- **New electricity infrastructure and 'smart grids'**
  European electricity infrastructure is ageing and investment in new grids is needed, with the power system being operated intelligently.

- **Wind power technology research and development**
  The European Wind Initiative (EWI), in the framework of the EU's SET Plan, should be funded, as it is a roadmap for research needed to achieve the European 2020 objectives and beyond and focuses on key technology objectives to bring down the costs of onshore and offshore wind energy.

2 For further reading see: EWEA: *Pure Power – Wind energy targets for 2020 and 2030*. 2009.

Hydropower Vision up to 2050

Introduction

For centuries civilisations have taken advantage of the power of water. Once used by the Greeks for grinding wheat into flour, the water wheels of the past have been updated to today's highly efficient turbines that generate electricity by spinning water. Small hydropower, defined by installed capacity of up to 10 MW[3], is the backbone of electricity production in many countries in the European Union.

Small hydropower is based on a simple process, taking advantage of the kinetic energy and pressure freed by falling water or rivers, canals, streams and water networks. The rushing water drives a turbine, which converts the water's pressure and motion into mechanical energy, converted into electricity by a generator. The power of the scheme is proportional to the head (the difference between up- and downstream water levels), the discharge (the quantity of water which goes through the turbines in a given unit of time), and the efficiency of the turbine.

Technology Today

In 2008 there were over 21,000 SHP plants in the EU-27 and if candidate countries as well as Norway, Switzerland, Bosnia and Herzegovina and Montenegro are included, the number of plants increases to a total of nearly 23,000. The installed capacity of EU-27 was over 13,000 MW – or more than 15,000 MW if candidate countries, Norway, Switzerland, Bosnia and Herzegovina and Montenegro are included. In 2008 the total electricity generation from SHP in the EU-27 accounted for over 43,000 GWh, and if including candidate countries, Norway, Switzerland, Bosnia and Herzegovina and Montenegro, the figure is nearly 52,000 GWh. This would be enough to supply electricity to over 12 million households in Europe, contributing to annual avoidance of CO_2 by 29 million tonnes, which translates into annual avoided CO_2 cost of about 377 million Euros. In 2008 about 1.2% of the total electricity generated as well as 9% of the RES-E in the EU-27 came from SHP. On average, in 2008, a SHPP (Small Hydropower Plant) in the EU-27 had a capacity of 0.6 MW and produced about 2.0 GWh. The range of investment costs can vary from 1,000 €/kW (Greece, Spain, Bulgaria, Czech Republic, Estonia) to 12,000 €/kW (Germany). In terms of average SHP production cost, the range varies from 0.4 €cent/kWh (Bulgaria) to 17.4 €cents/kWh (Italy).

Technology Outlook[4]

The benefits and relevance of hydropower for both the renewable energy and the energy sector are obvious. In particular, hydropower will play a key role in 2030 and 2050 through:

- Development of hybrid systems combining several technologies to guarantee the maximum energy production in the most efficient way.
- Development of multipurpose hydro plants with applications in the fields of drinking water supply systems, irrigation channels, flood control and protection, the creation of adjoining environmental areas, waste water treatment plants and recreational purposes.
- Adding security and stability to the European grid thanks to the pump storage.
- Mitigating Climate Change: SHP production, for example, reduces greenhouse gas emissions such as CO_2 by 29 million tons annually and sulphur dioxide by 108,000 tons annually.
- Supporting the development of rural areas by the installation on economically advantage conditions of SHP off-grid units.

The scenarios for 2030 and 2050 for the hydropower sector presented in Table 4 of chapter 6 (section *Renewable electricity up to 2050*), in terms of capacity, so 148 GW and 194 GW respectively) refer to a prediction of the economic potential taking as basis the latest figures and the forecasted 2020 figures. According to Table 5 of chapter 6, by 2020 the second largest contribution to RES-E in the EU will be hydropower.

3 There is no international consensus on the definition of SHP. However, 10 MW is the generally accepted limit adopted by ESHA and the European Commission.
4 For further reading see: ESHA: ***Stream map - the way forward for the EU Hydro Sector.*** Forthcoming (www.streammap.esha.be).

Technology-specific Recommendations

Hydropower technology is already highly efficient and affordable (in terms of investment cost and internal rate of return); furthermore the technology has a long life span. Nevertheless, in order to achieve the forecasted vision of the sector for 2030 and 2050 or surpass these estimations the following issues must be tackled:

- **Reconciling targets of the Water Framework Directive (WFD) and the RES Directive**
  The implementation of the WFD is currently restraining the present and future development of the sector, as the interpretation of the Directive at a national level is having direct consequences in terms of the approval of new projects and in terms of the allocation of concessions and permissions.

- **Environmental measures**
  Hydropower needs a more objective approach from the environmental community and from stakeholders since current and future legislation could limit in a severe way the benefits of such a source of energy.

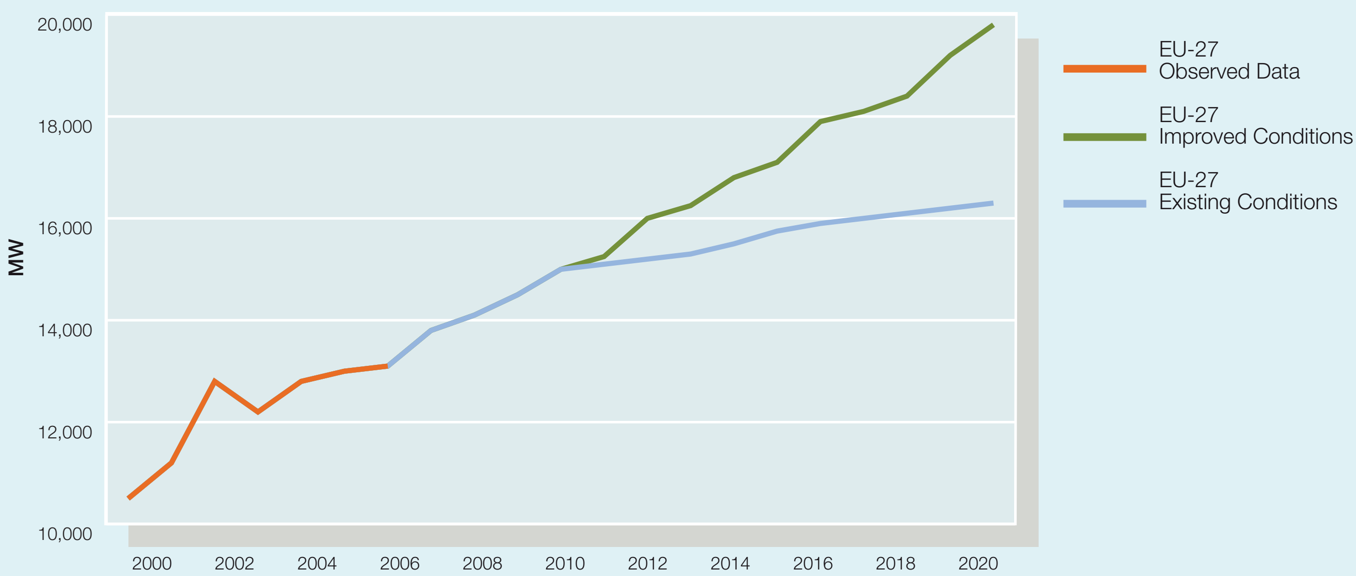
- **Removal of administrative and regulatory barriers**
  Administrative procedures to get a hydropower plant operating are still one of the most important barriers for the sector. The long time periods required for obtaining licences, concessions and permissions discourage developers from bringing projects to an end. A more flexible, simple, centralised and homogeneous European system could ease the procedure.

- **More attractive incentive regimes (especially in the new MS)**
  Hydropower and in particular small units are currently benefiting from European support schemes. Nevertheless, in comparison to other renewables and comparing between countries, the level of support is not satisfactory in terms of cost-benefit and market competition.

- **Need for proactive cooperation and better communication at a local level**
  In the case of hydropower projects, the rapid establishment of a participatory approach involving the different stakeholders affected by the realisation of the project and in particular the environmental and fishing community is a must for the future development of the sector.

- **Investment in R&D and change of thinking**
  The hydropower technology of the next decades will evolve towards more sustainable solutions. However, in order to minimise the environmental impact while at the same time maximising electricity production, a change of thinking is required and investment in current and future R&D is highly recommended to explore and test different solutions.

Figure 1 **SHP Capacity 2000-2006 and Forecast to 2020**



Photovoltaics Vision up to 2050

Introduction

'Photovoltaics' is a combination of two words: 'photo', from Greek roots, meaning light, and 'voltaic', from 'volt', which is the unit used to measure electric potential at a given point. Photovoltaic systems use cells made of semi-conducting materials to convert light into electricity. Discovered by Edmond Becquerel in 1839, photovoltaic electricity undergoes its first real application as an energy source for space satellites. Even though certain applications were used for several decennia, the real large scale commercial take-off of photovoltaic electricity connected to the electricity grid started at the dawn of the 21^{st} century.

Technology Today

Despite the economic crisis, around 6.5 GW of photovoltaic systems were installed in the world during the year 2009 and a steady market development is expected to continue in 2010 with a growth of at least 25%. At the beginning of 2010, more than 21 GW of PV systems are already installed in the world, delivering large quantities of electricity.

On the one hand, the contribution of PV to electricity production in Europe is steadily growing, with PV contributing significantly to peak power generation in many countries, notably in Spain and in Germany. On the other, the cost of PV electricity is constantly decreasing, with PV price reduction being particularly significant in 2009 due to increased industrial capacity and increased competition. A 20% learning curve factor (i.e. the price decreases by 20% each time the cumulated production is doubled) was observed for the last 30 years and is expected to continue, driving prices down substantially through the next years and decades, a trend which will render PV electricity more affordable and grid parity a likely reality for most of European countries during the current decade. Residential grid parity is expected to be reached as early as 2011 in some Southern European regions.

The different PV technologies are listed below:

- Crystalline silicon technology: Crystalline silicon cells are made from thin slices cut from a single crystal of silicon (monocrystalline) or from a block of silicon crystals (polycrystalline or multicrystalline). This is the most common technology representing about 80% of the market today. In addition, this technology also exists in the form of ribbon sheets.

- Thin Film technology: Thin film modules are constructed by depositing extremely thin layers of photosensitive materials onto a substrate such as glass, stainless steel or flexible plastic. This final application, on flexible plastic, opens the range of applications, especially for building integration (roof-tiles) and end-consumer purposes. Four types of thin film modules are commercially available at the moment: Amorphous Silicon, Cadmium Telluride, Copper Indium/Gallium Diselenide/Disulphide and multi-junction cells.

- Other emerging cell technologies (at the latest development stage or early commercial stage): Concentrated Photovoltaic, consisting of cells built into concentrating collectors that use a lens to focus the concentrated sunlight onto the cells, and Organic Solar Cells, whereby the active material consists at least partially of organic dye, small, volatile organic molecules or polymer.

Technology Outlook

It can reasonably be assumed that photovoltaic electricity will become a mainstream power source in Europe by 2020 and a major power source in 2050. The "SET for 2020" study (www.SETFOR2020.eu), carried out by EPIA (European Photovoltaic Industry Association) with the support of the Consulting firm AT Kearney, considered that, provided some boundary conditions were met, PV could supply up to 12% of the electricity demand in Europe by 2020, thus representing 390 GWp of installed capacity and 460 TWh of electricity generation.

The 2030 and 2050 targets are based on a more conservative scenario, in line with the baseline scenario and accelerated scenarios of the "SET for 2020" study, representing respectively 4% and 6% penetration of PV in electricity demand by 2020.

For 2030 to 2050, the scenario assumes a progressive decrease in growth rate to cope with the increased contribution of other renewable energy sources. Nevertheless, the potential of photovoltaic electricity in Europe could be at least 50 % higher by 2050. Available land area and buildings in "zero impact areas" (areas not in competition with food production, natural reserves, housing, industry or other purposes) represents a potential of more than 5,000 TWh of yearly PV electricity production. The capacity of the industry to manage the foreseen growth of the PV market from 2010 to 2050 is not questionable.

All assumptions are based on current knowledge of technological evolution to be expected in the coming years. With the expected evolution of technologies such as concentrated PV and nanotechnologies, even higher efficiency and output performances can be expected.

Table 1 PV Installed Capacity and Yearly Production up to 2050

	2010	2020	2030	2050
Installed Capacity	15 GWp	150 GWp	397 GWp	962 GWp
Yearly Production	20 TWh	180 TWh	556 TWh	1347 TWh

Technology-specific Recommendations

- Sustainable Feed-in Tariffs (FiT) have so far proven to be the best support schemes for successful PV deployment. Support schemes must evolve with the growing share of PV at different levels of competitiveness.

- Streamlining and simplifying administrative and connection procedures is essential to accelerated PV deployment.

- Temporary policy support for PV is essential during its pre-competitive phase. An EU-wide introduction of time-of-use electricity billing and net metering, EU funded research, development, demonstration and deployment programmes are essential for a timely achievement of full PV competitiveness.

- Measures to foster the integration of PV in buildings should also be taken at national level, especially in the framework of the implementation of the Energy Performance of Buildings Directive. PV is one of the only distributed electricity sources that can be seamlessly integrated into dense urban environments. As such, PV is a key technology to enable the transition from energy consuming to energy producing buildings.

- A steady development of photovoltaic electricity will require enhancing storage capabilities on the network in parallel to establishing aggregations of Virtual Power Plants (VPP) and smart grids as well as hybrid systems. Large scale storage (using hydropower or other technologies) as well as decentralised storage devices will help to accelerate the deployment of PV across Europe.

Solar Thermal Electricity Vision up to 2050

Introduction

Solar Thermal Electricity (STE), also known as Concentrated Solar Power (CSP), has the largest potential and the most suitable characteristics to convert solar radiation into electricity. STE plants are fully dispatchable, meet the demand curve and can additionally provide other fluent renewable conversion technologies with the necessary back-up. STE generation is highly predictable, and it can be coupled with thermal storage or hybridization, with gas or biomass, providing stability for the electricity networks. STE plants have favorable inertial responses and the capacity for primary, secondary and tertiary electrical regulation in both ways, up and down. STE plants can meet the demand needs at day and night, and can supply electricity at peak hours if previously planned. STE is produced using concentrating solar radiation technologies. STE plants provide clean and reliable power units ranging from 10Kw to 300 MW.

The four main STE technologies are:

1. **Parabolic Trough Plants:** use line-concentrating parabolic trough collectors which reflect the solar radiation into an absorber tube. Synthetic oil circulates through the tubes heated up to approximately 400°C. Some of the plants under construction have been designed to produce not only the nominal power during sunny hours but also to store energy, allowing the plant to produce an additional 7.5 hours of nominal power after sunset, which dramatically improves the integration of STE plant into the grid. Molten salts are normally used as storage fluid in a hot-and-cold two-tank concept. Plants in operation in Europe: Andasol 1 and 2 (50 MW+7.5 hour storage each); Puertollano (50 MW); Alvarado (50 MW) and Extresol 1 (50 MW + 7.5 hour storage).

2. **Central Receiver Plants:** also called tower plants, use mirrors (heliostats) larger than 100m^2 which are almost flat and track the sun on two axes. The concentrated radiation beam hits a receiver atop a tower. The working fluid temperature depends on the type of fluid which is used to collect the energy and is within the range of 500 to 600°C. Hybridization is feasible. Plants in operation in Europe: Solucar PS10 and PS20 (10 MW + 20 MW).

3. **Dish Stirling Systems:** solar concentrator in a dish structure that supports an array of curved glass mirrors. The dish tracks the sun throughout the day and concentrates the radiation onto the heat absorption unit of a Stirling engine. The solar thermal energy is then converted to grid-quality electricity throughout a closed cycle: high-efficiency solar Stirling engine using an internal working fluid (Hydrogen or Helium) recycled through the engine. The fluid is heated and pressurized by the solar receiver, which in turn powers the Stirling engine.

4. **Linear Fresnel Systems:** collectors are line focusing systems like parabolic troughs with a similar power generation technology, which particularity is the fixed absorber position above a field of horizontally mounted flat mirror stripes, collectively or individually tracking the sun. Plant in operation in Europe: Puerto Errado (2 MW).

Technology Today

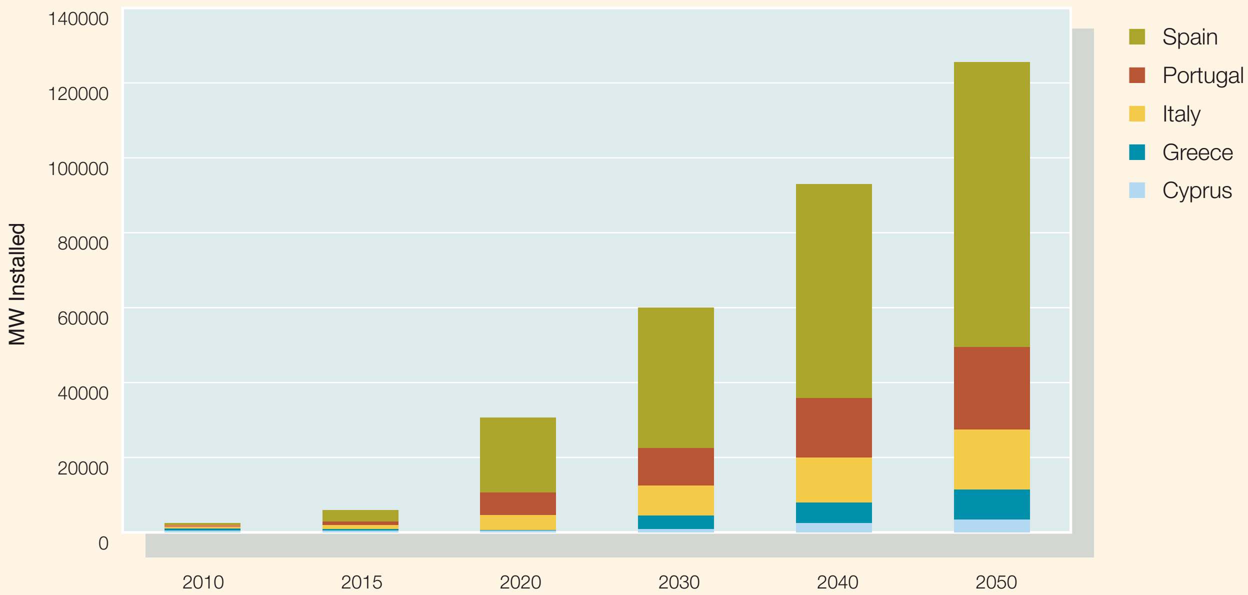
In Europe around 1,800 MW of STE plants are either operating or under construction. Currently, more than 30 Parabolic Trough plants of 50 MW each and one Central Receiver of 17 MW with 15h storage are under construction in Spain. By the end of 2010 there will be 850 MW connected to the grid and the medium-term potential in European countries is estimated at 30 GW by 2020. There are open tenders and approved projects to build STE plants all around the world (U.S.A., Algeria, Morocco, South Africa, Arab Emirates, China, Australia, etc).

Market Perspectives for STE Plants are high, as electricity generated by STE plants is dispatchable and can be enhanced by new technologies and/or hybrid concepts using other renewable or conventional fuels. Dual applications will bring important benefits in some specific areas (i.e. electricity and water desalination). Costs will be brought down by innovation in systems and components, improvement of production technology, increase of the overall efficiency, enlargement of operation hours (storage), bigger power blocks, decrease in the O&M costs, learning curve in construction and economies of scale.

Technology Outlook[5]

The installed capacity in Europe is expected to be of 2 GW by 2012, 30 GW by 2020, 60 GW by 2030 and 125 GW by 2050. The technical potential in Europe can be estimated 20 times that figure within reasonable generation costs. For long-term renewable supply in the EU, regional approaches are of paramount importance. Focusing on STE, the EU and its Member States should take advantage of the fact that the largest potential of the world is in Southern Europe and the Union's neighboring countries of the Mediterranean, partners in the Union for the Mediterranean. North African countries should develop clean technologies to face the increasing domestic energy demand. In the medium-term targets of 20 GW by 2020, 85 GW by 2030 and 430 GW by 2050 are feasible taking into account the grid infrastructure to be developed in the region.

Figure 1 STE Estimates 2010-2050: Installed Capacity in Southern Europe (MW)



Technology-specific Recommendations

Policy support has been fundamental for the present growth of the STE sector. The European industry currently benefits from world leadership in STE technology. **Feed-in tariffs (FiT)** have proved to be the most effective tool to boost the development of STE. The FiT applied in Spain has allowed for the extraordinary development of the STE sector. The best policy measure that could help implement STE would be to settle a specific FiT in the countries with STE potential (Italy, Spain, Cyprus, Malta, France, Portugal, Greece, Bulgaria, Romania). Other EU countries could develop their STE manufacturing industry through "Statistical Transfers and Joint Projects" between Member States, as stipulated in the 2009/28/EC RES Directive.

The chosen support scheme should foster innovation and allow for cost reduction. Premiums or higher FiT for the plants with Storage or Hybridization should be given as they highly increase the dispatchability.

In addition, STE has a huge potential in the neighbouring Mediterranean countries, and the EU industry, as a world-leader, could contribute to the economic development of the MENA region. The **Mediterranean Solar Plan (MSP)** could be the driving force to develop the political, legal and financial tools for further deployment in the long-term. These common framework and tools shall be jointly agreed by the EU and Mediterranean neighbours and partners. The MSP could be boosted and developed under the scope of the 2009/28/EC RES Directive: "Joint projects between Member States and third countries".

5 For further reading see: ESTELA: ***CSP 2025.*** 2010; Greenpeace, ESTELA and SolarPACES: ***Concentrated Solar Power Global Outlook 09, Why Renewable Energy is Hot.*** 2009.

Solar Thermal Vision up to 2050

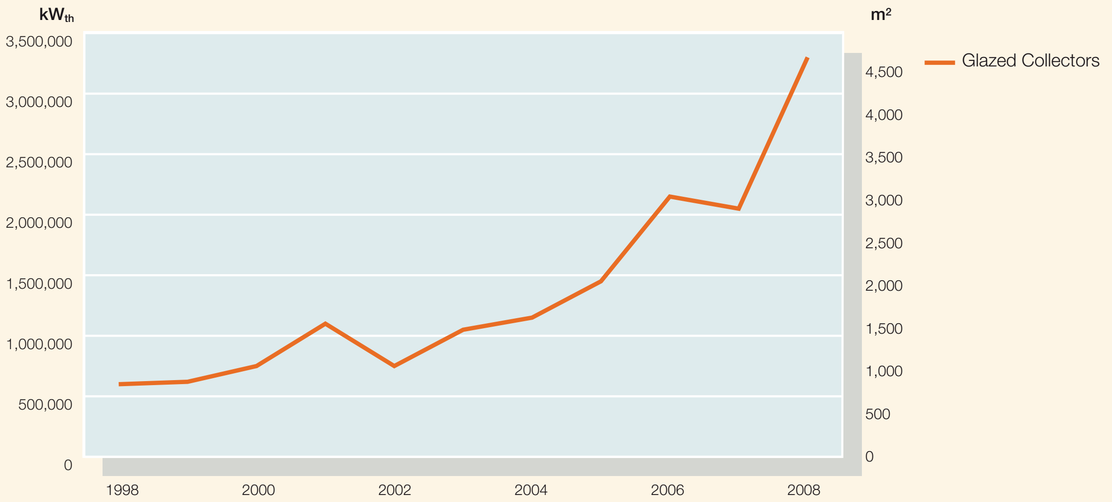
Introduction

Solar thermal (ST) collectors are based on a simple principle known for centuries. Solar radiation is captured using different types of collectors and the resulting heat conveyed to a heat transfer medium which is then used directly as in swimming pools or indirectly as in space heating. The whole ST value chain, from manufacturing to installation including components, has now matured to form a strong and highly reliable industry in which Europe undeniably has a competitive edge. Several market leaders today were the industry's pioneers, but this booming sector has also attracted investments from conventional heating system manufacturers. ST is mostly used for space heating and hot water preparation in the residential sector and the service sector space heating in the service sector, and is increasingly used for industrial low temperature heat (<250°C), and air conditioning and cooling. Furthermore, there is considerable scope for new applications such as sea water desalination and water treatment.

Technology Today

Continuing a decade-long trend, 2008 saw an impressive development in the solar thermal market, with a growth rate in excess of 60% in the EU and Switzerland, reaching 3,3 GWth of new capacity, representing 4,76 million m^2 of solar collector area. The overall installed capacity currently amounts to more than 27 million m^2 of glazed solar collectors, an equivalent of over 19 GWth. With an annual turnover exceeding the 3 billion Euro mark, the European solar thermal industry employs over 40.000 people full time in production, marketing, sales and maintenance.

Figure 1 Newly Installed Solar Thermal Capacity in EU-27 from 1998 to 2008



While current key areas for solar thermal technology applications are domestic hot water preparation and space heating for single and multiple family houses (with typical solar fractions between 15–30% of the overall heat demand), as well as hot water preparation in the hotel and service sectors, in some European countries (e.g. Austria, Denmark, Germany and Sweden), solar assisted district heating systems are also well established to date. Moreover, the number of solar thermal systems for cooling and air conditioning, mostly in southern countries, and industrial process heat has increased significantly in recent times.

Technology Outlook[6]

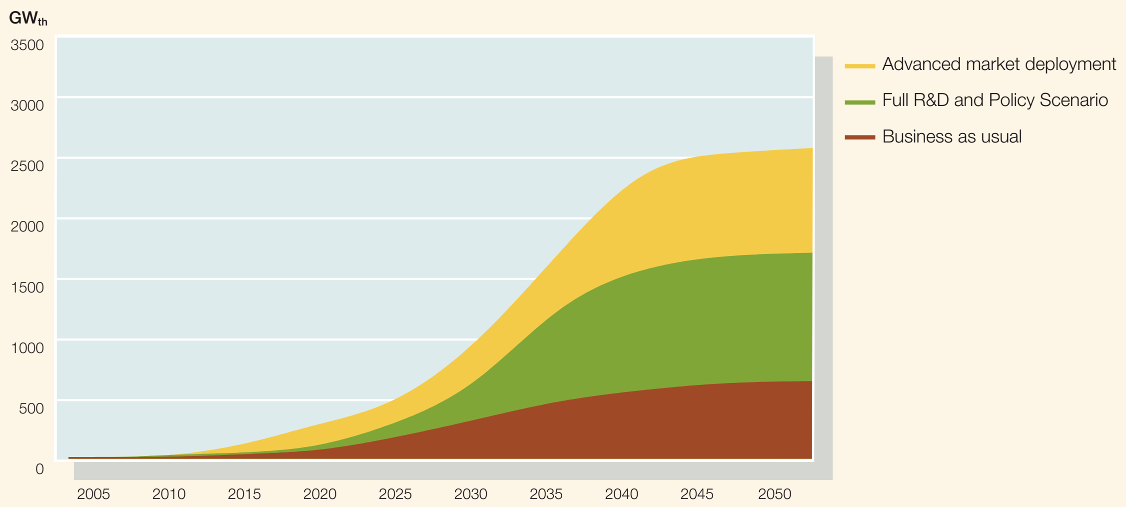
The importance of the heating and cooling sector has now been clearly recognized, as it currently meets roughly half of the entire final energy demand (49%) and will continue to be a major player in the energy supply. The overall energy demand will decline with the implementation of energy efficiency measures. Therefore, the deployment of renewable heating and cooling technologies (RES-H&C) must go hand in hand with major energy efficiency improvements in buildings to ensure a widespread take-up of renewable energy systems (RES). Solar thermal (ST) has unique and

6 For further reading see: ESTIF: *Potential of Solar Thermal in Europe.* 2009

specific benefits: direct reduction of primary energy consumption, can be combined with nearly all kinds of back-up heat sources, does not result in a significant increase in electricity demand, is available nearly everywhere, its costs are highly predictable and the systems' life-cycle has low environmental impact. Last but not least, the use of solar thermal contributes to the security of energy supply and creates local jobs.

Figure 2 indicates the solar thermal potential in the European Union (EU-27) based on three scenarios: "business as usual", "advanced market deployment" (by developing new technologies and application sectors) and "full R&D and policy scenario", assuming new applications where R&D is needed to develop them (such as compact heat storage and high temperature collectors).

Figure 2 Development of EU-27 Solar Thermal Capacity According to 3 Scenarios



The 2020 goal of the European solar thermal sector, in line with the "full R&D and policy scenario" developed by ESTIF, is to have an installed solar thermal capacity of 272 GWth equivalent to 388 Mio m^2 of solar collectors. This corresponds to an estimated 6.3% of the European Union's 20% renewable energy target, representing an annual sectoral growth rate of 26%. In this case there would be an annual saving of 155 TWh of energy produced from fossil sources and 69 Mt of CO_2 emissions would be avoided every year.

An energy efficiency of 9% by 2020 would lead to a reduction of 4,297 TWh in the heating and cooling demand. On the basis of reduced demand and additional collector area, the solar fraction would be 3.6% by 2020. In the medium-term (2030), the solar fraction would be 15%, based on a 20% reduction in demand compared with the 2006 level. And, in the long-term (2050), the solar fraction would be 47%, based on a 31% reduction in demand compared with the 2006 level.

Technology-specific Recommendations

Mature products exist already today to provide domestic hot water and space heating using solar energy. However, in most countries they are not yet the norm. Integrating solar thermal technologies into buildings at the design stage or when the heating (and cooling) system is being replaced is crucial, thus lowering the installation cost as well as limiting additional building costs. Moreover, the untapped potential in the non-residential sector will be revealed as newly developed technology become commercially viable. Key applications and elements which will widely contribute to achieve these goals include: the Solar Active House, solar refurbishment/active solar renovation, high density heat stores, solar thermal systems for medium temperatures/solar process heat, solar assisted cooling, and new materials for solar thermal systems.

These applications will need significant R&D investment to become mainstream, both from the private and public sector, as well as public support for market introduction. In a global market, the main competitive strength of the European solar thermal industry is high quality standards, driven by a fast growing internal market. The public sector plays a crucial role by implementing solar building codes or introducing near-zero energy building regulations, both for new and refurbished buildings.

Ocean Energy Vision up to 2050

Introduction

The ocean is an enormous source of renewable energy with the potential to satisfy an important percentage of the European electricity supply. Conversion of the wave energy resource alone could supply a substantial part of the electricity demand of several European countries, in particular Ireland, the UK, Denmark, Portugal, Spain and Norway, especially on islands and in remote areas.

The best ocean energy resources within the EU Member States are wave energy and marine currents, which have seen the most technological development. Salinity gradient systems are being developed in Norway and the Netherlands. Ocean Thermal Energy Conversion (OTEC) technologies are not yet available in Europe but can be harvested at latitudes closer to the Equator with technologies developed by European companies.

The technologies used to exploit the different ocean resources (waves, tidal range, tidal stream/marine currents, salinity gradients and ocean thermal energy conversion) are quite diverse. They can be categorised according to their basic principles of conversion.

The different concepts for wave energy conversion can be onshore, nearshore and offshore and rely on several working principles (oscillating water coulumbs (OWC), overtopping and oscillating bodies). Tidal barrage technologies produce electricity from the same basic principle as hydropower dams, but adapted to ebb and flood tides. Marine current devices are less diversified than wave energy devices. They can use horizontal or vertical axis rotors, oscillating hydrofoil and venturi enhancement of the flow speed; and they can either be rigidly mounted in the seabed, piled mounted, semi-submersible with moorings or attached to a floating structure. The technology to harness salinity gradient power uses the osmotic pressure differences between salt and fresh water or waters of different salinity. OTEC relies on using the temperature differences between shallow and deep sea to drive a turbine.

Over the past few years, dedicated infrastructure for wave and tidal sea trials have been created in several European countries. They facilitate deployment of technologies from prototype to commercial phase by making cable connection available and/or simplifying the licensing procedure. At present, several grid connected test areas are under development, scheduled to be operational within the coming 1 to 3 years.

Technology Today

At present, tidal barrage is the only ocean energy technology that has been operating for decades. La Rance, France, was inaugurated in 1966 and has been exploited commercially ever since. Several wave and marine current technologies are currently in (full scale) demonstration stage. Salinity gradient and OTEC are still largely in R&D stage. However, the first salinity gradient prototype installation is operational since December 2009 (Statkraft, Norway).

Although ocean energy R&D started decades ago, remarkable development has only taken place since the beginning of this century. Overall, ocean energy development is no longer limited to academic research. Recently, large companies, utilities and industrial consortia have started to invest substantially in ocean energy projects demonstrating the ambition of the sector. Political engagement is being demonstrated by Member States with high ocean energy resources by means of dedicated research funding programmes, support schemes and ambitious national targets.

The installed capacity in 2009 was approx. 250 MW. This included La Rance in France that has an annual production of 550 GWh. The cost of current prototypes are of the order of 3,500 to 13,000 €/kWh.

Technology Outlook[7]

In terms of electricity production generated by the sector, EU-OEA (European Ocean Energy Association) estimates the following: 0.62 TWh in 2010, 8.94 TWh in 2020, 150 TWh in 2030, 549 TWh in 2040 and 645 TWh in 2050. These assumptions are based on the development of offshore wind and assume saturation in 2050.

Growth of the sector to 2020 is estimated by using an exponential curve that follows the growth since 1998 leading to projected installed capacity of 3,6 GW by 2020. Considering ocean energy faces similar challenges as the offshore wind sector, a similar growth curve has been used to project the 2030 and 2050 scenarios leading to a projected installed capacity of 54 GW by 2030 and 188 GW by 2050. Furthermore, it is considered highly likely that ocean energy will form synergies with offshore wind.

In terms of cost, it has to be noted that the cost of ocean energy is very technology specific. Cost figures are still being developed as devices enter long-term energy production stage. The 2006 Carbon Trust report 'Future of Marine Energy' estimates the cost for wave energy to be between the equivalent of 0.1 to 0.65 €/kWh, depending on the full load hours, interest rates, depreciation period and operation and maintenance costs, as well as the different technologies.

Technology-specific Recommendations

- **Financial incentives**
  Up to now, financing of ocean energy projects has been done mainly through financing of research projects. However, the real challenge for this sector is to demonstrate technologies that have advanced to the pilot and demonstration stage. Thus, more financing should be allocated to these stages of ocean energy projects at both national and EU level. R&D funding should address improvement of existing technologies rather than new concepts. The need to go from a single pilot device installation to farms with tens of MW calls for targeted investment in specific and ambitious projects. This requires large scale public–private partnerships. It is therefore recommended that policy makers put in place incentives for private bodies to invest in ocean energy technologies such as tax incentives.

- **Grid availability**
  One of the main hindering factors for ocean energy expansion will be the availability and capacity of the offshore and coastal electrical grid. Unlike the offshore wind sector, which has been involved in the planning process for the grid expansion and development for many years, the ocean energy sector has difficulties to push in favour of its inclusion in grid development planning. Policy makers at both national and EU level have to ensure that all options for future offshore energy sources are taken into account.

- **Integrated Maritime policy**
  Large scale deployment of ocean energy farms entails using a significant portion of the maritime area. The independent management of maritime space, with fair allocation of resources and transparent participatory procedure for allocation will therefore be crucial for the development of the ocean energy sector.

7 For further reading see: OEA-EU. *Ocean Energy Technology Roadmap.* Forthcoming.

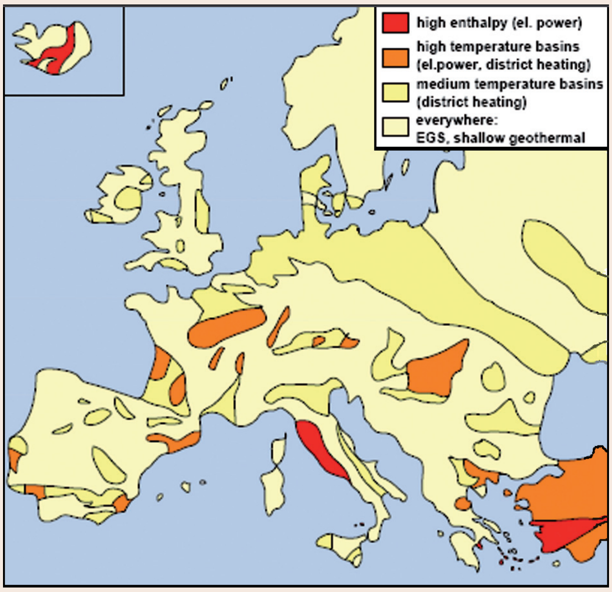
Geothermal Vision up to 2050

Introduction

There is no geographical restriction for the exploitation of geothermal energy, the resource is present anywhere on Earth, day and night, throughout the year, and can be exploited both for heating and cooling needs (directly or with geothermal heat pumps) and for electricity production ("classic" geothermal power plants as well as Enhanced Geothermal Systems) (see Table 1 for more details). However, some regions benefit from more favourable conditions, which has allowed an earlier development of geothermal resources in such regions (see figure 1).

Geothermal energy as a heat resource is available all the time. Converted into electric power, it is therefore particularly adapted to provide the electricity system with the necessary back-up; many geothermal power plants have a track record of operating more than 8,000 hours per year, which represents more than 90% availability. Geothermal energy also is an ideal answer to the different energy needs of a local community: electricity, heating and cooling, domestic hot water, and thermal energy storage.

Figure 1 Map of the Favourable Areas for Geothermal Energy Use in EU



Technology Today

In the EU today, the total installed capacity for geothermal power is ca. 1,000 MWe, which is expected to generate almost 8 TWh in 2010. At present, new electricity projects representing a total of 400 MWe are ongoing in the EU (EGS and low temperature power plants). In total, electrical plant construction and well drilling costs about 4-7 million € per MWe of electrical capacity, while the energy cost is 0.04-0.20 € per kWh.

In terms of sectoral growth, geothermal heating and cooling appears to be on the right track for reaching the 2010 White Paper objectives. Between 1995 and 2009, the annual number of newly installed geothermal heat pumps increased by a factor of five. Residential geothermal heat pumps with a capacity of 10 kW are routinely installed for around 1,000-3,000 € per kW. District heating systems may benefit from economies of scale if demand is geographically dense, as it is in cities. The capital cost of a geothermal district heating system is estimated at somewhat over €1 million per MW. Finally, geothermal energy is highly scalable: a large geothermal plant can heat and power entire cities, while a smaller power plant can supply a rural village.

Technology Outlook[8]

According to EGEC, geothermal energy can substantially contribute to heating and electricity production, with ca. 20% of the total EU consumption, or 70 Mtoe for electricity and ca. 30 % of the total EU consumption, or 150 Mtoe for heating and cooling (see Table 1 for more details). The availability of the resource, all day and all night, throughout the year, provides a back-up to the electricity grid anywhere.

By 2020: Strengthening the European geothermal industry by developing hydrothermal resources in Europe and expanding the EGS concept, as well as by increasing the market penetration of geothermal heat pumps and ensuring a wider spread of geothermal district heating and cooling systems.

By 2030: Towards a competitive source of energy by bringing down EGS plant cost, starting the implementation of massive construction programs, and transferring EGS technology outside Europe. Geothermal heat pumps and direct uses will be firmly established and further developed, notably in view of agricultural applications (e.g. heating greenhouses), new applications for pre-heating in industrial processes (high temperature) and new district heating systems for dense urban areas.

By 2050: Powering Europe and the world from geothermal with EGS developed everywhere at a competitive cost, replacing conventional base-load power plants (coal, nuclear, fuel, etc.) and geothermal heating and cooling systems being available and economic for both individual buildings and urban areas.

Table 1 Geothermal Electricity and Heating & Cooling up to 2050

Geothermal Electricity - EU-27	2010	2020	2030	2050
Electricity conventional (MWe)	990	1,500	*7,000*	*10,000*
Electricity EGS (MWe)	10	4,500	*15,000*	*90,000*
Total Installed Capacity (MWe)	1,000	5,000	20,000	100,000
Yearly Electricity Production (TWh)	8	50	234	780
Heating & Cooling - EU-27 (Mtoe)	**2010**	**2020**	**2030**	**2050**
Geothermal Heat Pumps	2.3	6	*12*	*70*
Geothermal Direct uses	1.8	2.5	*6*	*20*
Heating from CH&P	0.2	2	*12*	*60*
Total Heat and Cold Production	4.3	10.5	30	150

Technology-specific Recommendations

- Draw the attention of politicians, the general public and the industry so as to give geothermal energy (mainly EGS) the high profile it deserves
- Develop heating & cooling networks integrating geothermal heat pumps and geothermal storage (UTES) (to become a norm in urban planning)
- Remove regulatory barriers on licensing procedures, ownership and grid access
- Educate and train a qualified labour force
- Develop geothermal solutions for retrofitting existing infrastructure & develop products and methodologies for cost effective building energy-related refurbishment
- Launch wide underground exploration programs to allow for optimum allocation between different potential uses (oil & gas, mining, nuclear waste and CCS)
- Establish government incentives (feed-in tariffs, green certificates) and a European risk mitigation scheme for geothermal projects
- Adopt measures on environmental impact and seismicity monitoring

8 For further reading see: TP GEOELEC: *Vision document geothermal electricity*. Forthcoming; RHC Platform: *Vision document geothermal heating and cooling*. 2009.

Bioenergy Vision up to 2050

Introduction

Bioenergy can play an important role in combating climate change as well as improving the security of energy supply in Europe. However, biomass for energy is a complex matter, as there are many different biomass-to-energy-value chains.

Sources of raw material include:

- forests (firewood and round wood) and agriculture (rape seed, cereals, corn for biofuels or short rotation coppices or energy grass for heat and electricity production),
- wood industry by-products (residues, bark, saw dust, shavings, chips, pellets, black liquor etc.) and agricultural by-products (straw, manure, fruit wood etc.),
- waste streams.

The final energy can be used for heat, electricity and transportation fuel or as biomethane. Many different conversion pathways from feedstock to final energy exist today, such as small scale combustion, large industrial combustion units, gasification, pyrolysis, steam process, Organic Rankine cycle (ORC) process, fermentation, and estherification. In order to achieve development in the bioenergy sector over the coming years and up to 2050, there is a real need for a favourable policy environment. Technological and scientific advances must also be made.

Technology Today

The Renewable Energy Directive lays down a 20% RES target for 2020 and states that 10% of final energy consumption in road transport would have to come from renewable energy sources. With these targets in mind, it is evident that a range of bioenergy technologies need to be deployed over the coming years in order to meet those targets. Experts believe that biomass is likely to contribute half the 20% renewable energy target. Today 61 Mtoe of biomass is used as final heat, main raw material fire wood, chips, pellets and other by-products, 9 Mtoe as electricity and 8 Mtoe as biofuel. In efforts to achieve competitiveness, the renewable energy industry is today faced with technological and economic challenges. In addition to these general challenges, bioenergy is confronted with pressing and controversial questions relative to its feedstock. The competition with other uses of biomass (i.e. energy vs. food, feed and fibre), and requirements for sustainable bioenergy production, now dominate discussions.

Technology Outlook[9]

Future development depends to a large extent on the economic framework created by Member States. The leading principles for the further development of bioenergy in future energy systems are sustainability criteria, efficiency and competitiveness. Bioenergy has to bring to commercial maturity the most promising technologies that fit these principles. Developing a longer term R&D programme to support the bioenergy industry beyond 2020 and looking towards 2050 is a key parameter for the success of the sector.

The topics that will affect R&D in the area in the coming years are the integration of bioenergy into supply structures with new conversion technologies, monitoring conversion technologies, monitoring biogas plants, modelling of the whole biogas chain, the development of digestion technologies and the development of both consulting and training programmes.

9 For further reading see: Michael Sterner: ***Bioenergy and renewable power methane in integrated 100% renewable energy systems. Limiting global warming by transforming energy systems***. 2009.

The technologies that have the biggest market potential and are already developed and robust are co-firing of biomass and combustion of biomass by Combined Heat and Power (CHP). At this moment in time, the weakest technology is bio-hydrogen production, however, it is predicted to have a great market potential as it is developed in the coming years. Biofuels and bioliquids have a ‘middle status’ but they will reach a higher market potential with the introduction of 2nd and 3rd generation products and as bioliquids are produced for the aviation sector.

Due the downscaling of each individual technology’s targets for heat and electricity in the EREC report, less biomass is used for these purposes than projected in Table 1 below by AEBIOM and EUBIA (370 Mtoe in 2050). The EREC scenario allows for a higher use of biomass as transport fuel (105 Mtoe by 2050) under the assumption of comparatively high incentives for this sector.

Table 1 Proposed Targets for Bioenergy

Unit: Mtoe

	2007	2020	2030	2050
total gross inland consumption	98	220	300	370
total final energy consumption	78	175	261	362
hereof				
heat (direct heat and derived heat)	61	123	182	231
electricity	9	20	35	56
biofuels	8	32	45	70

When thinking of the power system in 2050, many options are currently being discussed on how to integrate variable renewable energy sources, for example via Virtual Power Plants and different transmission and storage options on the supply side and demand side management on the energy customer (end-use) side. Bioenergy is an attractive solution to the challenge of integrating renewable energy in the electricity grid. It is a renewable energy source with the properties of fossil fuel (high energy densities) and is as such stored chemical energy. It is therefore suitable to substitute fossil fuels in the transport sector and in the heat and power sector. Bioenergy is also of interest as a balancing power. Electricity production based on biomass should be concentrated in CHP plants of different sizes. Micro CHP still has to be developed for the market. CHP offers high efficiency, but requires in many cases new district heating (DH) grids.

In the future, more than two thirds of the contribution of bioenergy to the final energy consumption in Europe could be in the heating sector. This would require the heating systems in tens of millions of houses to be changed, the building of many district heating systems (large and small), and the change of the heating system in many companies of the production sector. The technology is available – efficient and low emission wood logs, wood chips and pellet boilers/stoves for small scale applications and DH plants running on various biomass fuels.

Biofuels are important to improve the security of the transportation sector. First generation biofuels, mainly from Europe, will maintain a significant share of the total, as they have the advantage that the production delivers almost double the amount of protein feed (defined in energy units), as liquid fuels. Second generation biofuels will slowly be introduced, from plants operating efficiently. Bio-refineries contribute sustainable processing of biomass into a spectrum of marketable bioenergy products and they will develop over the coming years and will have an important role in a 2050 strategy. Biofuels offer the possibility of having multiple energetic and non-energetic products from a mix of biomass feedstock (wood, energy crops, organic residues, aquatic biomass).

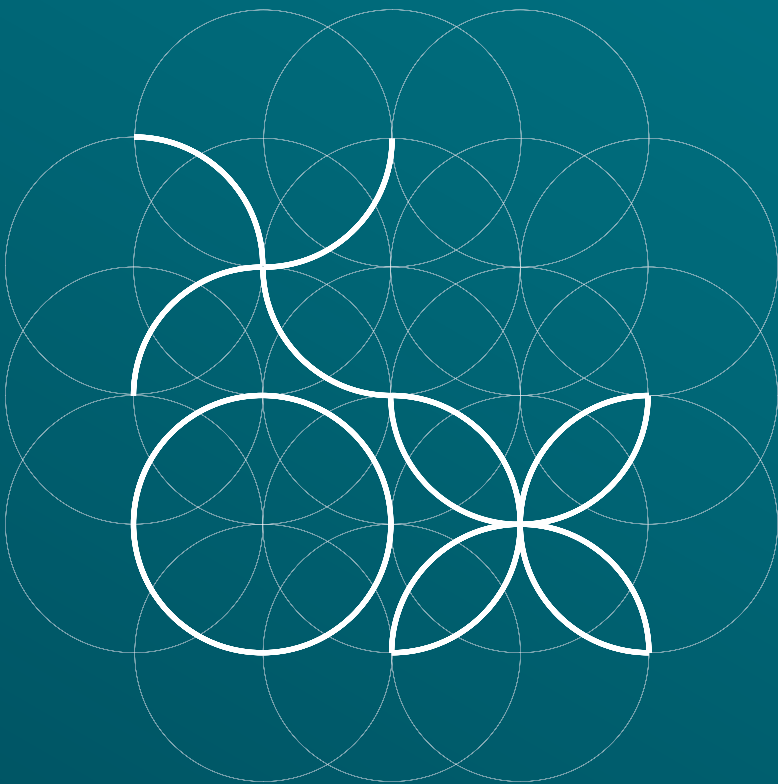
Technology-specific Recommendations

Firstly, there is a need for multi-disciplinary scientific knowledge, so that a mixture of technologies can be developed that are adapted to individual energy issues. The setting up of an efficient network of EU Centres of Excellence, with the aim of collecting information on the bioenergy sector, helping the communication between stakeholders and disseminating information on a variety of relevant issues, will be key to achieving the bioenergy objectives set out above. Last but not least, it is very important to have international collaboration.

- Sustainable biomass is limited and therefore a focus should be on the strategic functions of biomass in future energy systems, in particular balancing power demand with variable renewable sources;
- BioSNG/Biomethane seems the most promising target function of biomass in the long term;
- Rapid development of small scale CHP and of 2nd generation fuels;
- Financial support programs for DH, for private house owners and small companies to switch from fossil fuels to biomass for the heat supply;
- Programs to better combine solar thermal and biomass;
- Training of plumbers for this new combined use of RES;
- 40% of all investment to change the energy system to renewable has to be realized in private houses or companies – better support program for this kind of investment is urgently needed.

Projects that will be important in the coming years in the sector of biomass/biofuels that currently form the technology roadmap of the European Industrial Bioenergy Initiative (EIBI) are:

- Lignocelluloses to intermediate solid with pyrolisys
- Lignocelluloses to intermediate solid with torrefaction
- Lignocelluloses to synthetic gas via gasification
- Lignocelluloses to biofuels via gasification
- Lignocelluosic to biofuels via pyrolisys and torrefaction
- Lignocelluloses (household waste) to biogas via chemical and biological processes
- Algae or micro-organism to biofuels and bioliquids via biological and chemical processes



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