EREC

European Renewable Energy Council

Renewable Energy Technology Roadmap

20% by 2020

RENEWABLE ENERGY TECHNOLOGY ROADMAP

Introduction

In March 2007, the Heads of States and Governments of the 27 EU Member States adopted a binding target of 20 % renewable energy from final energy consumption by 2020. Combined with the commitment to increase energy efficiency by 20 % until 2020, Europe's political leaders paved the way for a more sustainable energy future for the European Union and for future generations.

In January 2008, the European Commission presented a draft Directive on the promotion of the use of energy from Renewable Energy Sources (RES) which contains a series of elements to create the necessary legislative framework for making 20 % renewable energy become a reality. The Directive sets the legislative framework that should ensure the increase of the 8.5 % renewable energy share of final energy consumption in 2005 to 20 % in 2020.

In order to reach the binding overall 20 % target outlined in the RES Directive, the development of all existing renewable energy sources and a balanced mix of the deployment in the sectors of heating and cooling, electricity and biofuels are needed:

Electricity from renewable energy sources

The European Union aims to have 21% of its electricity coming from renewable energy sources by 2010. This target has been formulated in the Directive 2001/77/EC on the promotion of renewable electricity. While some Member States such as Germany, Spain and Denmark are well on track in reaching their targets, others are far behind. The Renewable Energy Framework Directive needs to maintain and strengthen the existing legislative frameworks for renewable electricity. It needs to establish minimum requirements for the removal of administrative barriers, including streamlined procedures such as one-step authorization. Issues such as priority grid access and a more balanced sharing of the costs related to grid connection need to be addressed.

Heating & cooling from renewable energy sources

As far as the heating and cooling sector is concerned, the Directive finally closes the legislative gap which existed so far for this sector. Until recently, Renewable Heating and Cooling (RES-H) has received little political attention and in most EU Member States there is not yet a comprehensive approach to support RES-H. This is particularly striking in view of the fact that nearly half of the EU's final energy consumption is used for the generation of heat, making the RES-heating sector a sleeping giant.

Biofuels for transport

The EU's biofuels policy kicked off in 2003 with the first Biofuel Directive, which set indicative targets to promote the use of renewable fuels in the transport sector. For 2010 the target was set at 5.75% by energy content. As the experience with the existing Biofuels Directive shows, fuel distributors only use biofuels if there is a financial incentive or because they are forced to use them. Therefore the Renewable Energy Directive introduces a binding target of 10% renewable energy in transport by 2020. However, only sustainably produced biofuels are allowed to count towards the target and the Directive proposes a comprehensive sustainability scheme.

The RES Directive should be adopted in early 2009 before the elections of the European Parliament in June 2009. If timely adopted and adequately transposed in national law, the Directive would become the most ambitious piece of legislation for renewable energy in the world!

The RES Directive

1. Sets mandatory national targets for renewable energy shares of final energy consumption in 2020, including a 10% renewables in transport target

The Renewables Directive sets mandatory national targets for renewable energy shares of final energy consumption in 2020 which are calculated on the basis of the 2005 share of each country plus both a flat-rate increase of 5.5 % per Member State as well as a GDP-weighted additional increase to come up with the numbers as outlined in the table below:

Table 1: Mandatory national targets set out in the Directive (2005 and 2020)

	Share of energy from renewable sources in final consumption of energy, 2005	Target for share of energy from renewable sources in final consumption of energy, 2020
Belgium	2.2%	13%
Bulgaria	9.4%	16%
The Czech Republic	6.1%	13%
Denmark	17.0%	30%
Germany	5.8%	18%
Estonia	18.0%	25%
Ireland	3.1%	16%
Greece	6.9%	18%
Spain	8.7%	20%
France	10.3%	23%
Italy	5.2%	17%
Cyprus	2.9%	13%
Latvia	34.9%	42%
Lithuania	15.0%	23%
Luxembourg	0.9%	11%
Hungary	4.3%	13%
Malta	0.0%	10%
The Netherlands	2.4%	14%
Austria	23.3%	34%
Poland	7.2%	15%
Portugal	20.5%	31%
Romania	17.8%	24%
Slovenia	16.0%	25%
The Slovak Republic	6.7%	14%
Finland	28.5%	38%
Sweden	39.8%	49%
United Kingdom	1.3%	15%

2. Sets interim targets

The Directive sets interim targets per country for 2011/12, 2013/14, 2015/16 and 2017/18 as a % share of their 2020 target. These interim targets are crucial for monitoring the progress of renewable energy development in a Member State. The Commission proposal contained an indicative trajectory. However, EREC is concerned that these interim targets need to be of mandatory nature in order to avoid delay in renewables deployment.

EREC believes that the Commission should as a consequence impose direct penalties on Member States which fail to comply with the binding interim targets. These penalties should be set at an appropriate level to provide strong incentives for Member States to invest in renewable energy.

3. Requires national action plans from Member States stating how they intend to reach their targets

Member States shall adopt national action plans which set out their targets for the shares of energy from renewable sources in transport, electricity and heating and cooling in 2020 and adequate measures to achieve these targets. Member States shall notify their national action plans to the Commission for examination.

These plans should provide for two things: they give Member States the flexibility to decide for themselves how they want to meet their national targets, but at the same time they create investor security and help to mobilize private capital by setting clear goals and mechanisms on the national level. National action plans should include detailed mandatory outlines and targets for the different renewable energy sectors (heating/cooling, electricity and transport fuels), which show the way ahead on the national level. In addition, support measures to meet the national targets must be outlined.

4. Requires reduction of administrative and regulatory barriers to the growth of renewable energy, improvements in information and training and in renewables' access to the grid

Administrative barriers are still a major problem for renewable energy development and need to be removed. There are a number of non-cost related options to be integrated for any Member State in its regulatory framework in order to really push renewable energies. This is reflected in planning regulation and administrative procedures. The Directive provides important provisions to further remove administrative and regulatory barriers which must be put in practice to pave the way for a quick and large-scale RES deployment.

Infrastructure development and priority access for renewables to the grid are key for a large-scale penetration of renewables. This should not only apply to electricity networks but should also apply to district heating networks sourced by renewables and gas pipelines for the increased use of biogas.

On information and training, the Directive requests Member States to introduce a certification of installers by accredited training programmes. EREC welcomes this provision as it should positively contribute to the widening of knowledge of renewable energy technologies. EREC believes it is essential that the quality of the installations is ensured via certified installers in the framework of the obligation to introduce minimum levels of renewable energy sources in new or refurbished buildings. A sufficient adaptation period should however be granted for the development of certification schemes as the latter are still in an embryonic stage in a number of Member States.

5. Creates a sustainability regime for biofuels

The binding nature of the 10% target has triggered the very important debate on sustainability criteria and a certification scheme. Notwithstanding the fact that EU biofuel producers comply already today with the highest possible global farming standards, the EU biofuel objective justifies the building of a sustainability and certification scheme. This scheme will serve as an example for biofuel production standards globally. The industry is committed to strict but practical sustainability standards that apply for domestic production as well as imports and that will eventually be applied to all energy sources be it biomass, food or fossil fuels.

EREC's Renewable Energy Targets for 2020

EREC has for the first time in January 2004 called for a binding 20% renewable energy target by 2020. Within the RESTMAC project co-funded by the 6th EU Framework Programme for Research & Technological Development (FP6), EREC together with its members and ADEME have drawn an EU Technology Roadmap outlining how the EU Renewable Energy Industry foresees to reach the 20 % renewable energy consumption target. The estimates given by the Renewable Energy Industry are based on a feasible annual growth scenario for the different technologies. Some renewable energy sectors have developed much more ambitious projections showing that the European renewable energy industry could deliver much more than 20 %.

This publication gives an overview of a possible contribution of the different renewable energy sectors towards the 20 % target, the state of the respective industry sectors as well as sectorial technology roadmaps up to 2020.

Contribution of Renewables to Electricity Consumption for the EU-27 by 2020

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 2 outline the new targets for 2020 with the expected annual growth rates and the necessary growth rate to increase the share of RES-Electricity significantly.

Table 2: Renewable Electricity Installed Capacity Projections [1]

Type of energy	2002 Eurostat	2006 Eurostat	Annual growth rate 2002-2006	Projection 2010	Annual growth rate 2006-2010	Projection 2020	Annual growth rate 2010-2020
Wind	23.1 GW	47.7 GW	19.9	80 GW	13.8	180 GW	8.5
Hydro	105.5 GW	106.1 GW	0.2	111 GW	1.1	120 GW	0.8
Photovoltaic	0.35 GWp	3.2 GWp	73.9	18 GWp	54.0	150 GWp	23.6
Biomass	10.1 GWe	22.3 GWe	21.9	30 GWe	7.7	50 GWe	5.2
Geothermal	0.68 GW	0.7 GW	0.7	1 GW	9.3	4 GW	14.9
Solar thermal elect.	-	-	-	1 GW	-	15 GW	31.1
Ocean	-	-	-	0.5 GW	-	2.5 GW	17.5

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 3: Contribution of Renewables to Electricity Consumption

	2005 Eurostat TWh	2006 Eurostat TWh	2010 Projections TWh	2020 Targets TWh
Wind	70.5	82.0	176	477
Hydro [2]	346.9	357.2	360	384
Photovoltaic	1.5	2.5	20	180
Biomass	80.0	89.9	135	250
Geothermal	5.4	5.6	10	31
Solar thermal elect.	-	-	2	43
Ocean	-	-	1	5
TOTAL RES	504.3	537.2	704	1370
Total Gross Electricity Generation EU27 (Trends to 2030-Baseline) * (Combined RES and EE) **	3320.4	3361.5	3568	4078 3391
Share of RES	15.2%	16.0%	19.7%	33.6-40.4%

* - European Energy and Transport: trends to 2030 – update 2007, 2008, European Commission Directorate General for Energy and Transport
** - European energy and transport: Scenarios on energy efficiency and renewables, 2006, European Commission Directorate General for Energy and Transport

Depending on the development of the total electricity generation, renewable energies will be able to contribute between 33% and 40% to total electricity production. Assuming that the EU will fulfill its ambitious energy efficiency roadmap, a share of over 40% of renewables in electricity production by 2020 is realistic.

1 - These figures are based on integrated growth rate projections. EPIA (European Photovoltaic Industry Association), believes that the Photovoltaic figures could be much higher if the development of the industry continued similar to the previous years. EPIA estimates that in 2020 350 GWp of Photovoltaic could be installed. EUBIA (European Biomass Industry Association) believes that the installed capacity for electricity generation from biomass could be in the order of 70 GW by 2020 if certain conditions are met, such as higher promotion of co-firing through incentives for utilities and for biomass production. ESTELA (European Solar Thermal Electricity Assocation) foresees the installed capacity of Solar Thermal Electricity in the range of 30 GW by 2020. As far as the geothermal sector is concerned, it must be noted that the Eurostat figure for 2006 does not take all geothermal technologies into account, which affects the entire calculation of the respective growth rates.

2 - Normalised according to the formula proposed in the RES Directive

Contribution of Renewables to Heat Consumption for the EU-27 by 2020

The lack of a favourable political framework in Europe for the renewable heating and cooling sector up until now was preventing higher market penetration so far. 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 4: Renewable Heat Consumption Projections

Type of energy	2002 Eurostat Mtoe	2006 Eurostat Mtoe	AGR 2002-2006	Projection 2010 Mtoe	AGR 2006-2010	Projection 2020 Mtoe	AGR 2010-2020
Biomass [1]	51.2	60.0	4.0%	75	5.7%	120 [2]	4.8%
Solar thermal	0.51	0.77	10.8%	1.5	18.1%	12 [3]	23.1%
Geothermal	0.59	0.68 *	3.6%	3 **		7 **	8.8%

*- Includes only district heating
**- Includes all applications incl. shallow geothermal heat pumps

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.

Table 5: Contribution of Renewables to Heat Consumption (2006-2020)

	2005 Eurostat Mtoe	2006 Eurostat Mtoe	2010 Projections Mtoe	2020 Projections Mtoe
Biomass [1]	57.5	60.0	75	120 [2]
Solar thermal	0.68	0.77	1.5	12 [3]
Geothermal	0.63	0.68	3	7
TOTAL RES HEAT	58.8	61.45	79.5	139
Total Heat Generation EU27 (Trends to 2030) * (Combined RES and EE) **	579.2	570.1	583.5	606 541
Share of RES	10.2%	10.8%	13.6%	22.9-25.7%

* - European Energy and Transport: trends to 2030 – update 2007, 2008, European Commission Directorate General for Energy and Transport
** - European energy and transport: Scenarios on energy efficiency and renewables, 2006, European Commission Directorate General for Energy and Transport

1 - Biomass for heat and heat derived from co-generation and district heating
2 - AEBIOM (European Biomass Association) believes that a target of 147 Mtoe is achievable by 2020 for biomass for heat and derived heat
3 - Based on the assumption that 1m² of solar thermal collector area per EU inhabitant is achievable by 2020, ESTIF's target is 21 Mtoe of solar thermal energy in 2020.

Contribution of Biofuels to Transport Fuel Consumption for the EU-27 by 2020

The EU depends heavily on imported energy for running its economy. For the transport sector there is hardly any diversification of energy sources: crude oil fuels more than 98% of the EU's transport sector. Biofuels have a major role to play both in improving energy security and tackling climate change, which are the core objectives of the EU's biofuels policy.

The current Biofuels Directive sets an indicative target of 5.75% in 2010. In 2007 the EU consumed between 2.5% and 3% of biofuels for road transport. Giving the fact that the European biofuels industry experienced strong double-digit annual growth rates during the past several years, Europe is well on track to reach the 5.75%. With the 10% binding target for the transport sector the Renewable Energy Directive sends a clear signal to investors and confirms the EU's strong commitment to renewable transport fuels. The 10% target is ambitious but feasible without any adverse effects on the environment or food availability.

Table 6: Biofuels Production Projections

Type of energy	2002 Eurostat Mtoe	2006 Eurostat Mtoe	AGR 2002-2006	Projection 2010 Mtoe	AGR 2006-2010	Projection 2020 Mtoe	AGR 2010-2020
Transportation Biofuels	1.05	5.38	50.5%	16	31.0%	34	7.8%

The Renewable Energy Directive will set an important framework for the future growth of the industry and will pave the way for a stable investment climate. New technologies and applications of biofuels will be developed and marketed up to 2020. 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 years, **the European biofuels industry is committed to reach the share of 10 % biofuels by 2020.**

Table 7: Contribution of Renewables to Transport Fuel Consumption

	2005 Eurostat Mtoe	2006 Eurostat Mtoe	2010 Projection Mtoe	2020 Projection Mtoe
Transportation Biofuels	3.13	5.38	16	34.0
Gasoline and oil consumption (Trends to 2030-Baseline) * (Combined RES and EE) **	297.2	300.4	317.3	349.5 323.9
Biofuels' Share %	1.05	1.79	5.0	9.7-10.5

* - European Energy and Transport: trends to 2030 – update 2007, 2008, European Commission Directorate General for Energy and Transport
** - European energy and transport: Scenarios on energy efficiency and renewables, 2006, European Commission Directorate General for Energy and Transport

Contribution of RES to Final Energy Consumption Eurostat Convention (Mtoe)

Given the present state of market progress and strong political support, the European Renewable Energy Industry is convinced it can reach and exceed the 20 % renewable energy share in final energy consumption by 2020. The estimates by the Renewable Energy Industry are based on a moderate annual growth scenario for the different technologies. Strong energy efficiency measures have to be taken to stabilise the energy consumption between 2010 and 2020.

Table 8: Contribution of RES to total final energy consumption (Mtoe)

	2005		2006		Projection 2010		Targets 2020	
Type of energy	Eurostat	%	Eurostat	%		%		%
Final Energy Consumption [1] (Trends to 2030) * (Combined RES and EE) **	1,211.5		1,214.8		1,272		1,378 1,266	
Wind	6.06	0.50	7.05	0.58	15.13	1.19	41	3.0-3.2
Hydro [2]	29.82	2.46	30.71	2.53	30.95	2.43	33	2.4-2.6
Photovoltaic	0.13	0.01	0.22	0.02	1.72	0.14	15.5	1.1-1.2
Biomass	67.51	5.57	73.11	6.02	102.60	8.07	175.5	12.7-13.9
Geothermal	1.10	0.09	1.16	0.10	3.86	0.30	9.4	0.7
Solar Thermal	0.68	0.06	0.77	0.06	1.5	0.12	12	0.9-1.0
Solar Thermal elect.	0		0		0.16	0.02	2.2	0.2
Ocean	0		0		0.08	0.01	0.4	0.03
Total RES	105.3	8.69	113.02	9.30	156.0	12.3	289	20.9-22.8

EREC and its members assume that a 20% share of Renewable Energy of final energy consumption by 2020 is a realistic target for the EU under the condition that certain policy developments will occur and a continuation of the existing policy instruments are ensured. The individual sector projections are based on moderate estimates, some of the sectors forecast much higher numbers for their sectors by 2020.

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 of a real sustainable energy mix for Europe. The table below gives an overview of the resulting contribution of renewable energy in the electricity, heating and cooling and biofuels sectors towards attaining the overall 20% target.

Table 9: Contribution of RES to Total Final Energy Consumption by sector (Mtoe)

	2005		2006		Projections 2010		Targets 2020	
Type of energy	Eurostat	%	Eurostat	%		%		%
Final Energy Consumption [1] (Trends to 2030) * (Combined RES and EE) **	1,211.5		1,214.8		1,272		1,378 1,266	
Electricity	43.36	3.6	46.19	3.8	60.5	4.8	116	8.4-9.2
Heating and Cooling	58.81	4.8	61.45	5.0	79.5	6.2	139	10.1-11
Transport biofuels	3.13	0.3	5.38	0.5	16.0	1.3	34	2.5-2.7
Total RES	105.3	8.7	113.02	9.3	156.0	12.3	289	20.9-22.8

1- Including electricity and steam transmission/distribution losses and own consumption
2- Normalised according to the formula proposed in the RES Directive
* - European Energy and Transport: trends to 2030 – update 2007, 2008, European Commission Directorate General for Energy and Transport
** - European energy and transport: Scenarios on energy efficiency and renewables, 2006, European Commission Directorate General for Energy and Transport

Geothermal Technology Roadmap up to 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 Iceland.

In South-East Europe, Greece, Turkey and the Caucasian region huge, yet unexploited reservoirs, may contribute to a sustainable energy supply.

Meanwhile, innovative power plants permit the production of electricity using low thermal water temperatures in the order of 100 °C. A major advantage of geothermal energy is the availability of the resource all day and night, throughout the year: a load to the grid, operating up to 100% of the time. Recently, Austria and Germany have also produced electricity from low temperature geothermal sources.

The technological developments of recent years have opened new ways to use the heat from the interior of our planet. The excellent results achieved on the Enhanced Geothermal System projects in Soutlz-sous-forêt show that electric power can be produced from geothermal energy throughout Europe at economically and ecologically acceptable conditions, and not only in regions known for high ground temperatures.

Heat supply from geothermal energy in Europe is achieved by using hot water from deep aquifers for district heating or other direct uses, or via a large number of small to medium shallow geothermal plants. Shallow geothermal allow the delivery of heating and cooling every time and everywhere, and can be used for thermal energy storage.

To achieve the targets, besides economic incentives, research and technical development is required in the geothermal sector. Technology evolution can be expected in both power and heat sectors, and towards increasing the usable geothermal potential, improving plant efficiency, and decreasing installation and operational cost: decrease to 2-5 €ct/kWh in 2020, for electricity generation.

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

- Develop enabling technologies for the exploitation of geothermal resources: innovative drilling technologies, resource assessment, utilization of lower temperature resources, exploitation of supercritical zones etc.
- Proliferation of the EGS (Enhanced Geothermal Systems) to other sites and regions.
- Increased overall efficiency in geothermal Combined Heat and Power (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 such as de-icing and snow melting on roads, airport runways, etc., sea-water desalination, and geothermal absorption cooling

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

Bioenergy Technology Roadmap up to 2020

Biomass

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. Biomass can take different forms (solid, liquid or gaseous), and can directly replace coal, oil or natural gas, either fully or in blends of various percentages. Bioenergy is CO_2 neutral, as all carbon emitted by combustion has been taken up from atmosphere by plants beforehand.

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 levels, providing flexibility to countries that have less biomass resources.

Technological development up to 2020

Significant progress has been achieved on biomass production 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. Pellets in particular offer possibilities for high energy density and standard fuels to be used in automatic systems, offering convenience for the final users. The construction of new plants to produce pellets, the installation of millions of burners/boilers/stoves and appropriate logistical solutions to serve the consumers should result in a significant growth of the pellet markets.

Stoves and 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.

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 medium scale CHP from 400kW to 4MW is now commercially available in the form of the Organic Ranking Cycle (ORC) systems or steam turbine systems. The first commercially available units for small scale CHP (1-10kW) are just arriving on the market, a breakthrough for the gasification of biomass in the size between 100 and 500kW might occur in a few years.

Biogas

The biogas-technology is becoming an important part of the biomass-to-energy chains. Biogas is produced from organic matter under anaerobic conditions in nature (swamps), in landfills or in anaerobic digestion facilities (fermenters). Various types of anaerobic micro-organisms produce biogas from liquid manure, silage, left over food, waste or other organic materials. Biogas can either be used to fuel a gas engine, which is coupled with a generator to produce electricity and heat or – after upgrading to pure methane – in natural gas grids or in filling stations as transportation fuel for gas vehicles. Typically biogas is used in a CHP unit to produce electricity and heat but also its role as transport fuel will increase in the next years.

Biogas produced from energy crops such as corn, sweet sorghum or others yields high energy outputs per hectare, because the total plant can be used as raw material and 65 - 80% of the carbon contained in the raw material can be converted to biogas.

Electricity production

The use of biomass for power generation has increased over recent years mainly due to the implementation of a 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, combustion 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.

Feedstock

Biomass resources cover various forms, such as products, from forestry and agriculture, by-products from downstream agro and wood based industries, as well as municipal and industrial waste streams (the biodegradable fraction). Dedicated woody or herbaceous energy crops can be grown, and transformed into various forms of energy. Improved agricultural and forestry practices can result in higher yields per hectare and 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.

Biofuels

Introduction

The two most commonly used biofuels are bioethanol and biodiesel. At a global scale bioethanol is the preferred biofuel (90%). However, in Europe 75% of the market is biodiesel. Bioethanol is the principle fuel used as a petrol substitute for road transport vehicles whereas biodiesel substitutes fossil-derived diesel. These first generation biofuels have the big advantage that during their production not only liquid fuels are produced but also protein feed, which is in terms of quantity as important as the fuels.

Bioethanol. Bioethanol, also known as alcohol, is a renewable fuel made by fermenting sugars mainly from cereals such as wheat, maize, triticale, rye, barley and from sugar cane or sugar beet. Since 1986, EU law has permitted up to 5% bioethanol in petrol, and today most of the European petrol fleet can accept a 10% blend. Bioethanol can also be used in much higher concentrations in adapted cars such as E85 cars that run on a blend of up to 85% bioethanol and 15% petrol. Pure ethanol also fuels buses and trucks in Europe.

Biodiesel. Biodiesel is the renewable transport fuel produced from plants such as sunflower or rapeseed as well as from used cooking oils, tallow or algae. It is a convenient transport fuel solution in Europe, being allowed in 5% to 7% blends in diesel for normal cars. In captive fleets for public transportation it can be blended from 30% to 100% with some engine and filter modifications.

The Biofuels industry

Bioethanol. Europe's fuel ethanol sector was a slow starter. It took almost 10 years to grow production from 60 million litres (47 ktons) in 1993 to 525 million litres (414 ktons) in 2004. In 2005 and 2006 there were double-digit growth levels of over 70%. In 2007 production increased by 'only' 11% to 1.7 billion litres (1.34 million tonnes). The top 4 EU producers of ethanol are France, Germany, Spain and Poland. Production capacity for bioethanol fuel in the EU is rapidly increasing. At present there is an installed capacity of 4 billion litres (3.16 million tonnes) and another 3.5 billion litres (2.76 million tonnes) under construction. Most of this capacity is located in France, followed by Germany and then Spain.

Biodiesel. In 2008 a total of 214 biodiesel production facilities stand ready to produce up to 16 million tonnes of biodiesel per year. Production in 2007 was 5.74 million tonnes, reflecting a difficult year due to the presence of unfair US B99 subsidised imports. While at European and international level biodiesel production increased rapidly in absolute terms, more recently biodiesel production growth has decreased by a factor of 3 due to unfair competition from the US. This case is now being handled by competition authorities in EU and US.

In addition there is an increasing diesel deficit at EU level, which makes European consumers economically vulnerable in front of unstable suppliers like Russia or Middle East countries. To this problem, biodiesel brings a practical and green solution having capacity already in place for substituting part of the fossil fuel demand.

Employment and economic impact

Rural areas of Europe suffer higher than average rates of unemployment and underemployment. Those with jobs receive incomes significantly below the EU average. European biofuel farming and processing means more jobs, and increased wealth for rural communities. The European Commission estimates that a 10% market share of home-grown biofuels would lead to a net increase in EU employment of approximately 150,000 jobs.[1] This would lead to an increase in the European Union gross domestic product by at least some €25 billion and an increase in GDP of 0.17%.[2]

Moreover the sustainability path in which the Biofuels industry is engaged, ensures a balanced development for the rural areas and a decrease in disparities among European regions. For European production, CAP cross-compliance rules ensure already that a high sustainability standard is met.

1- These numbers were based on an oil price of $48/barrel and therefore considerably underestimate job creation in Europe. Source: Commission Staff Working Document, Sec (2006) 1721: Biofuels Progress Report, Review of economic and environmental data for the biofuels progress report

2- Renewable Energy Roadmap impact assessment

Technological development up to 2020

Despite the fact that biofuels production is a well-known and proven technology, many crucial research tasks remain to be accomplished aiming at maximising the benefits of biofuels in Europe. The most important R&D objectives are further GHG emission reduction whilst enhancing economic viability. The main developments expected for 2020 are the following:

Feedstock

Bioethanol. Advanced generations of bioethanol fuel offer the prospect of sourcing energy from an even wider range of feedstock. These include non-food crops such as grasses; agricultural residues such as cereal straws and corn stover; industrial, municipal and commercial wastes and processing residues such as brewer's grain; and forest products and residues such as wood and logging residues. Those new pathways will provide even higher greenhouse gas savings.

Biodiesel. Biodiesel production is expanding its feedstock and technological processes due to constant investment in Research and Development. New crops are being added to the traditional ones: algae or monocrops from deserted land (i.e. jatropha curcas), used cooking oils or animal fats. These new pathways have an overwhelming positive impact on: GHG savings, productivity increase, soil fixation, water purification, and nonetheless third world country development.

Conversion technology

Biomass Enzymatic Hydrolysis. Compared with a conventional dry-mill process, production of ethanol from new feedstock requires extensive processing to release the sugars in cellulose and hemicellulose that account for 30 to 50% and 20 to 35% of plant material, respectively. However, the composition of biomass is variable and more complex than starch-based grain feedstock. The right combination of the "enzymatic cocktail" will be able to attack the cellulose and hemicellulose fractions, releasing sugars for fermentation. Research is being carried out to bring down the substantial costs of enzymes and thus the overall production costs of advanced bioethanol.

A further challenge is efficient co-fermentation of both hexose (six carbon, C6) and pentose (five carbon, C5) sugars to ethanol. None of the yeasts or other microorganisms currently in commercial use can ferment C5 sugars. Research is proceeding to develop organisms that can effectively use both types of sugars in order to maximize ethanol yields per ton of biomass feedstock. Efficient conversion of both types of sugars to ethanol is needed to make the whole process economical.

Thermo-chemical conversion. The biomass first undergoes a severe heat treatment. In the presence of a controlled amount of oxygen, a process called gasification takes place. The product gas from gasification is called synthesis gas or syngas. If the process is conducted in the absence of oxygen, the process is called pyrolysis; under certain conditions, this process might yield predominantly a liquid product named bio-oil.

The syngas can be used in a catalytic process for the synthesis of a variety of products. In a Fischer-Tropsch (FT) process, the syngas will be used for the production of transportation fuels like diesel and gasoline, along with other chemicals. The syngas can be used as well for the synthesis of methanol, ethanol and other alcohols. These in turn can be used as transportation fuels or as chemical building blocks. The bio-oil can be burned for direct energy production in a combustion process or can be gasified to syngas. Another potential use is the extraction of chemicals.

This **biorefinery** concept, where biomass is processed into a wide spectrum of marketable products, resembles a petroleum refinery: the feedstock (conventional or advanced) enters the refinery and is, through several processes, converted into a variety of products such as transportation fuels, chemicals, plastics, energy, food and feed. The feedstock is used in the most efficient way thus enhancing economic, social and environmental sustainability.

New utilizations

Bioethanol in Fuel Cells. One of the newest markets being looked at for bioethanol uses is fuel cells. Electrochemical fuel cells convert the chemical energy of bioethanol directly into electrical energy to provide a clean and highly efficient energy source.

Bioethanol is one of the most ideal fuels for a fuel cell. Besides the fact that it comes from renewable resources, highly purified bioethanol can solve the major problem of membrane contamination and catalyst deactivation within the fuel cell, which limits its life expectancy. Extensive research activities ensure that bioethanol remains among the most desirable fuels for fuel cells, delivering all the benefits that the bioethanol fuel cell technologies promise.

E-Diesel. The bioethanol-diesel blend, better known as E-diesel, contains up to 15% bioethanol, diesel fuels, and additives. Compared with regular petrol-diesel fuel, E-diesel can significantly reduce particulate matter and toxic emissions, and improve cold flow properties. Research is underway to make E-diesel commercially available.

Algae Biodiesel and jet fuel applications. While algae biodiesel has the same characteristics as normal fuel, the production process can be also used to capture CO_2 from power stations and other industrial plant (synergy of coal and algae). Algae oil production per acre is extremely high and does not even require agricultural land as it can be grown in the open sea, open ponds or even on industrial land in photobioreactors. Moreover algae biodiesel production can be combined with wastewater treatment and nutrient recycling, where polluted water (cleaned by algae) acts as a nutrient in their growth. But most importantly is that algae biodiesel jet fuel represents the best potential answer for the sustainability of the aviation industry.

Solar Thermal Roadmap up to 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-incidence 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

Much 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 a 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.

Photovoltaic Technology Roadmap up to 2020

Photovoltaic (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 2007, which makes photovoltaics one of the fastest growing industries. In 2007, a world-wide production volume of 3 GWp of PV modules was reached, and with a turnover of more than €14 billion, the PV industry employs over 119,000 people.

New Photovoltaic Industry Target: 12% of final EU electricity demand by 2020

EPIA (European Photovoltaic Industry Association) redefined in September 2008 its industry objectives in the light of recent technology progress and the context of rising energy prices. The industry unanimously agreed that photovoltaic energy could provide 12% of European electricity demand by 2020.

The evolution of solar photovoltaic technology will be quicker than previously announced. Based on the concept of Grid Parity (when photovoltaic electricity is equal or lower than the retail electricity price), EPIA has shown that the addressable market for PV within the EU-27 will represent about 60 % of the final EU electricity demand in 2020. This is mainly due the rising electricity prices in the different European countries and the decreasing cost of PV according to its 20% experience curve factor - the price of photovoltaic is reduced by 20% each time there is doubling of the cumulative installed capacity. Countries like Italy with high irradiation and high electricity prices are expected to reach Grid Parity in 2010. This Grid parity will be reached in Germany in 2015 and will cover progressively most other EU countries until 2020.

In order to reach this target, the PV industry does not expect any major technological change but only a continuous technology improvement. The acceleration of cost reduction will be achieved by economy of scale due to an accelerated PV deployment. The PV industry committed itself to make the necessary investments (annual growth rate 40%) in order to achieve the necessary price degression.

It is absolutely vital and necessary to point out that this ambitious goal can only be achieved if in most of the 27 EU member states appropriate support programs - ideally in form of a well structured feed-in law with appropriate degression - will be in place for the next few years until pure economics are driving this sector.

Achieving a 12% of European electricity demand in 2020 will place photovoltaic as a major source of electricity supply within the EU, which means that the photovoltaic installed capacity will reach 350 GWp generating 420 TWh annually. Under such a scenario, the target of 20% renewables in the European end energy mix by 2020 may be exceeded, especially when taking into account the contribution from other renewable energy sources.

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 75% of the PV system price is represented by the module, 10% 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 current 4 €/Wp to 2 €/Wp by 2020.

The electricity generating cost has already declined from 55-110 €ct/kWh in 1990 to 22-44 €ct/kWh today, and will further decrease via 11-22 €ct/kWh in 2020 towards 7-13 €ct/kWh in 2030 - lowest value accounts for countries with high sun irradiation (1,800 full sun-hours per year) while highest value is for countries with low irradiation (900 full sun-hours per year).

The Si wafer based solar cells in their different forms - mono-crystalline (Cz-Si), multi-crystalline (mc-Si), ribbon - represented in 2007, 90% of the photovoltaic market. The remaining 10% is covered by thin film technologies, mainly amorphous silicon (a-Si), cadmium telluride (CdTe) and Copper indium (Gallium) Selenide CI(G)S.

The share of Thin Film PV technologies is rapidly increasing due basically to both its low production cost and the recent poly-silicon shortage which has affected the crystalline silicon producers. This shortage is expected to be overcome during 2009. EPIA expects thin film technologies to increase their market share to 20% and 35% in 2010 and 2020, respectively.

Concerning Si based technologies, 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 goals in this field for 2010:

- Average material (Si) consumption for crystalline silicon from 9 gram per Watt peak [g/Wp] to 7.5 g/Wp
- Ribbons from 8 g/Wp to 4 g/Wp
- Wafer thickness from 240 μm to 150 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 targets for the European PV industry up to 2020:

- Average efficiency increase for mono-crystalline silicon from 16.5% to 22% (although some commercial cells are already on the range of 19-22% efficiency)
- Efficiency increase for multi-crystalline silicon from 14.5% to 20%
- Ribbon efficiency from 14% to 19%

PV thin film technology, constructed by depositing extremely thin layers of semiconductor materials on a low-cost backing (glass, steel, flexible steel and plastic foils), offer the potential for significant cost reductions and flexible integration in buildings. 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 crystalline technologies where individual cells have to be mounted and wired together, thin films are produced as large and integrated series-connected modules.

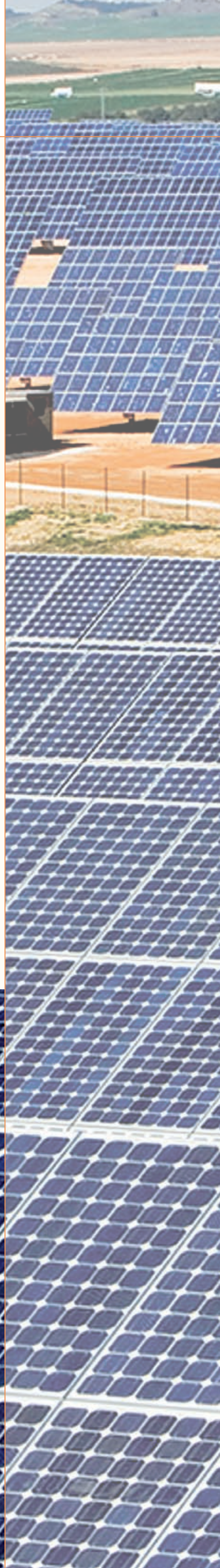
EPIA has defined two targets for thin film technologies up to 2020:

- Module thin film aiming at efficiencies between 10% and 17% (a-Si/mc-Si, CI(G)S and CdTe)
- Building integrated PV (BIPV) with low cost per m^2, price reduction of 75%

Future material developments include further optimization of the previously identified cell concepts but also the development and commercialization of new concepts such as polymer solar cells and other types of organic solar cells (dye sensitive 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 40.7% under concentrated light have been demonstrated in the laboratory, and concentrating systems have shown efficiencies over 25%. Concentrating systems using highest efficiency solar cells are becoming an interesting opportunity for installations in southern countries with high levels of direct irradiation.

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) components, 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.



Solar Thermal Electricity Roadmap up to 2020

Introduction

Solar Thermal Electricity is produced using concentrating solar radiation technologies. It is also known as Concentrating Solar Power (CSP) technologies. Solar thermoelectric power plants are fully dispatchable, match perfectly with the demand curve and can additionally provide the necessary back up to other fluent renewable conversion technologies.

Solar thermo-electric generation is highly predictable, and it can be coupled with thermal storage or hybridization, with gas or biomass, providing stability factors for the national or European electricity networks. Solar thermo-electric plants have favorable inertial responses as well as the capacity for primary, secondary and tertiary electrical regulation in both ways, up and down. Solar thermo-electric power plants can meet the demand needs at any time, day and night, and can supply electricity at peak hours if previously planned. Furthermore these plants can also easily respond to the demand curve and contribute to the electrical system's stability, making possible the presence in the electrical systems of huge amounts of other less dispatchable renewable resources.

The Solar Thermo-Electric technologies can be classified as follows:

- Parabolic-Trough Collector Plants;
- Linear Fresnel Systems;
- Central Receiver Plants;
- Dish-Stirling Systems

The industry

The great dynamism, the high potential, the operational reliability, the current production capacity of the European industry and the good dispatchability characteristics of this sector, makes solar thermo-electric generation a strategic resource for planning the 2020 European electricity scenario.

Europe, particularly Germany and Spain, is the world leader in this technology as demonstrated not only by the number of plants under construction in Spain but also by the ownership and construction of new plants in the USA and the international tendering of plants in northern Africa or the middle East which are being awarded to European companies, as well as by the number of R&D activities promoted and developed by research centres and by the industry.

Regarding components manufacturing, there are factories in many EU countries, for parabolic mirrors, absorber tubes, collector structures, heliostats, steam turbines, alternators, transformers etc. European solar plant construction and engineering are world references for these projects.

The plants require skilled labour for construction, maintenance and operation. The types of jobs initially created would most likely be technical or in construction, but opportunities for manufacturing and service jobs may also develop as facilities evolve. For Solar Thermo-Electric Power Plants, every 100 MW installed will provide 400 full-time equivalent manufacturing jobs, 600 contracting and installation jobs, and 30 annual jobs in O&M.

In summary, the European industry is perfectly prepared to lead the development of these technologies worldwide.

Technological Innovations

1. Parabolic-Trough Collector Plants

These plants use line-concentrating parabolic trough collectors which reflect the solar radiation into an absorber tube. Synthetic oil circulates through the tubes and is heated to about 400 ºC.

Parabolic trough collectors are the most mature solar thermo-electric technology in the market. It can present a track record since the 80s in the USA with a total power installed of about 350 MW. New plants have been constructed in the last years. Today 18 plants are under construction in Spain which amounts to 700 MW.

This technology is commercially and technically viable and the plants are being financed by banks on a regular basis. Nevertheless, public promotion and support schemes by means of direct investment, tariff increase (feed in) or by means of compulsory power objectives, are still necessary.

Some of the Spanish 50 MW power plants under construction have been designed to provide not only the nominal power in 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 solar thermal power plants into the grid. Molten salts are normally used as storage fluid in a hot and cold two tanks concept.

The expectations on the reduction of the kWh generating costs are based upon the efficiency increase based on higher working fluid temperature, a more efficient use of the generation group by means of the storage, new concepts for the collector design and/or the contribution of the other primary sources (gas or biomass), by the size optimization, and also by market evolution, without artificial administrative barriers.

R&TD programmes are being carried out in several countries (Germany, Spain, Italy, U.S.A., etc) in order to improve the performance and reduce the cost of these plants. The maximum nominal efficiency of these plants is currently about 16 % and it is limited by the working fluid temperature. R&TD activities are being carried out in order to find more efficient fluids such as direct steam generation or molten salts. These technologies are not commercially available today, but there are many ongoing development initiatives, which are expected to be commercially available shortly.

Up to now more than 10.000 MW of projects under development were registered in Spain in October 2008.

2. Linear Fresnel Systems

Linear Fresnel collectors are line focusing systems like parabolic troughs with a similar power generation technology and thus with the same limitations. These systems are in a developing stage with first demonstrators recently built and operated. The difference to parabolic troughs is the fixed absorber position above a field of horizontally mounted flat mirror stripes collectively or individually tracked to the sun. Demonstration plants in the several MW-scale have to be built to evaluate and prove electricity generation costs and to gain operation experience and eventually commercial confidence.

3. Central Receiver Plants

This conversion technology uses big mirrors (larger than 100 m^2) which are almost flat, called heliostats, which track the sun in two axis. 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 in the range of 500 up to 600 ºC.

The PS 10 of Abengoa in Seville is the only power plant of this kind in operation today. The nominal power output is 10 MW and it is designed with a northern heliostat field and saturated steam as working fluid in the receiver. The storage system is only designed to cope with the transient situations. A second plant of 20 MW nominal power, in the same site and with a similar design will commence operation in the forthcoming months.

Another 17 MW plant owned by Torresol is in a fairly advanced development phase. It will be placed as well in the province of Seville and it will be of a circular field type with a molten salt receiver and with a storage capacity of 15 hours.

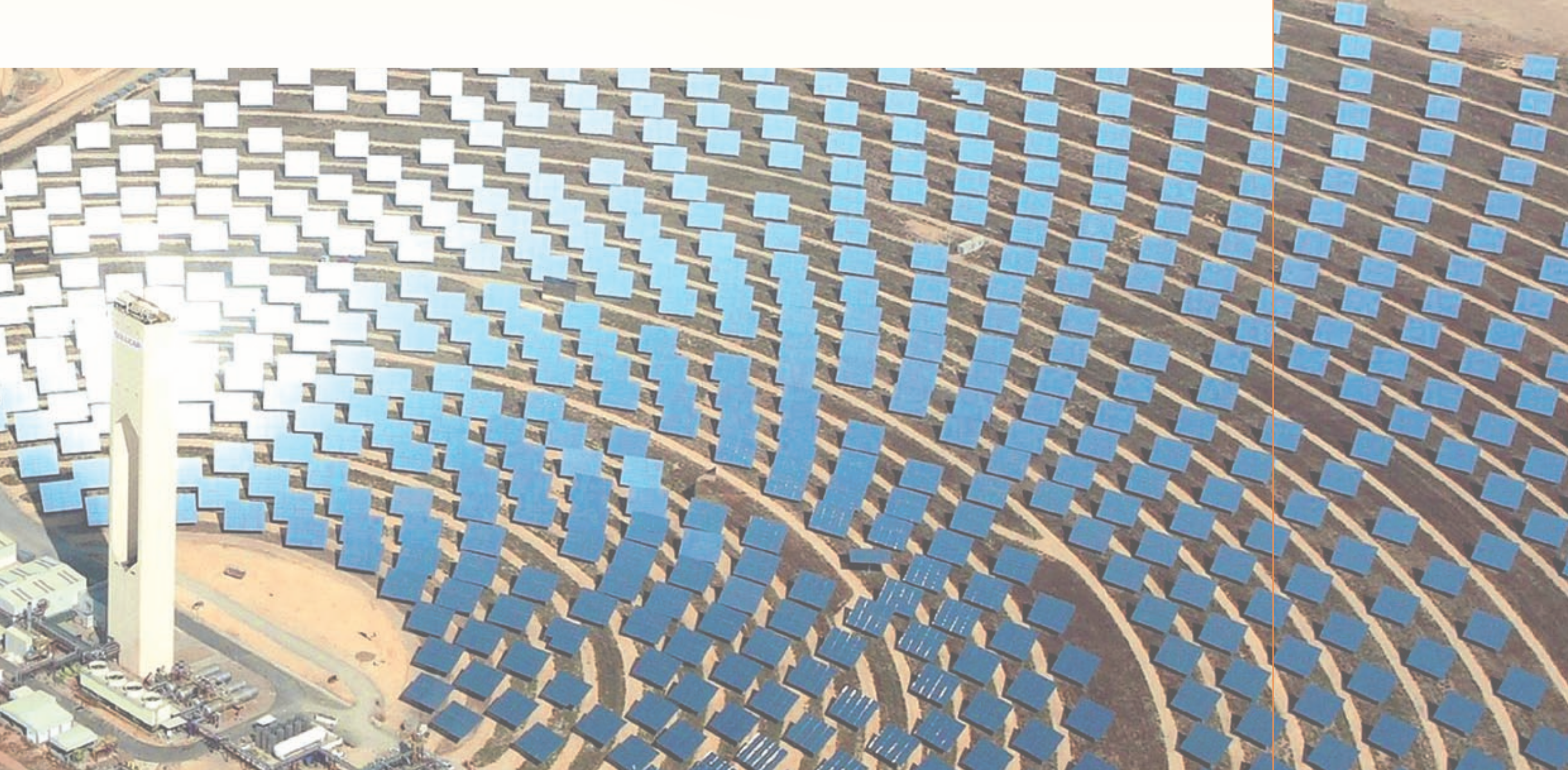
The commercial confidence in this technology will grow as more operational plants are being built and it will certainly improve in the near future.

4. Dish-Stirling Systems

In this case the system consists of a parabolic dish, which tracks the sun and concentrates the radiation onto one spot where the heat absorber of a Stirling motor is placed. Helium is mostly used as a working fluid. This alternative is particularly well suited for decentralized power generation in the range of some 10 kW, although a larger power output could be achieved with the corresponding number of units arranged in a farm concept. The efficiency of the dish-stirling systems is higher then the two previously mentioned technologies and it might be around 25%.

Until now there are only a few systems in operation, mostly as demonstration units, and the number of stirling motor manufacturers is also very small. Therefore there is not yet any sufficient experience and cost/power ratio data.

Improved efficiency and the ability to supply electricity in isolated areas makes this technology very attractive for these types of applications.



Small Hydropower Roadmap up to 2020

Introduction

Small Hydropower (SHP, up to 10MW of installed capacity) can be one of the most cost effective methods of generating electricity. Small hydro plants have a long life span and relatively low operation and maintenance costs. Once the high up-front costs are written off, the plant can provide power at low costs as the life time of a SHP plant could be up to 100 years. 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 2006, and produced about 79% of total Renewable Electricity production in the same year (10% SHP and 69% Large Hydro).

Small Hydropower is not growing as expected mainly due to administrative and environmental barriers. Nevertheless the sector has real potential, especially in the New European Member States (it has been estimated an additional 7, 7 TWh in the New Member States for 2020).

The hydro industry

The European Small Hydropower sector has a turnover of about € 120-180 million. The sector currently employs around 20,000 people in Europe and could easily reach in 2020 some 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 continue to develop techniques specific to Small Hydropower, in order to face the following challenges:

- Foster environmental integration
- Decrease cost
- Maximize electricity production
- Hybrid systems
- Standardisation
- Energy storage for the other RES

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
- Improved 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 and impacts into the ecosystems. 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 power plant design and construction. Indeed the global objective is to reach an optimal solution and a good environmental integration for every specific hydropower plants, both for new projects and restoration of old plants. The multipurpose schemes envisaging different uses and applications of the SHP is gaining importance as well in order to increase the social acceptance of the projects.

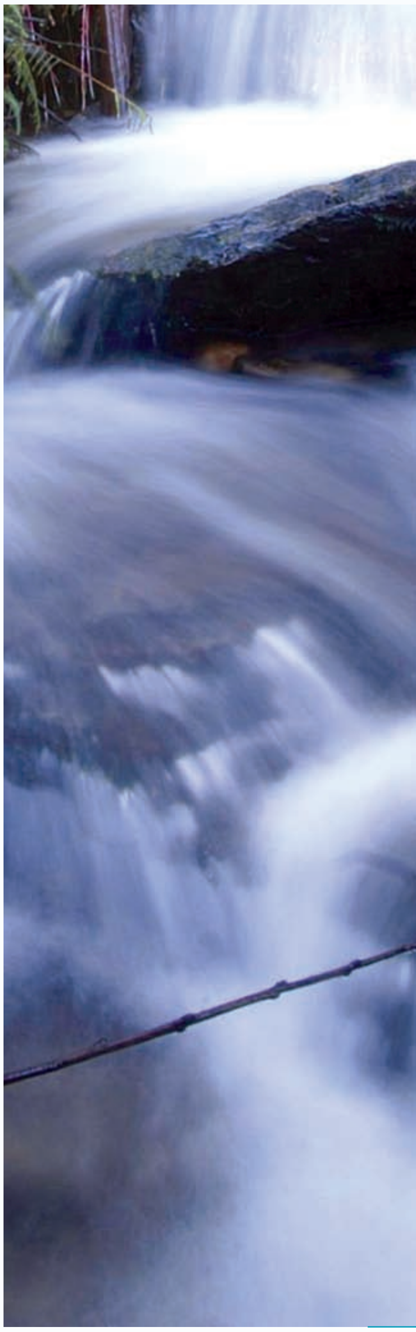
R&D results on **electrical engineering** are providing the SHP sector with available solutions ranging from generators, to grid connection, electric drives, and the control and management of the whole power plant.

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 grid integration, increase reliability and reduce the operation and maintenance costs.

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 in 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.



Ocean Technology Roadmap up to 2020

Introduction

Ocean Energy (OE), particularly offshore wave energy, is a significant source of energy, and has the potential to satisfy an important percentage of electricity supply worldwide. Globally, the exploitable potential of OE has been estimated around 30.000 TWh. The most significant advantages of OE are the vast availability, high predictability and stability of the resource, and the very low visual impact.

Currently many different concepts and devices have been developed (tapping on tides, waves, current, thermal gradient, and saline gradient), many of them are in an advanced phase of R&D, large scale prototypes have been deployed in real sea conditions, and some have reached premarket deployment.

There are a few grid connected, fully operational commercial wave and tidal farms.

Electricity production

By 2020, the global installed capacity is estimated to be in the order of 21 GW, delivering an estimated power of 50 TWh, corresponding to 0.6 % of the estimated world electricity consumption. By 2050, ocean energy is expected to deliver 660 TWh.

Socio-economic and environmental impact

The creation of an ocean energy industry could lead to a significant increase in jobs that is estimated to be in the range of 10 - 20 jobs/MW in coastal as well as in other regions as many equipment suppliers are not in coastal areas.

Like any electrical generating facility, an OE power plant will affect the environment in which it is installed and operates. A number of the Environmental Assessment documents have been assessing the potential impacts of wave and tidal energy. These assessments, and the follow-on consents for installation of wave and tidal ocean energy conversation devices have provided findings of no significant environmental impacts. These findings support the general opinion that ocean energy represents a benign means of renewable energy generation with potential positive impacts in developing associated marine protected areas.

Technological development & research priorities

Ocean energy has a tremendous potential to make a significant contribution to the renewable energy mix. While developers work diligently on technology development, their ability to expand commercially may be significantly hindered unless non-technological barriers are addressed in earnest:

- Electrical grid access: ocean energy is a coastal resource. Except for coastal countries, like Portugal and the SW region of UK where this problem is less critical as they that have high voltage transmission lines available close to shore, coastal communities lack sufficient transmission lines capacity to provide grid access for any significant amount of electricity that can be generated from ocean energy.
- Regulatory framework: initial efforts in securing installation permits in a number of countries demonstrated that permitting is expensive, long, and intensive. Governments can significantly impact licensing of ocean energy systems by creating one-stop permitting structures.
- Availability of resource and other physical data: top-level analyses of the available ocean energy resources have been done and are widely available. Now, these top level analyses need to be overlaid with constraints that would prevent harvesting of ocean energy in specific areas, i.e. other uses of the sea, access to transmission lines, populations centres, ocean geology etc.
- Economic incentives: it is a known fact that artificial market conditions need to be created at the early stage of industry development to create a market pull and to incentivise early adapters. Such market pull can have three elements - incentives for investors (investment tax credits), incentives for end-users (investment and production tax credits) and feed-in tariffs that would make high-cost pre-commercial ocean energy converters competitive.
- Public awareness: ocean energy is lacking public awareness, as it is a developing industry. A public awareness campaign may provide similar benefits as was enjoyed by the wind industry in its early days.

Recommendations

OE can become a major player in the world-wide renewable energy mix in a fairly short time, provided that industry players have access to the same level of financial support and incentives as other emerging industries. In particular, governments and private investors have the necessary resources to propel OE from a demonstration stage to the commercial stage in less time that it took the wind industry to mature. The following are some of the recommendations that can stimulate the growth of this emerging industry:

- Permitting, licensing, consenting requirements needs to be simplified and coordinated;
- Market driven incentives drive innovation;
- As demonstrated from other industries, long-term, fixed feed-in tariffs become a major factor in attracting project financing;
- Infrastructure, such as grid access, requires a long-term outlook and planning;
- Support baseline studies and follow up programmes related to the environmental impact;
- Establish a better balance between funding of research and demonstration projects;
- Ocean energy should be assessed in conjunction with other developing technologies to develop hybrid systems.

Considering the harsh marine environment, design of OE systems has to address significant technical challenges, those to achieve high reliability, low cost and safety.

At present there is no commercially leading technology among ocean energy conversion systems, which will be attained only after significant deployment and operational experience. However, it is expected that a different principle of energy conversion will be used at various locations to take advantage of the variability of ocean energy resource.

Wind Technology Roadmap up to 2020

Introduction

In 2007, wind power grew more in Europe than any other power generation technology making it the largest contributor to economic activity and employment in that sector. Over the last 10 years, only gas has exceeded wind power in the EU in new installed capacity. Cumulative installed wind capacity is perhaps the most relevant proof of this amazing success story. By the end of 2003, the EU-15 had installed more than 28,000 megawatts (MW) of wind turbine capacity. By the end of 2007, the enlarged EU-27 had in excess of 56,000 MW of capacity.

These 56,000 MW met 3.7% of total EU electricity demand, provided power equivalent to the needs of 30 million average European households and avoided 91 Mt of carbon dioxide emissions. In addition, there were billions of euros saved on imported fuel costs in 2007, while more than 11 billion were invested in installing wind turbines in Europe.

As a result of the climate and energy crisis, the EU has set a binding target of 20% of its energy supply to come from wind and other renewable resources by 2020. To meet this target, more than one-third of European electrical demand will need to come from renewables, and wind power is expected to deliver 12% to 14% (180 GW) of the total demand. Thus wind energy will play a leading role in providing a steady supply of indigenous, green power.

Europe is the undisputed global leader in wind energy technology. Sixty per cent of the world's capacity was installed in Europe by the end of 2007, and European companies had a global market share of 66% that year. Penetration levels in the electricity sector have reached 21% in Denmark and about 7% and 10% in Germany and Spain respectively.

Within a few years, large wind turbine manufacturing companies and project developers/operators will construct wind power plants the size of conventional power plants, up to 1,000 MW which will lead to even greater penetration levels. The average wind turbine is in the 2-3 MW range. The largest individual wind turbine prototypes have already reached installed generator capacities of 7 MW and diameters of 125 m. In the beginning of the 1980s, wind turbines typically had a capacity of 0.022 MW.

But further penetration of wind in Europe's power supply depends on continued Research and Development efforts - leading to cost reductions - and efficient measures to integrate wind energy production into the electricity supply system.

Industry development

For the 2007 to 2010 timeframe, Europe's top 15 utilities and IPPs in terms of MW owned declared construction pipelines totalling over 18 GW, which translates into well over €25 billion in wind plant investment, based on current cost estimates per MW installed. Overall, the European wind market is expected to grow at a rate of over 9 GW installed annually through to 2010, which translates into annual investments of over €12 billion.

The European wind power market is coming of age with the technology's steady emergence into the overall power market. Wind has become an integral part of the generation mix, alongside conventional power sources, in markets such as Germany, Spain and Denmark. However, it continues to face the double challenge of competing against other renewable technologies while proving to be a strong energy choice for large power producers seeking to grow and diversify their portfolios.

Employment

By mid 2008 wind energy companies in the EU directly employed over 100,000 people; when indirect jobs are taken into account, this figure rises to 180,000. A significant share of direct wind energy employment (approximately 74%) is located in three countries, Denmark, Germany and Spain, whose combined installed capacity represents 70% of the EU total. However, the sector is less concentrated now than it was in 2003, due to the opening of manufacturing and operation centres in emerging markets and to the fact that many wind-related activities, such as promotion, O&M, engineering and legal services, are now carried out at a local level. Wind turbine and component manufacturers account for most of the jobs (59%).

Employment projections in the EU-27 wind power sector for the year 2020 indicate that up to half a million jobs will have been created in the wind sector. The actual numbers will depend on production volume, European production share, export outside the EU, regional market growth, productivity and cost reductions.

Technological development

In its recently published Strategic Research Agenda the European wind energy platform, TPWind, proposes an ambitious vision for Europe. In this vision, 300 GW of wind energy capacity will be implemented by 2030, representing some 25% of EU electricity consumption. Moreover, the TPWind vision includes a sub-objective on offshore wind energy, which should represent some 10% of EU electricity consumption by 2030. An intermediate step is the implementation of 40 GW offshore by 2020, compared to the 1 GW installed today.

But R&D is urgently needed to ensure the efficient implementation of the TPWind vision for wind energy. TPWind has established R&D priorities in order to implement its 2030 vision for the wind energy sector. In addition to market and policy recommendations, four thematic areas have been identified in order to improve current techniques and develop as much as possible the wind potential.

The main envisaged technology development achievements in 2020 are as follows:

1. Wind conditions

TPWind proposes an ambitious long-term '3% vision'. Current techniques must be improved so that, given the geographic coordinates of any wind farm (flat terrain, complex terrain or offshore, in a region covered by extensive data sets or largely unknown) predictions with an uncertainty of less than 3% can be made concerning:

- the annual energy production ('resource');
- the wind conditions that will affect the design of the turbine ('design conditions'); and
- a short-term forecasting scheme for power production and wind conditions.

2. Wind energy integration

To ensure the future technological developments of the network, TPWind focuses on how to integrate wind power on a large scale into the electricity system. The goal is to enable high penetration levels with low integration costs, while maintaining system reliability (security of electricity supply).

- The first R&D objective is to make the most of the existing grids:

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 next R&D objective will be the network reinforcement:

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 offshore wind resource.

3. Offshore deployment and operations

The objective is for offshore wind energy to represent more than 10% of Europe's electricity demand in 2030. Sub-objectives are to achieve generating costs that are competitive with other sources of electricity generation, using commercially mature technology for sites with a water depth of up to 50 m, at any distance from shore, and developing in parallel technologies for sites in deeper water, proven through full-scale demonstration. To achieve these ambitious objectives, the TPWind recommendations encompass:

- enabling the safe operation of offshore facilities,
- educating people with the necessary skills to develop the industry,
- improving and sharing knowledge on environmental aspects,
- manufacturing, delivering and implementing the necessary amount of substructures,
- assembling, installing and decommissioning the large-scale offshore wind farms,
- implementing the necessary offshore electrical infrastructure,
- developing specific designs for offshore wind turbines, and
- implementing adapted operation and maintenance strategies.

4. Wind turbines:

The future technological developments will focus on cost reductions with the main objectives of increasing the reliability, the efficiency and the accessibility of the machines.

The present advanced wind turbine concept (horizontal axis, three-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 elements bearing heavy dynamic loadings such as rotor blades, yaw systems, drive train parts and towers. New design tools will be used to efficiently design and manufacture very large wind turbines based on significant enhancements 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 about 1 kW to a few 100 kW), a substantial improvement in technical quality will be made, leading to expansion of the market, especially in remote areas, small isolated communities and sites connected to weak grids.

Created in 2000, the European Renewable Energy Council (EREC) is the umbrella organisation of the European renewable energy industry, trade and research associations active in the sectors of bioenergy, geothermal, ocean, small hydropower, solar electricity, solar thermal and wind energy. EREC represents the entire renewable energy industry with an annual turnover of more than 40 billion € and more than 400.000 employees.

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

- **AEBIOM** (European Biomass Association)
- **EBB** (European Biodiesel Board)
- **eBIO** (European Bioethanol Fuel 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)

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

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Contact:

EREC

European Renewable Energy Council

Renewable Energy House

63-67, rue d'Arlon
B-1040 Brussels
T: +32 2 546 1933
F: +32 2 546 1934
E: erec@erec.org
I: www.erec.org

RENEWABLE ENERGY TECHNOLOGY ROADMAP