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European Renewable Energy Council

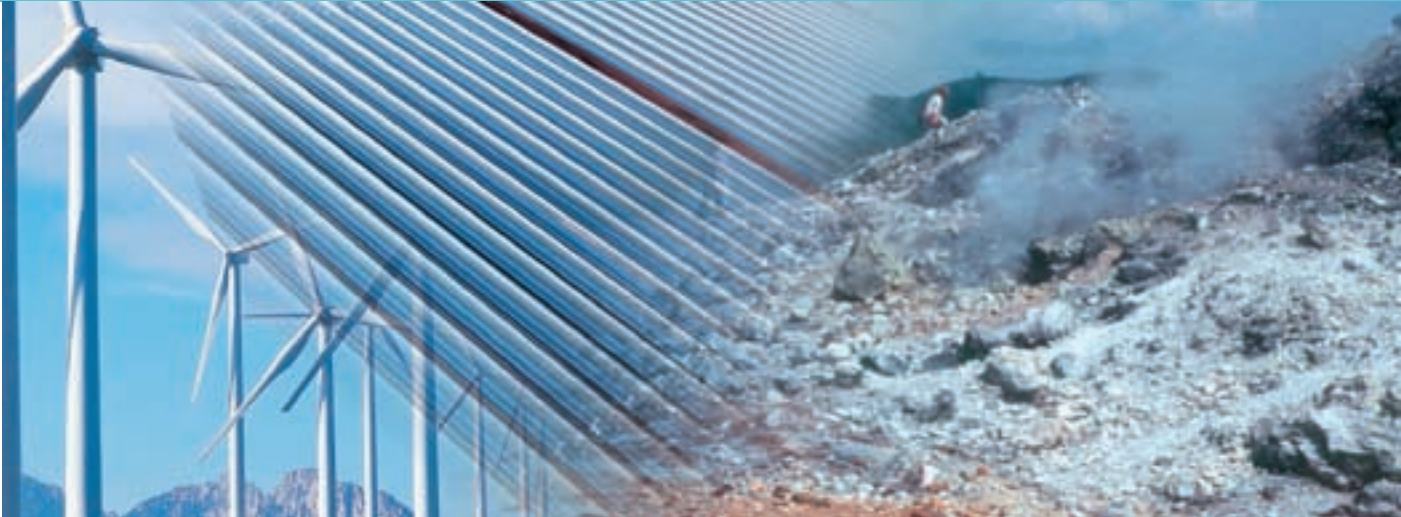


RENEWABLE ENERGY TECHNOLOGY ROADMAP

UP TO 2020



RENEWABLE ENERGY TECHNOLOGY ROADMAP



Introduction

The main characteristics of the present energy supply system in Europe are the dominating share of fossil fuels as well as the high dependence on energy imports. In the EU-25, fossil fuels contribute almost 80 % to the primary energy demand.

Concerning this structure it must be kept in mind that the resources of fossil and nuclear fuels are limited in principle. This might not restrict the energy supply in the short or mid term but the peak of production of, at least, conventional oil is already expected to occur in the next two to three decades, with some geologists seeing this peak occurring much sooner. An even more important problem with fossil fuels arises due to the fact that most of them need to be imported.

To make energy supply more secure the EU Commission's Green Paper, amongst others, recommends to tackle the EU's rising dependence on imported energy through an "integrated approach – reducing demand, diversifying the EU's energy mix with greater use of **competitive, indigenous and Renewable Energy**, and diversifying sources and routes of supply of imported energy"¹.

And the Commission's statements concerning Renewable Energies are very clear: "Action on Renewables and Energy Efficiency, besides tackling climate change, will contribute to security of energy supply and help limit the EU's growing dependence on imported energy." And more importantly, the Commission leaves no doubt that Europe must act urgently, because it takes many years to bring innovation in the energy sector. This is also true concerning Renewable Energies: At present the EU leads the world in promoting Renewable forms of Energy, yet this position must be reinforced.

Taking the results of the recently published baseline ("business as usual") scenario, written by Mantzos and Capros², Renewable Energies will not meet these expectations by 2020 without further political and legal attention. They will not meet them even if they fulfilled the targets fixed by the EU for 2010. It is true that from 2025 onwards Renewables will become the most important indigenous energy source, but according to the baseline scenario by Mantzos and Capros their contribution to the total primary energy demand will only be roughly 8% in 2010, slightly more than 12% in 2020 and only 12% in 2030 far away from any target set so far. And it is also much farther away from the huge potential within Renewable Energy Sources, as well as from the capabilities of the European Renewable Energy industry which is ready to commit to contributing a minimum 20% target in 2020 and respective sectorial targets for electricity, heating and cooling as well as biofuels for transport. To strengthen the security of supply and to contribute to the restructuring of the energy system by means of Renewable Energy, the European Union must set more ambitious long term mandatory sector targets to guarantee stability, and commitment for investment decisions.

Without a major shift towards Renewable Energy Sources in combination with energy conservation and efficiency we will lose the chance of securing our energy supply system. If we take that chance now, the EU could become the most energy import independent region in the world.

¹ Green Paper; A European Strategy for Sustainable, Competitive and Secure Energy, 8.3.2006, COM(2006) 105

² European Energy And Transport, Scenarios on energy efficiency and renewables, Dr.L.Mantzos and Prof. P. Capros, Institute of Communication and Computer Systems of National Technical University of Athens (ICCS-NTUA), E3M-Lab, Greece



Renewables Development in the Past

The European Union began to set targets for Renewable Energies in 1997 in its White Paper on Renewable Energy Sources. An overall target of doubling the contribution from Renewable Energy in the final EU energy consumption was set with a target date of 2010.

Since that time, new legislative frameworks have been put in place at EU level with a view to ensuring that these targets will be achieved in both the Renewable Electricity and Biofuels sectors. The relevant Directives include sector specific targets for each EU Member State up to 2010. The Renewable Heating and Cooling sector is still missing in legislation.

Targets represent a first step in policymaking, but it is not the only one. Targets indicate clearly the direction and provide for security for investors. Since energy investments are always long term investments, the existing targets are by no means sufficient any longer.

It is high time for the EU to set new targets and introduce the respective legislation for Renewable Energies for the year 2020. One of the main pillars of the Renewable Energy road-map should be the proposal of a new **overall target for 2020, followed by targets for the different sectors (electricity, heating/cooling, biofuels)** as was already requested by

the European Parliament. These targets would give clear and stable market incentives to the operators, in order to allow them to make long term commitments safely and according to policy priorities.

When faced with the fact that only a few EU Member States are currently on track to meet their targets for 2010, it is of utmost importance to ensure that these existing targets for Renewable Energies are being achieved and that a framework for the future is set.

This brochure shows the ambitions of the European Renewable Energy industry, while at the same time trying to make a concrete proposal for new targets.

Why aren't we on track to meet the current targets?

The White Paper target of 12% Renewable Energy by 2010 was too unspecific and not immediately followed by the necessary legislation and flanking measures.

Only four years after the publication of the White Paper, the first Directive for the promotion of Renewables Electricity came into force, including sector specific national targets. It took some years of implementation and analysis until more than a few frontrunner countries implemented the Directive not only in its words, but also in its spirit. Today we can see a second wave of countries following rapidly the RES-E development of the frontrunner countries through the refining of the national policy frameworks. The industry is still optimistic that the targets of 21% RES-Electricity by 2010 can be reached with such an approach. But a crucial factor is that the ongoing legislation does not become watered down or put at stake by new vague and ambiguous proposals or announcements.

This is not the right time for the creation of political instability and legislative vacuums. Existing policy approaches need to be kept and strengthened.

In the field of biofuels the implementation of the Directive was delayed for nearly two years because the Council could not decide on a related Directive concerning taxation. This delay and a similar slow and unequal implementation amongst the Member States is a decisive factor for a slow move towards reaching the targets.

One of the major factors for the slow development in reaching the overall 12% target is that in the third, but important sector – Renewable Heating and Cooling - no legislation has been proposed. Had a promotional Directive been implemented in the heating and cooling sector similar to the biofuels and electricity sectors, much more would have been achieved so far to reach the target.

The statistics of energy

Apart from the set of legislative problems mentioned before, one needs to take a look at the statistics and calculation methods of the European database, and more precisely, at the Eurostat methodology compared to the substitution principle. The real figures and the real uptake of Renewables would shine in a different light if the calculation methods were adapted according to the substitution principle.

In the Eurostat methodology the primary energy value of the electricity produced by the different energy sources is found by assuming a conversion efficiency factor for each source. For nuclear power, for example, the assumed conversion efficiency factor is 33% and for geothermal energy it is 10%. This means that the primary energy value (PEV) is approximately three times bigger than the electricity produced (EP) for nuclear power ($PEV=EP/0.33$), and ten times bigger for geothermal energy ($PEV=EP/0.1$). For the electricity produced from hydro, wind, solar and ocean power the conversion efficiency factor is assumed to be 100% and so the primary energy value of these sources is assumed to be the same as the electricity they produce. The consequence of these assumptions is that for the same amount of electricity produced, for example, by nuclear and hydro, the primary energy value of nuclear will be three times bigger than that of hydropower. A similar approach is used by International Energy Agency (IEA).

According to the substitution principle, the primary energy attributed to the electricity produced by the non-combustion-based electricity sources (nuclear, geothermal, hydro, wind, solar and ocean) is adjusted to reflect the fossil fuel energy required to produce an equivalent amount of electricity. Fossil fuels are converted to their primary equivalent by applying a universal conversion efficiency factor. The same is done for all these sources. The usual value, which is used, is 38.5%, reflecting the average efficiency of a thermal power station. This methodology was used in the past both by IEA and Eurostat but has now mostly been abandoned. It continues to be used, though, in several authoritative energy statistics, such as the BP's annual "Statistical Review of World Energy", the Shell Scenarios, and the annual "Renewables Global Status Report" of the REN21 network.

In political discussions RES targets are based on the Eurostat or the IEA methodologies. This clearly favours conventional and nuclear sources in terms of the percentage share of overall primary energy use. Sources such as wind, hydro and PV are underestimated.

To illustrate this argument, the following two tables explain the differences in the calculation methods.

Globally, the electricity produced by hydropower and nuclear power in terms of TWh is nearly the same as Table 1 shows. If one compared this to the percentage share in global electricity production one would find nearly the same shares, as the IEA's "World Energy Outlook" correctly determines. At the same time, exactly the same numbers, which are translated into the share of both technologies in terms of primary energy supply, lead to a completely different picture, because the primary energy value of nuclear is counted three times more than that of nuclear, as explained above.

Table 1: Electricity Production from Hydropower and Nuclear power worldwide

World - 2004				
	TWh	% electricity	Mtoe	% primary energy
Total	17,408		11,204	
Nuclear	2,740	15.7%	714	6.4%
Hydro	2,809	16.1%	242	2.2%

Source: IEA

A similar picture of nuclear compared to hydropower is shown in Table 2 for the EU-25. The electricity produced (in TWh) by nuclear power in the EU-25 in the year 2004 was approximately three times more than that of hydropower, but the primary energy value of nuclear counts almost ten times more than hydropower.

Table 2: Electricity Production from Hydropower and Nuclear power in the EU-25

EU-25 – 2004				
	TWh	% electricity	Mtoe	% primary energy
Total	3,179		1,747	
Nuclear	986	31%	254	14.5%
Hydro	337	10.6%	26	1.5%

Source: Eurostat

This difference in calculation obviously leads to different figures concerning the share of Renewables in total primary energy supply.

We believe that it is high time to rethink the applied statistics, and that one calculation method must be applied in the EU as well as in the IEA figures. This would enable us to estimate the real value of different energy sources in a transparent way. A change in the calculation method could open the eyes of decision makers for prioritising the necessary legislative frameworks for a future energy supply.

As long as the role of Renewables is underestimated in the ongoing discussions about a future energy mix, changes in peoples' attitudes will remain difficult. Therefore we demand from the European Union and the IEA to change their approach, which wrongly favours nuclear and conventional energies in their contribution to our energy supply.

These two different calculation methods are used in this briefing in order to show the opposing pictures of the development of Renewables in comparison to the one that is usually given.

The Existing Targets for Electricity

Table 3: Targets for Electricity as set out in the Directive for the Promotion of RES-Electricity in the internal market – Can they still be met?

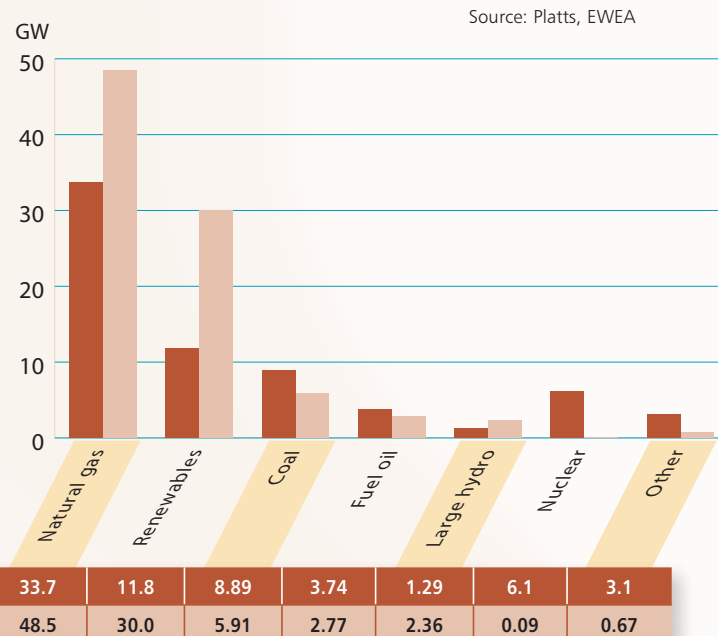
TYPE OF ENERGY	1997 Eurostat TWh	2004 Eurostat TWh	AGR 2000-2004 %	DIRECTIVE TARGET 2010 TWh	AGR NEEDED 2004 - 2010 %
Biomass	28.8	67.9	13.0		
Wind	7.3	58.5	34.6		
Photovoltaics	0.05	0.74	47.0		
Geothermal	4.0	5.5	4.7		
Total Renewable Energy without hydro	40.0	132.6	18.7	371	18.7
Hydro	310.4	303.8	-0.3	356	2.7
Total Renewable Energies	350.5	436.4	3.8	725	8.8
Total Electricity	2,740	3,179	2.1	3,456	1.4
Renewables' Share Without hydro%	1.5	4.2	-	10.7	
Renewables' Share %	12.3	13.7	-	21	

In the electricity sector the EU introduced its first legislative measure in the field of Renewable Energy in accordance with the White Paper to fulfil the targets. The Directive contains specific national targets for the share of RES-Electricity by 2010 in each Member State. These targets were set with the aim to raise the share of RES-Electricity from 14% in 1997 to 22.1% in 2010 – with the enlargement of the European Union the overall share had to be lowered due to the situation in the 10 New Member States and was set to 21%. If the measures set out in the Directive are fully transposed into national law and some additional measures are being put into place, the target can still be met. The annual growth rate for RES without hydro electricity will need to stay in the same order as during the last years to reach the target. In some Member States one can already see the positive effect of the Directive in terms of growth rates, and a second wave of Member States is following these examples. If other Member States follow now, then it is still realistic to reach the target.

The calculation is done without hydropower, mainly because the existing stock of hydropower is based on large hydropower and the fluctuations according to rainfalls are huge, but this should not interfere with the development of so called "new" Renewables.

The following graph shows the rapid growth of Renewable Electricity during the last couple of years compared to other newly installed technologies. As can be seen, Renewable Energy technologies grow even faster than coal, oil or nuclear. From 2001 onwards – after the adoption of the Directive - a real takeoff took place.

New Capacity Installed by Fuel in EU-15 (EU-25 from 2005)



Targets for Biofuels as set out in the Directive for the Promotion of Biofuels – Can they be met?

Table 4: Targets for Biofuels as set out in the Directive for the Promotion of Biofuels

	2000 Eurostat	2004 Eurostat	AGR 2000-2004	DIRECTIVE TARGET 2010	AGR NEEDED 2004-2010
	Mtoe	Mtoe	Mtoe	Mtoe	%
Transportation Biofuels	0.63	2.1	35.1	18.0	43.0
Gasoline and oil demand	277.3	290	1.1	313	1.3
Transportation Biofuels' Share %	0.2	0.72	-	5.75	

In the EU, the transport sector relies today on mineral oil for more than 90% of its energy, and a growing proportion of this will have to be imported in the future. The EU set out a second legislative measure in the field of biofuels, the Biofuels Directive. The Directive contains an overall target for the EU to reach a contribution of 5.75% by biofuels by the year 2010.

Contrary to the RES-Electricity Directive, the Biofuels Directive does not set out an individual target for each Member State, but the same 5.75% target for every Member State. In order to reach the target the annual growth rate needs to increase fairly significantly from about 35% in the last three years to 43% within the next years. Looking at the reality of market development and the uptake of biofuels in some major countries it seems to be possible to reach the target, even with an increase in total gasoline and oil demand.

Fundamentally, the Renewable Energy industry finds that setting targets is very important because they clearly show the way ahead. Experience shows that they need to be set "by sector" for the three different sectors involved:

- Electricity (RES-E)
- Heating/Cooling (RES-H) and
- Biofuels

These three different sectors all contribute to a sustainable, secure and competitive energy supply, but the industries, the needs, the barriers to growth and the necessary legislative frameworks behind are fundamentally different.

Targets for RES Heating/Cooling

For Renewable Heating and Cooling, the EU has not yet enacted specific legislative measures. However, the White Paper target of 12% Renewables by 2010 cannot be covered only by the existing Directives for Renewable Electricity and Biofuels. A large part must be covered by Renewable Heating and Cooling. Strong EU policies are necessary to achieve this target.

It is important to notice that an increased uptake of Renewables was seen in the two sectors that were targeted specifically with legislation and goals. This is the most successful and proven approach, since the three different sectors – electricity, heating and cooling and biofuels - have completely different needs. Still the market growth of RES-H is significant, but could be much higher.

EREC's Renewable Energy Targets for 2020

Contribution of Renewables to Electricity Production for the EU-25 by 2020

Given the present state of market progress and a strong political support, the current expectation is that the overall contribution of Renewable Energy to the energy consumption in 2020 will be 20% according to the Eurostat principle. The estimates by the Renewable Energy industry are based on a conservative annual growth scenario for the different technologies. In order to reach the target, strong Energy Efficiency measures have to be taken to stabilise the energy consumption between 2010 and 2020. The contribution of the different sectors varies significantly.

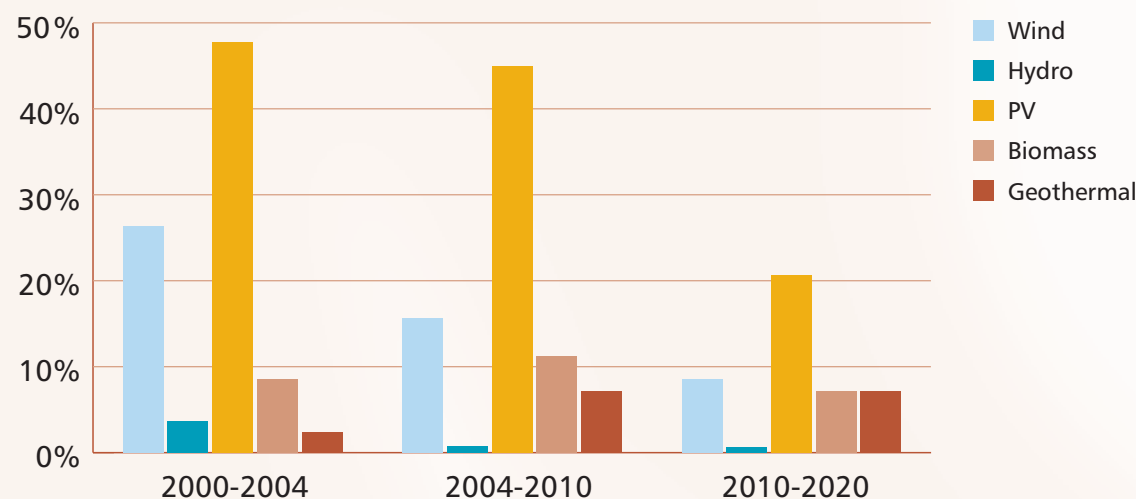
Table 5: Renewable Electricity Installed Capacity Projections

TYPE OF ENERGY	2000 Eurostat	2004 Eurostat	Annual growth rate 2000-2004	Projections 2010	Annual growth rate 2004-2010	Projections 2020	Annual growth rate 2010-2020
Wind	13.2 GW	33.6 GW	26.3	80 GW	15.6	180 GW	8.5
Hydro	93 GW	107.5 GW	3.7	113 GW	0.8	120 GW	0.6
PV	0.18 GW _p	0.86 GW _p	47.8	8 GW _p ³	45.0	52 GW _p ³	20.6
Biomass	9.5 GW _e	13.1 GW _e	8.6	25 GW _e	11.2	50 GW _e	7.2
Geothermal	0.6 GW	0.66 GW	2.4	1 GW ⁴	7.2	2 GW ⁴	7.2

Under the present state of market progress and the political support given to electricity generation from Renewable Energy Sources, the current target for RES-Electricity for 2010 can be met. The overall target can be reached through

a higher contribution by some of the more successful technologies. The figures of Table 3 outline the new targets for 2020 with the expected annual growth rates and the necessary growth rate to increase the share of RES-E significantly.

Growth rates and needed growth rates to reach the targets



³ These figures are based on a conservative and pessimistic projection. EPIA, European Photovoltaic Industry Association, firmly believes that these figures could be much higher if the development of the industry continued similar to the previous years. EPIA estimates that in 2010 already 11 GW_p could be installed and in 2020 134 GW_p.

⁴ These figures are based on a conservative and pessimistic projection. EGEC, European Geothermal Energy Association, firmly believes that these figures could be much higher (for instance 6 GW geothermal power by 2020, corresponding to 42 TWh, seems feasible) if the development of the industry continued similar to the previous years. It must also be noted that the Eurostat figure for 2004 does not take all geothermal technologies into account in all countries, which affects the entire calculation of the respective growth rates.

If the projected growth rates were achieved Renewable Energies would significantly increase their share in electricity production. The estimations below are based on the rather moderate growth rate projections.

Table 6: Contribution of Renewables to Electricity Production

	2004 Eurostat TWh	2010 Projections TWh	2020 Projections TWh
Wind	58.5	194	530
PV	0.74	7.5	55
Biomass for electricity	67.9	138	300
Hydro	303.8	356	384
Geothermal	5.5	7	14
Solar thermal elect.	-	2	9
Ocean	-	3	15
TOTAL RES	435.9	707.5	1,313
Total Electricity Generation EU-25 (Trends to 2030-Baseline) (Combined RES and EE)	3,178.6	3,483 3,314	4,006 3,250
Share of RES	13.7%	20.3-21.3%	32.6-40.2%

Depending on the development of the total electricity generation, Renewable Energies will be able to contribute between 32% and 40% to total production. Assuming that the EU will fulfil its ambitious Energy Efficiency measures, a share of over 40% of Renewables in Electricity production is realistic by 2020.

Contribution of Renewables to Heat Production for the EU-25 by 2020

The lack of a favourable political framework in Europe for the Renewable Heat sector is preventing higher market penetration so far. But with the creation of such a political framework the expectations can be raised and the contribution of RES Heating is especially significant in the biomass sector. But Geothermal and Solar Thermal energy will also be able to increase their shares significantly.

Table 7: Renewable Heat Generation Projections

TYPE OF ENERGY	2000 Eurostat	2004 Eurostat	AGR 2000-2004	Projection 2010	AGR 2004-2010	Projection 2020	AGR 2010-2020
Biomass for heat	44.7 Mtoe	48.4 Mtoe	2.0%	65 Mtoe	5.0%	105 Mtoe	4.9%
Solar thermal	0.38 Mtoe	0.68 Mtoe	15.6%	2 Mtoe	19.7%	12 Mtoe	19.6%
Geothermal	0.66 Mtoe	1.5 Mtoe	22.8%	4 Mtoe	17.7%	8 Mtoe	7.2%

Especially for the biomass heat sector our calculations and projections for 2010 are rather conservative and could be much higher if a Heating Directive or further national instruments would be introduced quickly.

If the projected growth rates were achieved Renewable Energies would significantly increase their share in heating production. The estimations below are based on the rather moderate growth rate projections and a share of 25% in 2020 seems to be possible.

Growth rates and needed growth rates to reach the targets

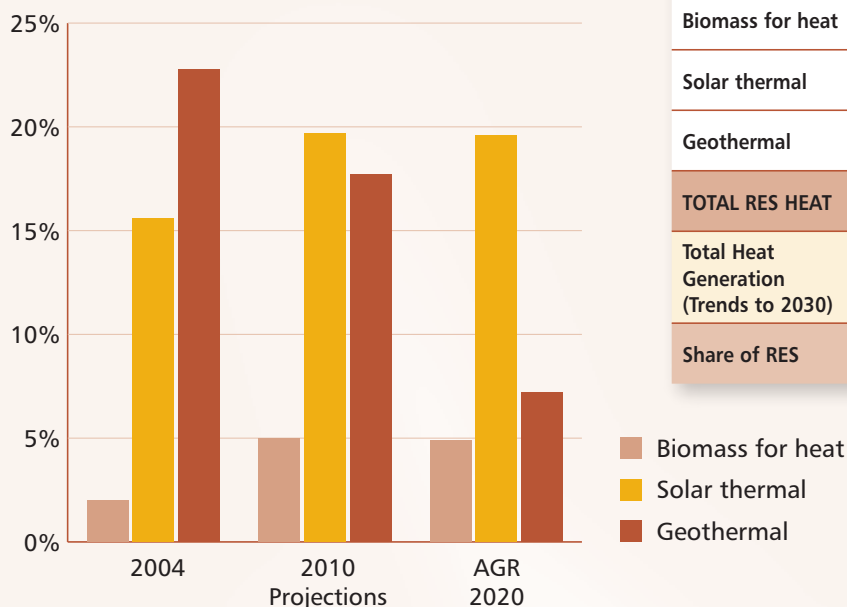


Table 8: Contribution of Renewables to Heat Production (1995-2020)

	2004 Eurostat Mtoe	2010 Projections Mtoe	2020 Projections Mtoe
Biomass for heat	48.4	65	105
Solar thermal	0.68	2	12
Geothermal	1.5	4	8
TOTAL RES HEAT	50.6	81	125
Total Heat Generation (Trends to 2030)	440	467	488
Share of RES	11.5	17.3	25.6

Contribution of Renewables to Transport Fuel Production for the EU-25 by 2020

In order to reach the 2010 target of 5.75 % biofuels an accelerated growth will be necessary during the next couple of years. Assuming the rapid growth of the last years is increased we could still meet the target. If this basis will be reached by 2010 a rather moderate growth rate of the sector would be enough for reaching a share of about 12% in 2020.

Table 9: Biofuels Production Projections

TYPE OF ENERGY	2000 Eurostat	2004 Eurostat	AGR 2000-2004	Projection 2010	AGR 2004-2010	Projection 2020	AGR 2010-2020
Transportation Biofuels	0.63 Mtoe	2.1 Mtoe	35.1%	18 Mtoe	43.1%	40 Mtoe	8.3%

Growth rates and needed growth rates to reach the targets

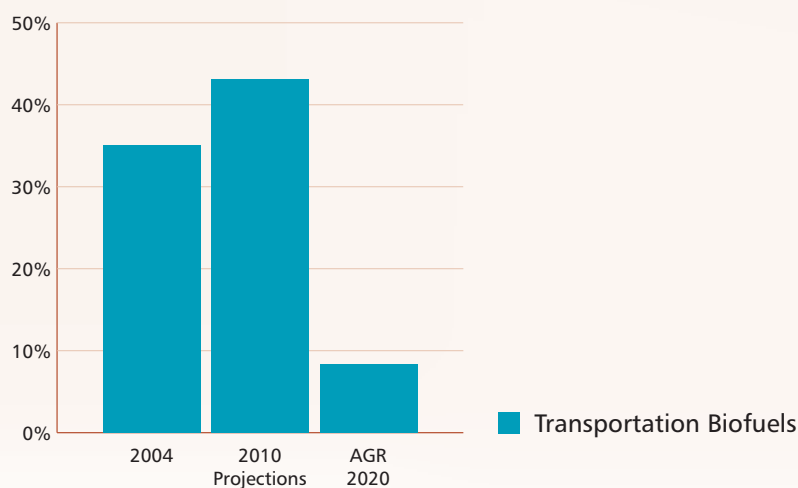


Table 10: Contribution of Renewables to Transport Fuel Production

	2000 Eurostat	2004 Eurostat	Projection 2010	Projection 2020
	Mtoe	Mtoe	Mtoe	Mtoe
Biofuels	0.63	2.1	18.0	40.0
Gasoline and oil demand (Trends to 2030-Baseline) (Combined RES and EE)	277.3	290	313	332
Biofuels' Share %	0.2	0.72	5.75	12.0-12.8

In the biofuels sector, as already outlined, with additional efforts in various Member States, which could be following the successful examples of Germany or Sweden, the 2010 targets can still be met. With this stimulation of the industry and a further coordinated development of biofuels throughout the EU and the possibilities of significantly reducing the oil dependence in the transport sector over the next 15 years, a share of more than 12% by 2020 seems to be realistic.

Contribution of RES to Total Primary Energy Supply Eurostat Convention (Mtoe)

Given the present state of market progress and a strong political support, the current expectation is that the overall contribution of Renewable Energy to the energy supply in 2020 can be in the range of 21%. The estimates by the Renewable Energy industry are based on a conservative annual growth scenario for the different technologies as presented in the previous chapter. In order to reach the target, strong Energy Efficiency measures have to be taken to stabilise the energy consumption between 2010 and 2020.

TYPE OF ENERGY	2004		Projections 2010		TARGETS 2020	
	Eurostat Convention	% of Total	Eurostat Convention	% of Total	Eurostat Convention	% of Total
Total Gross Inland Consumption	1,747		1,761 Combined RES and EE		1,633 Combined RES and EE	
Wind	5.03	0.29	15.4	0.87	43.9	1.69
Hydro	26.13	1.50	30.6	1.74	33	2.02
Photovoltaics	0.06		0.8	0.05	5.3	0.32
Biomass	71.9	4.11	125	7.10	235	14.4
Geothermal	5.36	0.31	8.2	0.46	16.4	1.00
Solar Thermal	0.68	0.04	2	0.11	12	0.73
Solar Power	0		0.2	0.01	0.8	0.05
Ocean			0.25	0.01	1.3	0.08
Total Renewable Energies	109.16	6.25	182.4	10.4	348	21.3

We assume that a share of Renewable Energy of 21% by 2020 is ambitious but at the same time realistic; but certain policy developments and a continuation of the existing policy instruments are an absolute necessity.

A crucial requirement for this target to become reality is that a European-wide approach towards the promotion of Renewable Energies in all sectors is established.

A development of all existing Renewable Energy Sources and a balanced mix of the deployment in the sectors of heating and cooling, electricity and biofuels guarantees the start into a real sustainable energy mix for Europe.

Substitution Principle

TYPE OF ENERGY	2004		Projections 2010		TARGETS 2020	
	Substitution Principle	% of Total	Substitution Principle	% of Total	Substitution Principle	% of Total
Total Gross Inland Consumption	1,793		1,830 combined RES and EE		1,760 combined RES and EE	
Wind	12.9	0.72	39.4	2.15	112.2	6.63
Hydro	66.9	3.73	78.3	4.28	84.5	4.80
Photovoltaics	0.15	0.01	2.0	0.11	13.6	0.60
Biomass	71.9	4.01	125	6.83	235	12.5
Geothermal	2.7	0.15	5.5	0.30	11.1	0.63
Solar Thermal	0.68	0.04	2	0.11	12	0.68
Solar Power			0.4	0.02	2.0	0.11
Ocean			0.6	0.03	3.3	0.19
Total Renewable Energies	155.23	8.66	253.2	13.8	460.1	26.1

When setting targets it must be clear under which calculation method they are determined. If the substitution principle was applied for calculating the energy statistics in the European Union (and globally), the picture would look very different in reality.

With the same real-production numbers for Renewables and the other sources, a share of more than 26% of Renewables to total energy consumption would be the result.

This is not just playing with numbers, but it would reflect the reality in a more transparent way than today. The sheer numbers very often undermine the role of Renewables. A major role is often not realised and the real contribution of Renewables to our energy mix is unseen.

This also shows that the initiated approach of supporting Renewables in Electricity and Biofuels sectors specifically does deliver results as planned.

The only possible logic and consequence would be to also introduce similar legislation in the so far "forgotten" sector of Renewable Heating and Cooling.

With such an approach Renewables could supply the European Union's energy needs by 2020 by more than a quarter and therefore significantly reduce the import dependency, create more than 2 million new jobs and reduce Green House Gas (GHG) emissions by at least 15% compared to 1990. In the following section the pathways for the development of the different technologies will be shown. All the sectors and technologies have different needs and expectations and are at different levels of maturity and development.

Geothermal technology roadmap for 2020

In some regions of Europe geothermal power plants already substantially contribute to an environmentally friendly and sustainable energy supply, using existing technologies exploiting steam and hot water reservoirs. This is done mainly in Italy, the Azores and other islands of volcanic origin in Europe including, last but not least, Iceland. In Iceland geothermal energy will be one of the two pillars upon which a fully Renewable Energy supply will be built. In South-East Europe, Turkey and the Caucasian region further huge, yet unexploited reservoirs, may contribute to a sustainable energy supply.

The technological developments of recent years have opened new ways to use the heat in the interior of our planet. The excellent results achieved by scientists working on the European Hot-Dry-Rock research projects raise the expectation that electric power will soon be produced from geothermal energy throughout Europe at economically and ecologically acceptable conditions, and not only in regions known for high ground temperatures.

Meanwhile innovative power plants permit the production of electricity using low thermal water temperatures of the order of 100 °C. A major advantage of geothermal energy is the availability of the resource all day and night, throughout the year. Using geothermal electricity, hydrogen may also be produced as a secondary energy carrier for automotive propulsion or use in fuel cells.

Heat supply from geothermal energy in Europe is primarily achieved by using hot water from deep aquifers for, for example, district heating, or in a large number of small to medium shallow geothermal plants. Shallow geothermal also supports the use of solar energy for heating, through underground storage of solar heat from summertime until its use in winter, and offers many other opportunities of long term thermal energy storage.

To achieve the targets, besides economic incentives, research and technical development is required on the geothermal sector. Technology evolution can be expected in both sectors, power and heat, and towards increasing the usable geothermal potential, improving plant efficiency, and decreasing installation and operational cost.

In the geothermal power sector, the main new developments can be expected concerning:

- Improved energy conversion efficiency for geothermal power plants, adapted to the reservoir temperatures on site, for conventional turbines as well as for ORC, Kalina, etc.
- Successful demonstration of EGS (Enhanced Geothermal Systems) on key sites like Soultz-sous-Forêts, France, and proliferation of the technology to other sites and regions
- Increased overall efficiency in geothermal CHP
- Improvement of exploration methods, installation technologies, and system components (pumps, pipes, turbines, etc.)

The future development of the geothermal heating and cooling sector is bound to achieve:

- Improved site assessment (incl. GIS-systems), exploration and installation, also for shallow systems, and dissemination of successful approaches from some countries to the whole EU
- Further increase of efficiency of ground source heat pumps, optimised system concepts, application of advanced control systems, improved components and materials (compressors, refrigerants, pipes, etc.)
- Construction of new district heating networks, and optimisation of existing networks and plants, in particular in East/South Eastern Europe and Turkey
- Increased application and innovative concepts for geothermal energy in agriculture, aquaculture, industrial drying processes, etc.
- Demonstration of new applications like de-icing and snow melting on roads, airport runways, etc., sea-water desalination, and geothermal absorption cooling

Also non-technical development is paramount, comprising administrative and legal clarity, suitable infrastructure in form of machines and skilled labour, information to the public, etc.



Biomass technology roadmap for 2020

Introduction

Biomass is a non-intermittent Renewable Energy Source that can provide energy to be used for heating and cooling, electricity and transport. Biomass fuels can easily be stored meeting both peak and baseline energy demands. In the form of biofuels (solid, liquid or gaseous), biomass can directly replace fossil fuels (solid, liquid and gaseous), either fully or in blends of various percentages. In the latter case, there is often no need for equipment modifications. Bioenergy is CO₂ neutral, if biomass is produced in a sustainable manner.

Bioenergy contributes to all-important elements of national/regional development: economic growth through business earnings and employment; import substitution with direct and indirect effects on GDP and trade balance; security of energy supply and diversification. Other benefits include support of traditional industries, rural diversification and the economic development of rural societies. Bioenergy can also contribute to local and national energy security that may be required to establish new industries.

Additionally, biomass fuels can be traded at local, national and international markets, and it is expected that the international trade in this sector will play a major role for the development of a bio-based economy.

Technological development up to 2020

Significant progress has been achieved on biomass procurement and conversion technologies over the last decade resulting in the increase of competitive, reliable and efficient technologies. They are represented by dedicated large and small scale combustion, co-firing with coal, incineration of municipal solid waste, biogas generation via anaerobic digestion, district and individual household heating, and in certain geographical areas, liquid biofuels such as ethanol and biodiesel. Nevertheless, new fuel chains addressing more complex resources, new conversion routes such as gasification and pyrolysis, and new applications, are under development.

Biomass heating

Biomass is the Renewable Heat source for small, medium and large scale solutions. Pellets, chips and various by-products from agriculture and forestry deliver the feedstock for bioheat. The installation of millions of new pellet burners, the construction of new plants to produce pellets and adapted burners/boilers/stoves, and new logistic chains to serve the consumers should result in a significant growth of the pellet markets.

Stoves and residential boilers operated with chips, wood pellets and wood logs have been optimised in recent years with respect to efficiency and emissions, however, more can be achieved in this area. In particular, further improvements regarding fuel handling, automatic control and maintenance requirements are necessary. Rural areas present a significant market development potential for the application of those systems.

There is a growing interest in the district heating plants which currently are run mainly by energy companies and sometimes by farmers' cooperatives for small scale systems. The systems applied so far generally use forestry and wood processing residues but the application of the agro-residues will be an important issue in the coming years.

Combined Heat and Power (CHP)

Significant improvement in efficiencies can be achieved by installing systems that generate both useful power and heat (Cogeneration plants have a typical overall annual efficiency of 80–90%). CHP is generally the most profitable choice for power production with biomass if heat, as hot water or as process steam, is needed, and if biomass resources are limited.

The increased efficiencies reduce both fuel input and overall greenhouse gas emissions compared to separate systems for power and heat, and also realize improved economics for power generation where expensive natural gas and other fuels are displaced.

The technology for small scale CHP is not yet fully commercially available. A breakthrough in small scale CHP - (based on the Stirling engine, the gasification process, the hot air turbine, a micro steam engine or the Organic Ranking Cycle (ORC)) will be achieved in the coming years if research in this area is intensified.

Electricity production

The use of biomass for power generation has increased over recent years mainly due to the implementation of favourable European and national political framework. In the EU-25 electricity generation from biomass (solid biomass, biogas and biodegradable fraction of municipal solid waste) grew by 19% in 2004 and 23% in 2005. However, most biomass power plants operating today are characterized by low boiler and thermal-plant efficiencies and such plants are still costly to build. The main challenge therefore is to develop more efficient lower-cost systems. Advanced biomass-based systems for power generation require fuel upgrading, combus-

tion and cycle improvement, and better flue-gas treatment. Future technologies have to provide superior environmental protection at lower cost by combining sophisticated biomass preparation, combustion, and conversion processes with post-combustion cleanup. Such systems include fluidized bed combustion, biomass-integrated gasification, and biomass externally fired gas turbines.

Biofuels for transport

There are several potential fuels that could technically be generated from bio-resources, such as methanol, ethanol, butanol, triglycerides, and fatty acid esters. In the longer term, it may even be that one or more of these could serve as the energy source for hydrogen generation, making bio-hydrogen. The possible methods of production range from various biological fermentations to thermochemical gasification with liquid fuel creation via the Fisher-Tropsch reaction using syngas. Currently, only ethanol (and its derivative ETBE) produced from food crops (such as cereals and sugar beets) and biodiesel from rapeseed (mainly Rapeseed Methyl Ester, RME) are applied on a commercial basis on the European market. They will remain the dominant forms of liquid biofuels production in the coming decade, as alternative biofuel technologies are still in the development stage.

Nevertheless, in the coming years new developments are expected such as bioethanol production from lignocellulose (which would activate a broad range of new feedstocks such as products and by-products from agriculture, forestry, wood industry, and pulp/paper processes) or the biodiesel produced by hydrocracking of vegetable oil and animal greases.

Feedstock

Biomass resources cover various forms, such as products, by-products and waste streams from forestry and agriculture, downstream agro-forestry industries, as well as municipal and industrial waste streams as well as municipal and industrial biodegradable waste streams. It can be grown in dedicated woody or herbaceous energy crops, and can be transformed into various forms of energy. Improved agricultural and forestry practices can result in higher yields per unit of input. New methods in erosion control, fertilization, and pre-processing can result in improved life cycle performance, sustainable practices, and enhanced feedstock production.



Solar thermal roadmap for 2020

Introduction

Solar thermal systems are based on a simple principle known for centuries: the sun heats up water contained in a dark vessel. Solar thermal technologies on the market are now efficient and highly reliable, providing solar energy solutions for a wide range of areas of use and potential users. Most of the systems sold today are intended to supply domestic hot water, and an increasing number of Combi Systems additionally provide thermal energy for space heating, thus lowering the conventional energy demand for space heating.

The solar thermal industry

What started in the 1970s as garage businesses is now an established international industry. Some of the pioneers are still amongst the market leaders. A number of major players from “neighbouring” sectors entered the market. At the same time, several solar thermal companies are diversifying into other Renewable Energies such as biomass heating or solar PV.

The large majority of the systems sold in Europe are manufactured within the EU or its Mediterranean neighbours. Imports from Asia are limited mainly to components such as evacuated glass tubes. For European manufacturers, exports outside the EU are becoming a growing market. The main selling point is their high quality and reliability.

The industry is in a phase of dynamic growth. Production lines are constantly being expanded. Employment in the European solar thermal sector already exceeds 20,000 full time jobs. With the expected growth of solar thermal, more than half a million people will be employed in the solar thermal sector in just a few decades.

As in all industrial sectors, manufacturing will be more exposed to global competition as the market develops. However, for solar thermal, nearly half of the jobs are in retail, installation and maintenance. These works are necessarily local, and create jobs mainly in small and medium sized enterprises, directly in the areas where the solar thermal market develops.

Technological innovations expected in the sector until 2020

Energy demand of buildings makes up approximately 40% of the total energy demand in Europe – most of which is due to low-temperature heat demand for domestic hot water and for space heating. Today, solar domestic hot water systems are mature technologies and Combi Systems, which additionally cover parts of the space heating demand, have become commonplace in several Central and Northern European countries.

Other applications, which are expected to play an important role in tomorrow’s energy supply have been successfully demonstrated and are slowly finding their way into the markets, for example, solar assisted cooling, solar industrial process heat, and solar desalination.

Increased funding for R&D - both from the private and the public budget - will enable solar thermal to cover an ever larger share of the low- to medium temperature heat demand. Refined integration with other heating and building technologies, as well as falling costs will guarantee a broad adoption of solar thermal solutions for heating and cooling.

Solar assisted cooling

The global market for cooling and air-conditioning technologies is growing rapidly. Most of the demand is met by conventional, electricity-driven machines and their electricity demand is putting an ever increasing burden on the power grids. Blackouts in summer are becoming a usual occurrence. Thermally driven cooling machines have existed for decades. They typically used waste heat from industrial processes or cogeneration plants and came in sizes above 100kW cooling capacity. In recent years, machines with smaller capacities (20-50 kW) have entered the market, which can be driven by solar thermal energy. And the next generation of 2-5kW machines is already in field tests. Because of the typically high co-occurrence of cooling demand and the availability of solar irradiation, solar cooling offers a convenient way to reduce unnecessary electricity demand in summer. Research focuses on new materials, lowering costs and the development of practical guidelines and planning tools for solar cooling installations. It is expected that Solar Combi+ systems, which provide domestic hot water, space heating

in winter and cooling in summer, will gain a major share of the solar thermal market by 2020-2030.

Solar industrial process heat

A lot of industrial and commercial heat demand is in the temperature range up to 250°C, which could be supplied by solar thermal. For this, new types of collector – specially designed for medium-temperatures – are being developed. So far, solar thermal has been used mainly for less critical processes, such as washing processes. With growing experience, solar thermal will spread to all kinds of industrial heat demands.

Solar desalination

The availability of drinking water is a growing concern for many countries all over the world. The energy demand for desalination of seawater is on the rise, and especially in areas without connection to central electricity grids, solar thermal desalination can be advantageous already today. With more R&D efforts into this promising approach, new and more cost effective solar desalinations will be made available.

Advanced heat storages

Most of the solar thermal systems used today use water to store heat for a few hours or days. Larger storage capacities are typically realised through increased tank sizes. Large underground water storages – natural aquifers or man-made concrete tanks – are already used for seasonal storage. But only advanced heat storage, which allows the efficient storage of larger amounts of thermal energy in smaller volumes will allow, e.g. existing buildings to be heated 100% by solar thermal energy. Phase change materials or thermo-chemical processes are being explored for these purposes. An increase of the energy density of heat storages by the factor of 8 would make it possible to convert the whole building sector into 100% solar heated buildings. While breakthrough cannot be expected in the short run, increased R&D efforts in this field could already provide these new storage technologies by 2030.



PV technology roadmap for 2020

PV solar electricity has a very high potential, since solar energy is a practically unlimited resource available everywhere. Therefore, it is ideally suited for distributed generation of electricity near the user, everywhere around the globe.

The PV Industry

During recent years the European PV industry has developed very successfully. All branches of PV (manufacturing, distribution, and system installation) are represented by strong companies, and their global market share is rising steadily. Technology development and research are on a high level, and the industry is in an excellent position regarding the challenges of the future. This Roadmap is designed to be an effective tool for maintaining, exploiting and strengthening European leadership in the PV sector.

Yearly growth rates for the PV industry were in average more than 40% between 2000 and 2005, which makes photovoltaics one of the fastest growing industries. In 2005, a world-wide production volume of 1.7 GWp of PV modules was reached, and with a turnover of more than € 8 billion, the PV industry employs over 70,000 people. The worldwide PV market will continue to grow at a high level, with a consolidation towards 19% in 2020, resulting in a full-time employment potential of 1.9 million.

Global installed capacity of solar power systems could reach 259 GWp by 2020, delivering an estimated power of 325 TWh, corresponding to approximately 1.8% of total electricity consumption in 2020. The corresponding annual module sales would be around € 200 billion, which is equivalent to today's semiconductor device industry sales. By 2040, the penetration of solar generation would be even greater, with a solar contribution of 16% to the world's electricity output. This would define PV solar power as an established world energy source.

Technological innovations

The production of PV cells is constantly improving as a result of both technology advances and changing industrial processes. Production costs need to be reduced considerably to penetrate the major electricity markets. Consequently, the main effort of research and industrial technology

development is directed towards reducing the production cost. About 70% of the PV system price is represented by the module, 15% by the balance of system components, and 15% by installation costs. The European Photovoltaic Industry Association (EPIA) expects that prices of systems will come down from about 6 €/Wp to 3 €/Wp – 4 €/Wp by 2010 and be cost competitive with peak power price. By 2020, EPIA expects grid connected PV systems to be price competitive with conventional electricity prices. The electricity generating cost has already declined from 55 (110) €/ct/kWh in 1990 to 20 (40) €/ct/kWh today, and will further decrease via 10 (20) €/ct/kWh in 2020 towards 5 (10) €/ct/kWh in 2030. The numbers in brackets are for more northern hemisphere areas (almost 900 full sun-hours per year), while the first number refers to sunnier places (with about 1,800 full sun-hours per year). The above mentioned electricity generating cost range is clearly within the generation cost of conventional large scale fossil and nuclear power plants.

Crystalline silicon solar cells in their different forms – mono-crystalline (Cz-Si), multi-crystalline (mc-Si), ribbon – have a market share of more than 90% and they will probably remain the dominant technology for the next 10-15 years. The remaining 10% of the market is thin film technology, mainly amorphous silicon (a-Si); the importance of other processes such as CIS, and CIGS is increasing. The cost of raw material and consequently the cost of the wafer is a substantial part of the total cost of solar cells. As such, cost reduction of wafer production is a real challenge for the industry. EPIA has adopted the following technological aims in this field for 2010:

- Material (Si) consumption for mono-crystalline silicon from 10 gram per Watt peak [g/Wp] to 7.5 g/Wp
- Ribbons from 8 g/Wp to 4 g/Wp
- Wafer thickness from 300 μm to 100 μm
- Kerf loss in the sawing process from 250 μm to 150 μm

Since the first solar cell was developed 50 years ago major improvements in efficiency have been achieved. With much potential still to be exploited, EPIA has defined the following aims for the European PV industry up to 2020:

- Efficiency increase for mono-crystalline silicon from 16.5% to 22%
- Efficiency increase for multi-crystalline silicon from 14.5% to 20%
- Ribbon efficiency from 14% to 19%

Thin film, constructed by depositing extremely thin layers of photosensitive materials on a low-cost backing, offer the potential for significant cost reductions. Firstly, material and energy costs should be lower because much less semiconductor material is required and much lower temperatures are needed during manufacturing. Secondly, labour costs are reduced and mass production prospects improved because, unlike thick crystalline technologies where individual cells have to be mounted and wired together, thin films are produced as large and integrated series-connected modules.

EPIA has defined two targets for thin film technology up to 2020:

- Thin film aiming at efficiencies between 10% and 15% (a-Si/mc-Si, CIS and CdTe)
- Building integrated PV (BIPV) with low cost per m², price reduction of 75%

Future material developments include further optimization of the previously identified cell concepts but also the development of new concepts such as polymer solar cells and other types of organic solar cells. Thin film solar cells on the basis of gallium arsenide (GaAs) and other III-V-compounds show the highest conversion efficiencies measured so far. Although they have a higher cost than Si-based cells, they are ideally suited for concentrating systems where the area price of solar cells is of minor importance. Solar cell efficiencies of nearly

40% under concentrated light have been demonstrated in the laboratory, and concentrating systems have shown efficiencies of 25% and more. Concentrating systems using highest efficiency solar cells will become an interesting opportunity for medium and large installations in the MW-range in southern countries.

Improvement in the lifetime of solar modules is another step to further reducing solar electricity prices. EPIA aims to expand their lifetime from 25 years to 35 years, for example by longer lifetime encapsulation material or new module architectures.

For the BOS (balance of system) substantial cost reductions will result from larger production quantities. The operation time of these devices should be extended to the lifetime of modules. Standardization of components and systems is important for mass production.



Small Hydropower roadmap for 2020

Introduction

Small Hydropower (SHP, up to 10MW of installed capacity) can be one of the most economic methods to generate electricity. Small hydro plants have a long life span and relatively low operating and maintenance costs. Once the high up-front costs are written off, the plant can provide power at low costs as such systems commonly last for 50 years or more. Small Hydropower can provide baseload capacity and its potential in Europe is not yet fully exploited.

Hydro (large and small) is still the largest Renewable Energy Source in the electricity sector. It contributed to 10 % of total electricity consumption in 2005, and produced 67% of total Renewable Electricity production in 2005.

Small Hydropower is not growing as expected mainly due to administrative and environmental barriers. Nevertheless the sector has a real potential, especially in the New European Member States.

The hydro industry

The European Small Hydropower sector has a turnover of about € 120-180 million. The sector employs currently around 20,000 people in Europe and can reach in 2020 about 28,000 jobs.

The European Hydro turbine manufacturers (large and small) have a turnover of about € 3.5 billion. For 2020 it is expected to increase the turnover to € 5.5 billion.

Technological innovations expected in the sector until 2020

Nowadays engineers working in the Small Hydropower field keep on developing techniques specific to Small Hydropower, in order to face up to the following challenges:

- Foster environmental integration
- Decrease cost
- Maximize electricity production

Small hydropower ought to be systematised as far as possible, so as to achieve an optimal design from a technical, environmental and economic point of view. This systematisation process has the advantage of guaranteeing the performance of the equipment, regarding the exact characteristics of the site to be equipped, thanks to the fact that it is based on laboratory developments. Therefore the turbine R&D on SHP has focused on very-low-head and low-head turbines, as these sites make up the important remaining potential in Europe.

The results of turbine R&D by 2020 will:

- Allow manufacturers to propose simple, reliable and efficient turbines with guaranteed performances
- Exploit the important remaining potential composed mainly of low-head and very-low-head sites
- Cover the high cost of laboratory development, especially for SMEs
- A better integration of SHP plants into the environment, by using water resources rationally, and by building submersible turbo-generators
- Increase the cost-effectiveness of the power plant, by simplifying turbine design, while optimising the annual electricity production and by using new materials



Such R&D is allowing SMEs to develop within the SHP market, and to increase their turbines' delivery per year. Such development also results in employment creation locally.

At present, most R&D efforts concerning **civil engineering** aim at standardizing design and technology, so as to reach an optimal integration of the SHP plant within the local environment while minimizing costs. Such objectives are reached by setting guidelines based on the latest design technology, new materials and best practice examples.

The development in civil engineering is continuously expanding and it is essential to integrate this development into the basic design technology through the whole chain of the power plant design and construction. Indeed the global objective is to reach an optimal solution and a good environmental integration for every specific hydropower plant, both for new projects and restoration of old plants.

R&D results on **electrical engineering** are providing the SHP sector with available solutions ranging from generators, to grid connection, electric drives, and the control and management of the whole power plant.

New generator designs such as high pole synchronous generators with permanent magnet excitation have been introduced to the SHP market. Designed for direct grid connection or in combination with a frequency converter for variable speed operation, such generators allow avoiding speed increasers and making very compact submersible turbine designs possible.

Current digital control systems offer site-specific optimization methods in order to adapt the overall control to any hydrological or other condition. New concepts such as scheduled production, prediction of the energy output and condition monitoring are currently under development also for SHP in order to improve the grid integration,

increase reliability and reduce the operation and maintenance cost.

The significant increase in research concerning the biological mechanism in rivers has consequently initiated the development of **environmental engineering**, focusing on minimizing the local negative environmental impact on the river ecosystem and on the mitigation of it. Well-known examples are fish bypass systems, environmental flow or river restructuring. The close cooperation with ecologists has led to excellent compromises between environmental targets and economic and technical restrictions.

Such engineering is in continuous evolution especially for the design of fish bypass systems and fish friendly turbines in order to minimise fish damage; future R&D will deliver appropriate fish screening systems for downstream and upstream migration and new technically optimised fish bypass systems that guarantee the highest fish acceptance while reducing the amount of bypass operation flow.



Wind technology roadmap for 2020

Introduction

Wind energy is the fastest growing power source, with cumulative wind power capacity in the EU increasing by an average 32% per year over the ten year period from 1995 to 2005. In the last 5 years 30% of all newly installed electricity generating capacity in the EU is wind power (Platts/EWEA). Over the last ten years, only gas has exceeded wind power in the EU in new installed capacity. While wind energy today meets some 3% of EU's electricity demand, the technology is already the second largest contributor to economic activity and employment in power generation.

Europe continues to dominate the wind power sector. The global market for wind energy increased by 40% in 2005 and European manufacturers hold an 80% share of the global market. 66% of the more than 70 GW installed wind power capacity in the world is in Europe. By the end of 2006 wind energy's share of national electricity consumption had become significant in countries such as Denmark (20%), Spain (8%) and Germany (7%). The European Wind Energy Association (EWEA) estimates that installed wind power capacity in the EU will reach 80 GW in 2010 and 180 GW by 2020 covering more than 12% of Europe's electricity demand. Within a few years, large wind turbine manufacturing companies and project developers/operators will construct wind power plants with the size of conventional power plants, up to 1,000 MW. The largest individual wind turbine prototypes have already reached installed generator capacities of 5 to 6 MW and diameters of 110-125 m. In the beginning of the 1980s, wind turbines typically had a capacity of 0.022 MW. Further penetration of wind in Europe's power supply depends on continued cost reductions and efficient measures to integrate wind energy production in the electricity supply system.

Industry development and employment effects

Annual EU investments in 2005 in wind power were approximately € 7 billion. In the period 2006-2010, the turnover is estimated to be approximately € 40 billion – corresponding to an added wind power capacity of approximately 40 GW, of which 3.3 GW offshore. The estimated total turnover in the period 2011 to 2020 amounts to € 145 billion, corresponding to an added capacity of 115 GW of which 55 GW offshore in the same period. The total manufacturing turnover in the period 2006 to 2020 is estimated to be € 185 billion.

Employment

The wind power sector currently employs around 64,000 people in Germany (BWE 2006), around 21,000 in Denmark (DWIA, 2006) and 35,000 in Spain (AEE). There is a large variety across European countries in the estimated total employment per MW installed, however, the average in Europe is around 12 individuals per MW installed. Employment projections in the wind power sector for the EU-25 for the year 2020 indicate 153,400 direct and indirect employees for manufacturing, 27,400 for installation and 16,100 for maintenance. This gives the total estimated employment for 2020 in Europe as around 200,000 (EWEA, Wind Energy The Facts, 2004). These figures do not include EU employment of technology supplied to non-EU markets. The actual numbers will depend on production volume, European production share, export outside EU, regional market growth, productivity and cost reductions.

Technological innovations in the wind energy sector

Despite the advanced state of modern onshore wind technology there are still many critical research tasks to be done, not least in offshore wind energy. In its Strategic Research Agenda (see www.ewea.org), the European wind energy sector has outlined the R&D priorities required to arrive at a maximisation of the value of wind energy for society. These priorities reflect a vision for the future direction of the different aspects of wind energy technology the next 10 years and beyond. The most important R&D objectives are continuous reduction of generation costs whilst enhancing the reliability and the scope for implementation, both onshore and offshore. The strategic research agenda will be implemented through the recently established Wind Energy Technology Platform (see www.wind-platform.eu). The main envisaged technology development achievements in 2020 are as follows:

Resource: Wind resource data for all regions of Europe will be available to ensure the efficient implementation of high quality projects for investors. Cost effective measuring methods will be available for the determination of wind resource characteristics – including advanced models and remote sensing techniques such as LIDAR and satellite observations.

Wind turbines: Providing cost efficient and reliable wind turbines are the key factors for success. The present advanced wind turbine concept (horizontal axis, 3-blade, variable pitch, variable speed, full size electronic converter for maximum control) is most likely to be pursued. Gearbox-based drive trains as

well as direct drive systems will co-exist in the years to come. The up-scaling of wind turbines - beyond the present dimensions - as seen during the last decade will continue.

Materials with higher strength to mass ratios and compliant components will increasingly be used in the design of components bearing heavy dynamic loadings such as rotor blades, yaw systems, drive train components and towers. New design tools will be used to efficiently design and manufacture very large wind turbines based on significant enhancements in know-how in the field of aerodynamics, aero-elasticity, control, drive train dynamics etc. Dedicated O&M methods and transport and installation systems will be used in extreme locations such as offshore, extreme cold climates and mountainous terrain. Integrated condition monitoring systems for early diagnosis and assessment of damage will be widely used to increase wind turbine availability and reduce the need for design conservatism.

In the market segment of small wind turbines (size from around 1 kW to a few 100 kW), a substantial improvement of the technical quality will be made, leading to expansion of the market, especially in remote areas, small isolated communities and sites connected to weak grids.

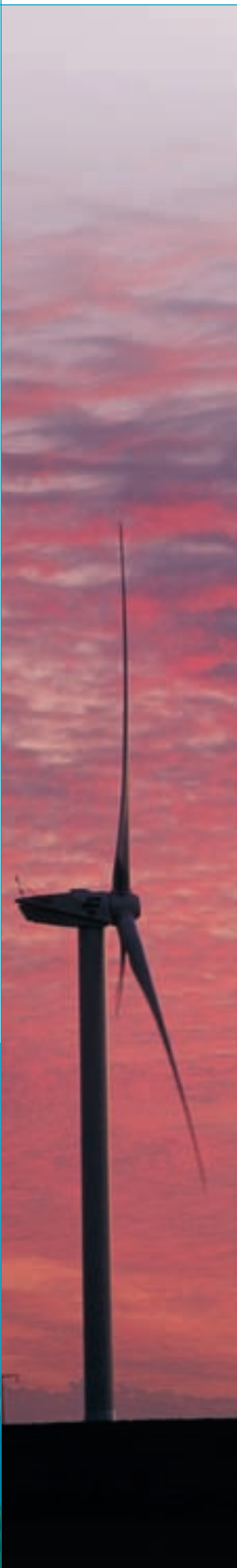
Wind power plants: Wind farms will increasingly be operated as conventional power plants. Their output power will be controlled by a combined use of advanced control using weather forecast, power electronics, and advanced storage systems at wind farm level. Wind farm concepts will include advanced management systems and environmental protection systems such as preventive systems for annoyance (sound and shadow) and bird collisions.

Grid integration: Advanced grid integration characteristics such as active power and voltage control, fault ride through capability and advanced power forecasting will be gradually implemented. Planning and operation of the remaining power system, including system balancing and maintaining system adequacy, will be based on a profound understanding of the interaction of wind power plants and the grid. The necessary planning and design process

for development of a trans-European grid will be undertaken in connection with the wider energy sector. Advanced dedicated grid systems will be developed for the exploitation of the European off-shore wind resource.

Standards and certification: The process of technology development will be accompanied by a continuous development of standards and certification procedures. Besides the presently available standards on wind turbine safety and testing, new standards will be developed on energy yield calculation, grid connection procedures, risk assessment methods, requirements for component certification and standardisation of O&M methodologies.

Research infrastructure: Shared research facilities will be available for testing very large wind turbines in onshore and offshore conditions, and for testing small turbines and hybrid systems. Test rigs will be available for full scale testing rotational dynamics of drive train from rotor to grid connection, for fatigue testing of very large wind turbine blades and composite components. Dedicated labs will be used for material developing and testing of new wind turbine materials with higher strength to mass ratio.





Created in the year 2000, the European Renewable Energy Council - EREC - is the umbrella organisation of the leading European Renewable Energy industry, trade and research associations active in the sectors of photovoltaic, wind, small hydropower, biomass, solar thermal and geothermal energy, thus representing the entire sector.

EREC is composed of the following non-profit associations and federations:

- **AEBIOM** (European Biomass Association)
- **EGEC** (European Geothermal Energy Council)
- **EPIA** (European Photovoltaic Industry Association)
- **ESHA** (European Small Hydropower Association)
- **ESTIF** (European Solar Thermal Industry Federation)
- **EUBIA** (European Biomass Industry Association)
- **EUREC AGENCY** (European Renewable Energy Research Centres Agency)
- **EWEA** (European Wind Energy Association)

For more information on EREC and its members: www.erec.org

The Renewable Energy House is

EREC shares its office with all its member associations in the Renewable Energy House. The Renewable Energy is:

- Headquarters for the European Renewable Energy sector
- A central meeting point for Renewable Energy issues in Europe's capital Brussels, close to the European institutions (European Commission, European Parliament, Council)
- Providing meeting facilities for Renewable Energy actors
- A Renewable Energy and Energy Efficiency showcase in a monument-protected building
- An information display of all Renewable Energy technologies

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