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Renewable energy: a major player in the European energy market

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INTRODUCTION

This staff working document accompanies the renewable energy Communication "Renewable energy: a major player in the European energy market". Together with the Impact Assessment, it provides further background material supportive of the narrative and arguments put forward in the Communication. It also presents the outline of certain actions that the Commission will be undertaking in the current year and next two years, as announced in the Communication.

The Communication explores how the current European policy and legal framework for renewable energy appears to be functioning, as planned by Member States in their national renewable energy action plans. Further background on this is contained in Chapter 1. The Communication then explores how national renewable energy support schemes to help achieve national targets are being reformed, discusses how further use should be made of the renewable energy Directive's cooperation mechanisms and how a special regime for developing renewable energy in the Mediterranean specifically could be developed. The Commission's actions on these points are elaborated in Chapters 2, 3, 4 and 5. Finally, the Communication highlights the importance of energy technology developments, and Chapter 6 contains a synopsis of key energy technology developments and expectations.

1. NATIONAL RENEWABLE ENERGY ACTION PLANS: SYNTHESIS AND ASSESSMENT

As required by Article 4(1) and 4 (2) of the Renewable Energy Directive, 27 Member States adopted their national renewable energy action plans setting out their national targets for the share of renewable energy consumed in electricity, heating and cooling and transport, and measures for achieving the national overall renewable energy targets and measures supporting the growth of renewable energy in each of the energy consuming sectors. All Member States submitted their plans to the European Commission in 2010 and the Commission evaluated the plans, including the adequacy of measures envisaged by the Member States for reaching their national RES targets.

The evaluation of the 27 NREAPs shows that the share of renewables in the EU final energy consumption would reach 20.6% in 2020. Renewable energy production is projected to increase from 99 million tonnes of oil equivalent (Mtoe) in 2005 to 245 Mtoe in 2020 (an average annual growth rate of 6% per year).

Based on Member State projections for renewable energy use and their sectoral targets, the combined EU renewable energy share in electricity will grow form 19,4% in 2010 to 34% in 2020, in heating and cooling respectively - from 12,5% to 21,5% and in transport from 5% to 11%. Renewable energy industry expectations for the renewable energy shares in the three sectors are higher – EU Industry roadmap[1] estimates that 2020 renewable energy share in the electricity sector could reach even 42%, in the heating and cooling – 23,5% and in the transport 12%. According to NREAP analysis, in the next decade the strongest growth will occur in wind power (from 2% to 14,1% of the total electricity consumption) and solar electricity (from 0% to 3% of the total electricity consumption).

[1] Mapping Renewable Energy Pathways towards 2020, EU Industry Roadmap, European Renewable Energy Council (EREC) (2011)

In the electricity sector, according to NREAP technology projections by 2020 wind would become the most important renewable energy source providing 40% of all renewable electricity compared to 25% in 2010, the contribution of photovoltaic and solar thermal electricity would also grow from current 3% to 9%, the contribution of biomass is expected remain almost unchanged (18% in 2010 compared to 19% in 2020), while the role of hydro would decrease from 50% in 2010 to 30% in 2020. The role of geothermal and wave and tidal are still expected to remain marginal in 2020 with respectively 1% and 0.5%.

In the heating sector the analysis of Member State projections in NREAPs indicate that biomass would maintain its dominance (80% of all renewable heating in 2020, down from 90% in 2010), solar energy based heating would increase to 6% compared to 2% in 2010 and geothermal is expected to contribute 2% in 2020 compared to the current 1%. The use of heat pumps would also increase from 6% in 2010 to 11% in 2020.

Concerning the transport sector, in 2020 the first generation biofuels (biodiesel and bioethanol) are still expected to maintain their predominance with 66% and 22% share of the total RES use in transport compared to the current 71% and 19%. The contribution of lignocellulosic biofuels and biofuels made from wastes and residues and the renewable electricity is expected to make up the rest of contribution - 12% - towards the renewable energy share in transport in 2020.

In addition to the Commission's evaluation of the NREAPs, various stakeholders have analysed the Member State renewable energy plans and have expressed their views on the Member State technology choices and the adequacy of measures planned to achieve the renewable energy targets[2]. The REPAP 2020 project provided an independent assessment of the NREAPs evaluating the quality of measures included in the action plans for tackling the administrative barriers to renewable energy development, improvement of energy infrastructure development and electricity network operation and support measures in each of the 3 energy consuming sectors. It found that the strongest weaknesses still existed in the field of administrative procedures and spatial planning followed by still rather weak support measures for renewable energy heating and cooling. It also found that further improvements were still required in many Member States in the area of support measures in the electricity sector. This assessment is also largely echoed in European Renewable Energy Council's (EREC) EU industry roadmap.

Conclusions

The review of the renewable energy plans shows that all Member States have taken a responsible and serious approach to the implementation of the EU's 2020 renewable energy commitment and to generating their national contribution to this commitment. National Renewable Energy Action Plans provide more comprehensive information on the renewable energy planning and policy measures in each of the 27 Member States than we have ever had before.

It is important that Member States complete the transposition and implementation of the Renewable Energy Directive and vigorously comply with their National Renewable Energy Action plans. Delays in transposition of the Directive and the stakeholder concerns on the Member State plans prove that implementation of the Member State commitments will require regular monitoring. The Commission will continue to assess the progress made in Member States on the basis of biennial Renewable Energy Progress reports required in the Renewable Energy Directive and it intends to publish its next Renewable Energy Progress report by the end of 2012. The Commission will take all appropriate measures, including infringement procedures, in the

[2] REPAP 2020 project report (2011), Mapping Renewable Energy Pathways towards 2020, EU Industry Roadmap, EREC (2011), EREC ECN/EEA report on Renewable Energy Action Plans (2011)

event of any member State's failure to comply with their own national action plans and renewable energy growth trajectories, or failure to fully implement any element of the Directive.

2. MEMBER STATE RENEWABLE ENERGY SUPPORT SCHEMES & REFORMS

In order to achieve the 20% target, the renewable energy Directive[3] sets mandatory national targets. In order to reach these targets, Member States my operate support schemes and may apply measures of cooperation. Member States' use different instruments and support schemes to achieve these targets in electricity, heating and transport (biofuels):

		AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
Electricity	FIT	x	x	x	x	x	x		x	x		x	x	x	x	x	x	x	x	x			x			x	x	x
	Premium					x	x	X	x	x						x					x					x		x
	Quota obligation		x													x	x		x			x		x	x			x
	Investment grants		x		x	x					x		x	x			x	x	x	x								
	Tax reductions/ exemptions		x							x	x		x						x		x	x			x		x	x
	Financial incentives			x			x		x											x	x	x				x		
heating	Investment grants	x	x	x	x	x	x		x		x		x	x	x		x	x	x	x	x	x	x		x	x	x	x
	Tax reductions/ exemptions	x	x					X				x	x			x	x				x				x			x
	Financial incentives			x			x		x			x											x					
	Premiums											x																
trans-port	Quota obligation	X		x	x	x	x	X		x	x	x			x		x	x	x		x	x	x	x		x	x	x
	Tax reductions/ exemptions	X	x		x	x	x	X	x	x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x

Source: (updated) Commission staff working paper on financing renewable energy SEC(2011)131

- Feed-in tariffs (FIT) are an energy-supply policy greatly reducing project risk. The producer is insulated from energy market prices and receives a fixed amount for the electricity.
- With Feed-in Premiums, the producer must sell the electricity in the market, and then receive a "green" premium. Thus the producer is, at least partially, exposed to market price risk and is integrated into the market.
- Certificate schemes with quota obligations typically require suppliers to derive a certain percentage of their energy from renewable energy sources and provide "green certificates" as proof. Renewable energy producers operate as normal market players, but receive a green premium from the sale of the green certificates they are issued upon the production of the renewable energy. In this instance, the producer is exposed to market risks.
- Fiscal incentives in the form of tax exemptions or tax reductions generally exempt renewable energy products from certain taxes (e.g. excise duty) in accordance with the Energy Tax Directive[4]. This Directive allows Member States to apply tax exemptions or reductions in order to compensate for the extra costs involved in the manufacture of these products as compared to conventional energy products with external costs. In addition, Member States would be able to provide further tax reductions during a transitional period (until 2023) to compensate for the higher costs involved in the manufacture of sustainable biofuels where the standard system of taxation does not suffice to promote their use.

3 2009/28/EC

4 Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity (OJ L 283, 31.10.2003, pp. 51–70).

- Investment grants are by name grants given in the form of subsidies on the initial investment cost of a project to promote the construction of new renewable energy power plants. Since they cover capital rather than operating costs, this should leave the producer free to optimise energy production according to need or market signals.

The Commission's 2011 Communication on renewable energy noted that different instruments were suitable for different markets and technologies. Large scale plants managed by industrial players are more capable of functioning in a market than micro generators of household level, for example, and immature technologies bear much greater risk (and may need support) than mature technologies. For this reason, the Commission noted that as the technology's scale increases, and as the technology and market matures, it should be capable of bearing more market risk, of being integrated into the electricity or other market. This should allow for reducing tariff levels to reflect declining technology costs, greater technology specificity to avoid windfall profits, and changing structures to ensure greater market integration of renewables. In the above Communication, the Commission stressed that any such reform should be pursued in a way that avoids creating investor uncertainty and that it will actively support national cooperation on this matter. It should be noted that 15 Member States now offer market oriented feed in premium or tradable green certificate support schemes.

Renewable energy support scheme changes

Whilst it is important that Member States reform and improve their support schemes to reflect decreasing costs of renewables and to encourage greater competitiveness on the part of renewable energy, they also need to avoid creating uncertainty and thereby discouraging investment from occurring. Recently a number of Member States have undertaken reforms that have caused disruption to industry and investors. Without prejudging possible justifications for the reform, such examples include:

- Stopping biofuel blending after only recently having introduced it.
- Avoiding legal constraints in cutting PV tariffs by imposing a levy instead, cutting expected returns to existing investors/producers retroactively.
- Reducing tariffs for most existing energy producers without notice.
- Proposals to apply new lower tariffs in exchange for an existing green certificate scheme, again, retroactively applied to existing producers.
- Ad hoc deferral of direct aid payments for biofuel production.
- Changes to an existing green certificate regime regarding technology eligibility and duration, directly affecting the price of green certificates for existing producers.
- A moratorium on support for new renewable energy production, which has an obvious direct and crushing impact on local renewable energy investment.
- Modifications of feed in tariffs for existing producers, cutting expected returns to investors significantly.
- Changes to timetables applying new, lower tariffs before announced or legally possible.
- Adding complicated project registration procedures to the authorisation process.

On the contrary, **best practice in the design, structure and reform of support schemes** should strike a balance between certainty and sufficient incentives to invest in new technologies, on the one hand; and avoiding overcompensation on the other. Principles for support schemes need to be established that address transparency and predictability, including greater use of feed in premium schemes, the need for "off budget" financing and common approaches to methods for calculating costs and premiums, scheme structure and technology banding[5]. If the scheme is flexible and able to adapt to changing market and economic circumstances (cost reductions, fiscal constraints, excess production), forced or unexpected changes are not necessary. Thus schemes with planned forms of automatic tariff digression with clear rules for support evaluation and revision are able to provide revenue stability to producers whilst introducing a quantity constraint on production. The method of tariff calculation and the nature of technology banding are all important determinants of the nature and development of the renewable energy market. Thus consistency between Member States on such issues facilitates creating a single, coherent European market for renewable energy equipment. Applying criteria commonly across Member States could also increase coherence and convergence of approach and thus reduce distortions arising from different national support schemes.

It is to further promote the application of best practice and avoidance of bad practice that the Commission intends to prepare and publish guidance on renewable energy support schemes to avoid fragmentation of the internal market.

3. THE "COOPERATION MECHANISMS" OF THE RENEWABLE ENERGY DIRECTIVE

3.1. Introduction

Directive 2009/28/EC on the promotion of the use of energy from renewable sources has introduced a stable legislative framework laying down individual mandatory targets for the share of renewable energy in final energy consumption for each Member State whilst allowing Member States to decide on the most cost-efficient technology path and support scheme to achieve those targets.

When designing the framework under the Directive, legislators were however aware, that intra-European trade has always been a source of growth and development for Europe, and that this would no less be the case with renewable energy. To obtain a competitive European energy market that efficiently exploits renewable sources for the generation of electricity for European consumers, the Directive therefore aims at encouraging strategic cooperation between Member States. With the objective of facilitating cross-border support of energy from renewable sources as a tool to optimise the energy system, the Directive defines a set of mechanisms giving Member States maximum flexibility to agree on the model for cooperation that best suits their respective interests. It encourages them to pursue all appropriate forms of cooperation, which can take place at all levels, bilaterally or multilaterally.

A recent study for the European Commission clearly highlights opportunities for surpluses from wind energy in the North of Europe (Sweden, Denmark, Finland, Germany) and from solar energy in the South-West of Europe (CSP in Spain and PV in France) to be traded using the cooperation mechanisms. This would bring economic advantages for supplying as well as off-taking Member States. The earlier the use of cooperation mechanisms is implemented the larger are the potential efficiencies to be exploited. The study compares two scenarios: one with cooperation starting early and continuing over several years between 2013 and 2020, and another one in which cooperation mechanisms are only used as a last resort to fill gaps in target achievement in 2020. This comparison shows that delaying cooperation to the last moment could reduce the cooperation potential, with all its benefits, by a factor of about 10.

[5] This will elaborate on suggestions contained in COM(2011)31 and SEC(2001)131

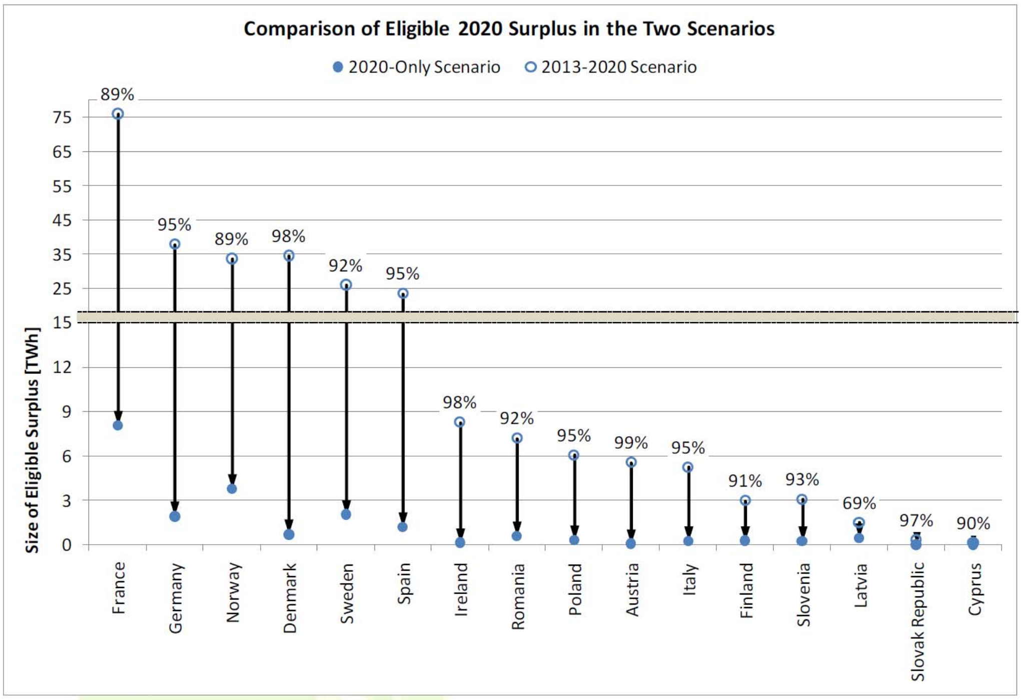

Figure 1: Comparison of surplus potentials analysed in the 2013-2020 and 2020 only scenarios of the RES4less study

Similarly to the efficiency potential that can be tapped by cooperation amongst Member States, the system can be furthered optimised by additionally allowing for cooperation with third countries. Under more restrictive conditions this possibility is also catered for under the Renewables Directive. Imported electricity produced from renewable energy sources outside the Union may also count towards Member States' targets if certain conditions are met, ensuring that such electricity generation contribute to replacing conventional energy in the EU and third countries and that net increases in greenhouse gas emissions are avoided.

All cooperation mechanisms have to be agreed upon bi- or multilaterally between Member States or – in the case of cooperation with third countries – between Member States and the third country. This paper aims to highlight the opportunities presented by the cooperation mechanisms provided for in the Directive, to lay out practical implications of their implementation and to identify potential Commission action to facilitate Member States' utilization of the mechanisms.

3.2. Overview of Cooperation Mechanisms

The Renewable Energy Directive provides for a set of cooperation mechanisms available to be implemented amongst two or more Member States, namely Statistical Transfers, Joint Projects and Joint Support Schemes. It also allows for cooperation with third countries

Article 6 of the Directive introduces the concept of "statistical transfers". These are agreements between Member States to transfer the statistical value of a quantity of renewable energy produced in one Member State to another Member State for target compliance purposes. The transfer is purely virtual, without any accompanying energy flow. This mechanism exists so that Member States with considerable renewable energy sources, or with effective support schemes that help develop such sources cost effectively, can offer any renewable energy production surplus to their requirements (either to their target or trajectory) to other Member States. The "other" Member States interested in purchasing such transfers would be those with limited domestic renewable energy sources or with inadequate support schemes for developing the available domestic resources. The transfer would normally be agreed for a number of years, for a price per MWh. In fact, most Member States wanting to buy the energy would likely want the supply to continue until at least 2020, in order to comply with their targets, or until their own domestic resources can be brought into production at a later stage. Once such an agreement is reached between two or more Member States, the European Commission will be notified, and at the end of each year the production statistics of the relevant Member States will be adjusted accordingly.

Articles 7 and 8 create “joint projects”. A “joint project” is a broad concept covering the building or co-financing of infrastructure or even an energy purchase agreement. The intention behind the mechanism is the same as for statistical transfers: to help build new plants and infrastructure in a Member State and sharing the resulting energy towards two or more Member States’ national targets, in order to reduce the overall cost of reaching the targets.

One key difference between joint projects and statistical transfers is the proposed inclusion of “private entities” in joint projects. A private entity, such as a power generator, infrastructure company, energy equipment manufacturer, a banking consortium, can identify projects in any Member State. Financing such a project could occur under the normal and existing domestic arrangements, but if such arrangements are insufficient, because the support is too low or does not qualify according to domestic priorities, the project would not be built. In such a case, the project developer could broker an agreement whereby another Member State agrees to help finance the project; again, this could be through loans, grants, tenders or access to national support schemes such as feed-in tariffs or green-certificate regimes. In exchange for this co-financing, the Member State would receive credit for a share of the renewable energy that was produced as a result of the project.

As in the case of “statistical transfers”, the European Commission will again be notified of the details of the joint project, and each year the agreed quantity of energy will be virtually exchanged. Such an arrangement does not preclude a project being completed and the actual energy, the heat or electricity generated, being sold physically, and exported to another country. In this case, the Member State would be buying the energy itself as well as its “green characteristics”.

The third element of the cooperation mechanisms established under the Directive is called “joint support schemes” created by Articles 10 and 11. Under these articles, Member States may agree to join or coordinate their national support schemes (e.g. a common feed-in tariff or green-certificate/obligation regime). The European Commission has regularly reported on the structure and functioning of support schemes and has maintained that efforts are needed to coordinate the evolvement of national schemes through the exchange of good practice to strengthen the gradual convergence of national schemes. Thus these articles of the Directive ensure that in the event of Member States coordinating or joining their support schemes, the targets can be adjusted to reflect the change.

In the event of the joining of schemes, the renewable energy produced under such conditions is considered “pooled” and shared out either as a “statistical transfer” or according to an agreed distribution rule of which the Commission has been notified. The above three mechanisms (statistical transfers, joint projects and joint support schemes) were created for Member States’ use, as the renewable energy policy and targets are focused on consumption in the EU. However, the Directive explicitly highlights that some non-Member States – “third countries” – may also take part in the use of these mechanisms. These include the European Economic Area (EEA) countries of Norway and Iceland (The EEA Joint Committee decided in December 2011 to incorporate the Directive into the EEA Agreement[6]). They also include the Contracting Parties of the Energy Community Treaty, an association of South-East European countries providing a legal framework for the gradual adaptation of these countries' energy markets to EU energy market laws. The Directive explicitly encourages the Energy Community to adopt the Directive (including the establishment of ambitious 2020 targets) so that the Contracting Parties to the Treaty would thereupon be eligible to make use of the cooperation mechanisms to help develop their energy production or energy infrastructure[7].

In addition to the cooperation mechanisms available to Member States, the Directive also creates an instrument (under Articles 9 and 10) that enables third countries to take part in developing renewable energy sources and contributing to the EU target, irrespective of their membership of the EEA or Energy Community Treaty. Accordingly, "joint projects" between Member States and third countries – similar in structure to the joint projects between Member States described above – can be established under Article 9 of the Directive. However, whilst joint projects between Member States can be purely "virtual trade" arrangements, joint projects with third countries have strict conditions attached to them to ensure that the arrangements generate new renewable energy production of electricity that is actually consumed in the EU. In particular, as proof of importation, the Directive requires that:

The electricity is firmly nominated to the allocated interconnection capacity by all responsible Transmission System Operators in the country of origin, the country of destination and, if relevant, each third country of transit;

The electricity is firmly registered in the schedule of balance by the responsible Transmission System Operator on the Community side of an interconnector; and

The nominated capacity and the production of electricity from the designated installation refer to the same period of time.

3.3. The implementation of cooperation mechanisms and existing practice

3.3.1. Statistical Transfer between Member States

The first type of cooperation mechanism created, in Article 6 of the Directive, is the "statistical transfer". The steps outlined in the Article are straightforward: the Member States agree a "virtual" transfer of a certain quantity of renewable energy, to be deducted from one Member State's statistics and added to another's. The energy itself is not physically exchanged, just the "credit" for having invested in producing renewable energy. For the purpose of statistical transfers the energy generated from renewable sources is only transferred ex-post, i.e. after having been generated, and the Directive does not specify, if the energy is consumed in the form of electricity, heat or fuel.

To recall that making statistical transfers must not put into danger a Member State's ability to meet its trajectory, target or other milestone, the text notes in the last sentence of Article 6(1) that the transfer shall not affect the achievement of the target; that is, the obligations contained in the rest of the Directive, regarding the trajectory and the targets themselves, remain in place.

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6 Liechtenstein was exempt from applying the Directive.

7 The Contracting Parties of the Energy Community Treaty are Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro, Serbia, the United Nations Interim Administration Mission in Kosovo, Republic of Moldova and Ukraine. Georgia, Norway, Turkey and Armenia take part as observers.

The application of this cooperation mechanism could be as follows: a Member States finds that with the target it faces, the support schemes it uses to develop renewable energy and the resource potential available, it can produce renewable energy at below average EU cost. It thus feels comfortable that it has the resources to meet its target and could in fact produce a surplus at a relatively low unit cost, which it could offer to another Member State. At the same time, the Member State may very much need the revenue flows from such an exchange in order to finance the development of its renewable energy resources. Thus a Member State could be interested to be a “seller”.

Conversely, there may be Member States with ineffective support schemes, high targets and/or relatively low levels of renewable energy potential which, facing a relatively high unit cost, could be interested to help develop renewable energy sources in another Member States more cheaply; who could be interested to be “buyers” to strengthen their national support scheme with the revenue from statistical transfers.

Article 6 explains the mechanism for cooperation in the event that a buyer and a seller agree to cooperate. The two Member States involved formally “notify” the European Commission. In essence, this means a letter is sent from the Member State government explaining the quantity and price of renewable energy that is to be transferred (usually for a price/MWh or other relevant unit of energy). There is no prescribed format for this notification other than the information it must contain. Once notified, the European Commission will publish the information on its transparency platform[8].

The first sentence of paragraph 2 is worth highlighting: “The arrangements [the agreed statistical transfer] may have a duration of one or more years…”. Member States who want to “buy-in” some of the contributions that will count towards their renewable energy trajectory and target are unlikely to want to do so on a year by year basis. In principle, they will be interested in a regular inflow that will help them follow their given trajectory for the growth of renewable energy, ending with their 2020 target. It can thus be expected that (unless a Member State plans a sharp burst in domestic production of renewable energy in the last years prior to 2020) agreements for statistical transfers (in fact for all cooperation mechanisms) will last from the initial year to 2020. This is clearly important for the Member State purchasing the statistical transfer. But it is also important for the Member State making the transfer: whether or not it is already financing the renewable energy production it agrees to transfer, a regular source of income is necessary for financing the expansion of the renewable energy production capacity of the country.

So far no formal agreement has been reached between Member States to implement a statistical transfer under the Directive. In February 2011 Luxembourg and Lithuania signed a Memorandum of Understanding envisaging the possibility of such cooperation, as the share of renewable energy in Lithuania has been rising above the indicative trajectory provided for under the Directive. The Memorandum provides for the exchange of information on common actions –transfer of statistical renewables indicator excess and joint projects. More concrete negotiations on the set-up of a statistical transfer are conducted between Luxembourg and Germany. Also in developing a major photovoltaic programme for electricity export to other Member States (the "Helios" project), Greece is planning to offer statistical transfers in an initial pilot phase. Such plans could generate major benefits but need a clear business case to be taken forward.

[8] See http://ec.europa.eu/energy/renewables/transparency_platform/transparency_platform_en.htm

3.3.2. Joint Projects between Member States

The second cooperation mechanism, “joint projects”, is a variation on the flexibility offered by statistical transfers. The principle of mutually beneficial trade is the same, but in this case the arrangement can include industry – private operators – and so need not be a purely governmental arrangement. Only projects in the electricity or heating and cooling sector are eligible as joint projects under Article 8 of the Directive.

The involvement of a private entity can increase the scope for cooperation. Compared to national governments, a private company can be expected to have more detailed knowledge of the renewable energy sources at its disposal, their relative costs, the nature of the market - both in its home country but conceivably also elsewhere in the EU; knowledge gained through its existing commercial or professional contacts. This knowledge can be used to propose and develop renewable energy projects in any sector – and propose them to the national government either in the Member State where the resource exists or to another national government who might be interested as a “buyer”.

This commercial initiation of a project is generally the means by which today’s renewable energy projects are undertaken: a potential renewable energy producer proposes a project; it is possibly a profitable proposition and could be developed commercially (for instance when drawing on a cheap resource such as municipal waste or biomass residues) or, more commonly, it could be a profitable enterprise if it received government support. Faced with such projects, a government determines whether it fits within its renewable energy strategy (for instance, if it is a resource or technology priority of the government) and whether it is eligible for support. If the Member States so decide, one Member State would pay a company to produce renewable energy in another Member State. With the agreement of the second Member State, that energy, or part of that energy, would be credited to the trajectory and target of the Member State financing the production.

If, for any reason, insufficient support is available to make such a joint project a commercial proposition, the private entity and/or the government could propose that a third party – another Member State government – be involved in the project. Such “involvement” – the nature of the “joint project” – is not prescribed in the Directive; “joint project” is a broad concept covering the building or co-financing of plant or infrastructure, an energy purchase agreement or access to the national support scheme of another Member States. The financial means of involvement could take several forms.

The intention behind Article 7 is the same as for statistical transfers – one Member State helping in the building of new plant and infrastructure in another and sharing the counting of the resulting renewable energy towards their national trajectories and targets to reduce the overall cost of reaching the targets. By way of illustration, the paying Member State could offer a tender for the production of X MWh in the other Member State, perhaps for a given technology or sub-technology (e.g. for highly efficient PV) or for renewable energy in a particular region. Alternatively, it could grant access to its support scheme (X MWh of green certificates or feed in tariff/premium), again for a specific technology or region in the other Member State.

Whatever the financial arrangements that are made, the Member States involved can determine between themselves how the energy resulting from the project will be shared in counting towards their targets. For instance, this could be in direct proportion to the financial contribution made.

Following such agreement, the Commission must be notified of the arrangement in the same manner as for a statistical transfer: a formal governmental notification of the Member States involved, the relevant installation, the energy to be shared and the period covered. As the project is concerned with planned production, a second stage of notification is necessary. Thus Article 8 explains that within three months of the end of each year for which the agreement holds, the European Commission is to be notified of the actual energy produced from the plant and the allocation of this energy between the Member States party to the agreement.

In both cases, statistical transfers and joint projects, the European Commission (Eurostat) will keep an account of energy statistics in accordance with the notifications.

3.3.3. Joint Support Schemes

A third form of potential cooperation between Member States is to go beyond sharing the financing of limited quantities of renewable energy, or specific projects, and to join their support schemes together (e.g. a common feed in tariff or green certificate/obligation regime). When Member States wish to do this, it is appropriate that they should easily be able to do so without any hindrance from the regulatory regime for target compliance – from the Directive. Therefore the means of linking joint support schemes to Member States' target compliance is straight forward, even if the mechanics of joining support schemes themselves together may not be.

The Article on Joint Support Schemes reflects the view that the efficiency of support schemes can be enhanced and the cost of developing renewable energy reduced if support schemes are joined and so distortions between different systems avoided. It is worth noting that the legal framework for the harmonisation of support schemes for electricity from renewable energy sources that existed in the Renewable Electricity Directive has not been replicated. That Directive created a seven year time frame and a consultation framework for any development of harmonisation initiatives. However the various discussions on the importance of the stability of support schemes and the need for somewhat differentiated approaches corresponding to the resources and market development in different regions, have resulted in an agreement that more effort should be put into cooperation and coordination of schemes rather than harmonisation.

That said, the Article on Joint Support Schemes exists because all parties involved recognise the benefits a common approach can have. The European Commission's recent reports[9] and the working of such groups as the International Feed-in Cooperation initiative highlight the need to continue to facilitate discussions of cooperation and convergence of support schemes. It is reasonable to believe that a gradual pathway to more consistent support frameworks can be developed which does not destabilise the market and would actually inspire investor confidence in the stability, removal of distortions and cost savings it could generate. It is worth noting that Article 23(8)(c) of the Directive requires the Commission to evaluate the use of the cooperation mechanisms to ensure that Member States are able to achieve their targets cost effectively.

The renewable energy produced under a joint support scheme is considered "pooled" and shared out either as a "statistical transfer" or according to an agreed distribution rule of which the Commission has been notified. The Member States concerned must determine and agree the rule by which the renewable energy produced will be shared out (for instance, in accordance with the level of national financing of the support scheme). The European Commission is then notified of this rule by formal letter of the governments concerned.

[9] COM(2011)31; SEC(2011)131

3.3.4. Joint Projects between Member States and Third Countries

In addition to facilitating cooperation and encouraging cost savings through "virtual trade" in renewable energy between Member States, the Directive also creates a framework for the extension of cooperation to third countries. It does this in two ways. Under certain circumstances a third country can be treated effectively as a Member State and take part in the system of statistical transfers and joint projects. More generally, the Directive provides a specific arrangement for third countries acting as third countries.

The inclusion of third countries in the framework for renewable energy development achieves several goals. As with other types of cooperation mechanisms, it provides flexibility in meeting the targets which can help reduce costs: physically importing renewable energy into the Union when it is cost effective to do so. In this respect, this type of cooperation clearly addresses European energy policy goals: it reduces European consumption of fossil fuels and so generates greenhouse gas savings, furthermore, it diversifies our sources of energy; even if the energy is still imported, the diversification in the number of countries, types of energy and suppliers of energy all contributes to improving the security of Europe's energy supplies. This mechanism also fulfils a development role: many countries on the periphery of Europe are less wealthy than Member States and often in need of further investment to boost their energy infrastructure. Cooperation with Member States can therefore also be beneficial for the third country – export revenues, commercial relations with Member States and infrastructure investment will all contribute to the third country's on-going development.

Whilst trade in renewable electricity contributes to a broader set of policy goals, it should also be recalled that the 20% target is a target for the consumption of renewable energy in the EU. The Directive reflects the view that if EU consumption can be combined with renewable energy production in third countries, it should be encouraged. For some fuels – biomass, biofuels etc. – it is relatively simple to encourage the production of the fuel in a third country and to import it for EU consumption. For electricity is it not quite so simple. For this reason a special framework was created to allow electricity generated from renewable energy sources to be imported into the EU and to count towards the target. The key element is that it has to be proven to be both from a renewable energy source, and actually imported.

The requirement that the energy is physically imported occurs because the fundamental aim of the Directive is to generate new renewable energy capacity to meet EU energy policy goals. It is submitted that the creation of new renewable energy production facilities in third countries is a positive development in itself, and that in terms of reducing greenhouse gas emissions, the displacement of fossil fuel consumption in one country has the same benefit as in another. However, in terms of reducing EU fossil fuel imports and diversifying the EU's energy supply mix and in terms of generating new European industries and jobs, the growth of renewable energy production in third countries is of little benefit. In contrast, when the energy is imported, it displaces EU fossil fuel consumption and it diversifies the energy supply. Thus, when the electricity is physically imported it contributes to the EU's energy policy goals, and for this reason the joint project regime for third countries was created.

The means by which electricity generated from renewable energy sources in third countries can count towards the target of a Member State is known as a "joint project" similar to those that are regulated by Article 7. Such a project can be established between a Member State and a third country under certain conditions. Recalling the primary objective of the Directive - a 20% share of renewable energy consumed in the EU – the article specifies that renewable electricity produced in third countries may be counted towards a Member State's target if it is produced by a new installation (operational after the entry into force of the Directive), and is proven to be imported into a Member State of the EU. The proofs required on this last point are specified in detail (paragraph 2(a)).

In addition, the energy that is produced and exported to the EU under the agreement may not receive operating support. This rule is applied to reduce the risk of paying double subsidies and over-compensating producers.

A limited exception to the requirement of physical import of electricity is included in Article 9(3). This article allows for the virtual transfer of electricity from a new plant if interconnector capacity is being built (construction started by 2016), if it will be operational after 2020 but no later than 2022 and if it will be used to export the electricity to the EU. This exception takes into account that some projects of high European interest in third countries, such as the Mediterranean Solar Plan, may need a long lead-time before being fully interconnected to the territory of the Community. To kick-start the development it was therefore decided to allow Member States to take into account in achieving their national targets a limited amount of electricity produced by such projects during the construction of the interconnection.

As with the other types of cooperation mechanisms, following notification of such schemes, the Commission will adjust the energy statistics.

When the above conditions are clearly met, this cooperation mechanism allows Member States to search even further afield than other Member States for cheaper renewable energy, providing further scope for cost reductions. With this instrument, the way is opened for trading arrangements not unlike the Clean Development Mechanism under the Kyoto Protocol and EU ETS for GHG emissions[10]. The requirement to import the electricity into the EU limits the scope of the instrument: it depends on new plants being built and electricity being exported through interconnector capacity between the country of production and the EU (including any transit countries). However, together with the ability to produce other renewable energy fuels (biomass, biofuels, biogas) and export them to the EU, this mechanism allows third countries to enter into a new market for renewable energy and access to a new potential source of investment and income for building up new renewable energy infrastructure, whilst at the same time helping to contribute to EU energy policy objectives.

3.4. Barriers to Implementation

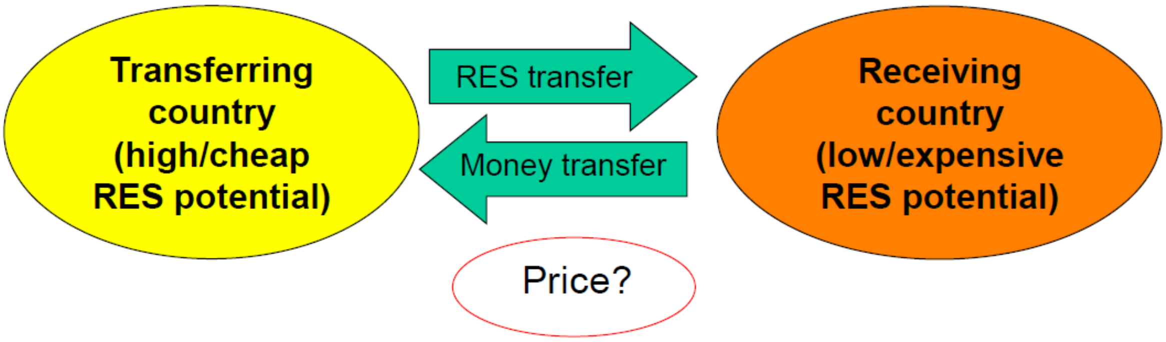
The Commission has noted that up to €8bn could be saved annually by Member States if they took advantage of trading renewable energy through cooperation mechanisms. The legal framework for such trade is established; the economic and fiscal rational is strong, and yet little use is made of the mechanisms. It is important to try to understand what lies behind the reluctance of Member States to initiate or even simply allow the use of the mechanisms. Several reasons, or barriers have been identified:

1. Political momentum to rely on domestic resources, because it is perceived to better justify action vis a vis their electorate (local jobs, domestic greenhouse gas savings)

2. First movers fear legal risks involved in stepping onto a new field

[10] The interaction of such schemes with carbon pricing schemes such as EU ETS would have to be taken into account.

3. Price setting: A question that arises under all mechanisms is how to share the costs and benefits of the deployment of renewable energy installations between the States involved.



Determined based on RES support costs and other direct and indirect costs and benefits?

4. Cross border grid (but also domestic transmission) infrastructure needs to be further improved (addressed through TEN-E, CEF)

5. Institutional set-up – complexity of the issue rising from statistical transfer to joint projects and joint support schemes

6. Barriers specific to one of the mechanisms: Statistical Transfers may suffer a risk of non-compliance; Joint Projects require clear definitions of the support scheme for the project, impact on and of the domestic support scheme, and mechanisms to share costs and benefits.

4. Future Actions by the Commission to Facilitate the Implementation of the Cooperation Mechanisms

The Commission has participated in numerous meetings and conferences, in Member States and in neighbouring 3rd countries, with governments and other stakeholders, explaining and discussing the nature of the cooperation mechanism and how they could be established. The Commission has also launched several projects exploring the different technical, legal, and economic issues surrounding the use of cooperation mechanisms. These include "RE SHAPING" (Shaping an effective and efficient European renewable energy market), "RES4LESS" (Cost efficient and sustainable deployment of renewable energy sources towards the EU 20% target by 2020 and beyond), work by the Secretariat of the Union for the Mediterranean, "Paving the way for the Mediterranean Solar Plan". Finally, in its regular meetings with Member States to discuss the implementation of the Directive, a special working group was established to deal expressly with the creation of cooperation mechanisms and to facilitate their creation and the removal of barriers.

Further initiatives could be undertaken to continue to remove the barriers identified and to facilitate the use of cooperation mechanisms. These include:

- Development of Guidelines for the implementation of Statistical Transfer and Joint Projects between MS and with third countries, including methodologies for price setting, legal and institutional framework conditions, model agreements.

- Since current cooperation mechanisms may not be used beyond 2020, a post 2020 renewable energy regime would need to refine the current mechanisms, improve their attractiveness (for instance explore a bonus scheme, or future use of European funds to encourage such trade).
- Promote, where feasible with EU support, the creation of cooperation in the exploitation of renewable energy between Member States, in particular in Greece (solar power) and in the northern seas. Further, continue to promote and facilitate the development of North African projects (solar power) through the creation of relevant cooperation mechanisms.
- Mandate for an Agreement with countries of North Africa (as already envisaged as a possibility in the Directive: Recital 35: "*Agreements with third countries concerning the organisation of such trade in electricity from renewable energy sources will be considered.*"). – see Chapter 5.

The Commission will continue to explore such initiatives and undertake further work to explore how best to develop cooperation mechanisms in the context of achieving the 2020 targets. In addition, given the constraint that the 2020 termination date imposes on the use of the mechanisms, consideration is also needed of the treatment of cooperation mechanism agreements beyond 2020 or in a post 2020 renewable energy framework.

Such work will contribute and form a part of the Commission's review of the cooperation mechanisms, required by Article 23(8)c of the Directive by 2014.

5. A LEGAL FRAMEWORK FACILITATING INVESTMENT AND TRADE IN RENEWABLE ENERGY IN THE MEDITERRANEAN REGION

In its Communication of 8 March 2011 "A Partnership for Democracy and Shared Prosperity with the Southern Mediterranean[11] the Commission had already hinted at the possibility of creating a new legal and regulatory framework for energy cooperation across the Mediterranean. This policy direction was reiterated in the European Neighbourhood Policy Communication of 25 May 2011[12] and the Communication "On security of energy supply and international cooperation - "The EU Energy Policy: Engaging with Partners beyond Our Borders" of 7 September 2011[13]. The latter includes as a key follow-up action to "Propose to partners a regional EU-Southern Mediterranean Energy Partnership initially focused on electricity and renewable energy market development in these countries by 2020".

These orientations were proposed at a moment when the Mediterranean Solar Plan, developed in the framework of the Union for the Mediterranean, and several public and private initiatives, on both shores of the Mediterranean, are being developed with the purpose to roll-out renewable energy generation in the region. Such activities address notably the policy and regulatory framework, the infrastructure issues and the financing aspects. A first success was achieved this year with the launch of the first large-scale CSP plant in the Southern Mediterranean countries (Ourzazate, Morocco) with the support of the European Union alongside with Moroccan and international institutions.

All activities carried out from public and private players in the last years and the experience of first concrete projects have demonstrated the need for a stronger legal framework to facilitate

[11] COM (2011) 200
[12] COM (2011) 303
[13] COM (2011) 539

large-scale investments and trade in electricity from renewable sources. This will be particularly important, beyond the 2020 horizon, in order to open new commercial possibilities to export, when commercially interesting, significant volumes of renewable electricity to the European Union.

The following proposals do not cover the wide spectrum of policies favouring renewable energy investment in the Southern Mediterranean countries, which is the scope of the Mediterranean Solar Plan "Master Plan" under elaboration with all interested countries. They rather address the range of legal provisions which could be included in an international instrument to support the creation of a renewed "EU-Southern Mediterranean Energy Partnership".

5.1. What legal aspects need to be developed?

Investments in renewable energy projects are long term capital intensive investments for which effective investment protection guarantees are essential in order to attract private capital. The current investment protection instruments are not regarded as sufficient by industry. This prevents investments to happen or increases the cost of capital and hence negatively affects the economic feasibility of projects. Appropriate additional investment protection instruments are thus needed.

For large-scale projects, only an integrated regional market can ensure commercial viability and deliver back-up capacities at economic conditions. This can only happen if basic conditions are set to trade electricity regionally, at least as regards wholesale markets.

Furthermore, preferential connection of renewable generation plants to the grid and access to transmission infrastructure is fundamental. This might imply to review or establish grid codes ensuring such preferential access and there would be a clear benefit in doing in a cooperative manner at regional level.

More generally, in order to shape investors' confidence, authorisation regimes and/or the award of concessions shall be transparent and non-discriminatory. This is of particular importance where availability of sites is limited or when the realisation of project is only possible if specific rights are granted by the public authority. As a general rule, foreign investors should be treated in the same manner as national investors.

Finally, measures concerning access to EU support, simplification of requirements for the implementation of Article 9 of Directive 2009/28/EC, and eligibility to the EU Emission Trading System could raise the interest of Southern Mediterranean countries.

5.2. What provisions could be explored?

Legal provisions facilitating investment and trade in renewable energy in the Mediterranean region could thus be developed in the following areas:

(1) Bilateral investment protection treaties link certain Member States and certain Southern Mediterranean countries. Several of them have also expressed interest to become party to the Energy Charter Treaty. However, it seems that additional provisions on investment protection are needed at EU-third country bilateral level.

(2) Regional exchanges will develop if import-export restrictions/monopolies are lifted and if other restrictions to trade in electricity of renewable origin are prohibited. Trade tariffs

should be kept to zero[14] both as regards electricity of renewable origin and related equipment/services. Non-tariff barriers to trade in renewable energy equipment should be minimized.

(3) Common provisions establishing a regional wholesale energy market (or sub-regional wholesale energy market) shall be established. This would notably include common rules for cross-border electricity exchanges such as a common methodology to establish Net Transfer Capacities (NTC), transparent capacity allocation and congestion management rules (at least bilaterally), and common charging principles for the use of the networks. These are questions where the input of the energy regulators (through their regional association MEDREG) and of the electricity transmission system operators (through their regional association MED-TSO) could be sought on the basis of mandates for specific grid codes.

(4) Within each network, grid connection rules and preferential access to the grid for electricity of renewable origin shall be established based on common general principles. Again, such general principles could be established with the support of MEDREG.

(5) The principle of national treatment should be established as regards any type of authorisation or licensing regime, allowing fair access of entities from all parties.

(6) Furthermore, provisions simplifying the physical import requirement set by Directive 2009/28/EC could be proposed. For instance, physical imports could only be made compulsory if netting off imports and exports is not possible.

(7) Finally, eligibility of carbon credits generated from new market mechanisms at UN level from solar activities serving local markets to the EU Emissions Trading System could be enabled and pilot projects encouraged.

5.3. In what legal framework?

The above-mentioned provisions could be distributed and articulated between the bilateral and the multilateral level, notably:

- Where it concerns trade related provisions, these could be inserted in the energy parts of the Deep and Comprehensive Free Trade Agreements to be negotiated with Morocco, Tunisia, Jordan and Egypt;
- A multilateral instrument focusing on renewable energy development in the Mediterranean.

Such multilateral instrument could be developed as an implementation measure for the Mediterranean Solar Plan and its principles could be approved at the occasion of the Energy Ministerial Council of the Union for the Mediterranean scheduled in 2013. Such political orientations would then open the way to a multilateral negotiations between the EU and a first group of countries. In a later stage, if politically supported, such multilateral agreement could become the precursor of more advanced Mediterranean Energy Community.

[14] The import of electrical energy in the European Union is not subject to customs duty.

6. DESCRIPTION OF STRATEGIC RENEWABLE ENERGY TECHNOLOGIES OF THE FUTURE

6.1. Introduction

Europe can deploy a secure, clean and efficient energy system by 2050 and maintain its global industrial leadership in the field of renewable technologies, only by leading the race for new generations of technologies, by spearheading the integration of renewables in the energy system and by developing and investing in high-tech manufacturing systems. The renewable sector has already demonstrated its vitality and innovation potential by rolling-out to the market new generations of technologies within short lead times. For instance, in less than 30 years, the size of wind turbines has increased by a factor of 10 while the cost of photovoltaic panels has decreased by more than 80%. These trends are bound to continue. The renewable sector by the variety of its resources, sunlight, wind, tides, waves, cellulose, household waste, or hydrogen from algae; and concepts such as production of aviation fuel using genetically modified microbes or synthetic photosynthesis, is a fertile ground for new concepts. The following sections provide a broad overview of the main trends expected in this field for the post-2020 horizon. The information is drawn mainly from the 2011 Technology Map of the SET-Plan[15]. The Technology Map is a regular report produced by the SET-Plan information system (SETIS), which provides a concise and authoritative assessment of the state-of-the-art of a wide portfolio of low-carbon energy technologies, their current and estimated future market penetration and barriers to large scale deployment, ongoing and planned R&D and demonstration efforts and reference values for their operational and economic performance.

6.2. Renewable energy technologies

6.2.1. Bioenergy

EU market and industrial status

In 2009, global ethanol production reached nearly 76 billion litres, in more than 40 countries. Global biodiesel production totalled 19.3 billion litres world-wide in 2009, 80% of biodiesel being produced in the European Union. The technology is therefore commercially mature. Mandates for blending biofuels into vehicle fuels have been set in at least 41 states/provinces and for 24 countries at the national level. Most mandates require blending 10–15 % ethanol with gasoline or blending 2–5 % biodiesel with diesel fuel. In the USA, the Energy Independence and Security Act of 2007 set overall renewable fuels targets of 136 billion litres by 2022. China proposed to produce 12 million tonnes of biofuels by 2020. The NREAPs estimate that biofuel use in transport in the EU-27 is likely to reach about 30 Mtoe in 2020. The greatest contribution in 2020 is expected to come from biodiesel with 21.6 Mtoe, followed by bioethanol/bio-ETBE with 7.3 Mtoe and other biofuels (such as biogas/biomethane, vegetable oils, etc.) with 0.7 Mtoe. Advanced generation biofuels are expected to be in production at commercial scale by 2020. The NREAP data show that in 2020 about 11 Mtoe biofuels could be imported by all the Member States in order to reach the 10% binding target for transport fuels. Imported biofuels would then represent about 37% of the biofuel use in the EU in 2020.

The installed bio-electricity capacity in EU-27 according to the NREAPs is expected to reach more than 43 GW in 2020, of which 30 GW from solid biomass plants, 11 GW from biogas plants and 2 GW from liquid biofuel plants. The installed capacity of biomass power plants is

[15] European Commission, DG JRC: 2011 Technology Map of the European Strategic Energy Technology Plan (SET-Plan) – Technology descriptions, EUR 24979, 2011.

expected to further increase in the EU-27 to 52 GWe by 2030. Technology for heat and power production is mature at commercial scale, although there is significant potential to improve the efficiency of conversion. Renewable heating and cooling will make a total contribution of almost 112 Mtoe in 2020 in the EU, according to the NREAPs. Biomass will still have the major contribution of 81% (~ 90 Mtoe) for heating and cooling in 2020, of which, solid biomass will provide 81.0 Mtoe, biogas 4.5 Mtoe and bioliquids 5.0 Mtoe.

Costs status and projections

The main barrier to widespread use of biofuels in transport and bioenergy heat and power production is cost competitiveness with fossil fuels. Bioenergy and biofuels have to compete in the same markets as fossil fuel energy and fossil fuels and thus need to match their costs. For example, the biomethane price to the customer will have to be the same as that for natural gas. For the other energy and fuels products from biomass a range of targets has been envisaged for 2020 by the European Bioenergy Industrial Initiative. These include a price lower than 80 €/MWh for synthetic liquid fuels by thermal processing and ethanol and hydrocarbons by biological processing. For electricity and heat production by thermal conversion, prices are projected to be less than 75€/MWh and 35€/MWh, respectively. All the above prices (reference 2010) are based on lower heat values, are for “the point of sale to the customer” (taxes not included) and assume an oil price of 86 USD/barrel. The main parameters affecting bioenergy and biofuel costs are conversion efficiency, feedstock availability at acceptable cost and investment costs for plant. Biofuels production depends on financial support (subsidies) and further cost reduction of first generation biofuels is needed in order to compete with fossil fuels. The development of second generation biofuels depends on the improvement of their technological and economic performances. Typically, lignocellulosic biofuel plants and most heat and power plants need to be of large scale in order to operate on a cost-effective basis. Biomass availability at low cost is an important issue. Increased use of biomass in the future will lead to increased prices. Biomass supply costs are influenced by the amount of biomass required and by transport distances. Infrastructure and logistical planning will be needed to ensure efficient utilisation of high volumes of biomass for bioenergy. There is already a significant challenge to balance the sensitive interplay between biomass price, biomass availability for long-term supply contracts and the bioenergy plant size that will allow economic operation.

Technology trends

First generation biofuels (bioethanol from crops such as sugar beet, maize and sugar cane, and biodiesel/bio-kerosene from edible vegetable oil or animal fat) will be predominant up to 2020. The first commercial plants producing advanced biofuels should contribute up to 4% of EU transportation energy needs by 2020. As part of this contribution, the Biofuels Flightpath 2020[16] is preparing the shift from conventional kerosene to liquid biofuel and where refinery sector is targeting to produce 2 million tons of bio-kerosene by 2020. Bioenergy should be covered mainly by biological and chemical pathways from lignocellulosic feedstock. Niche market opportunities will also provide small but important contributions from thermochemical technologies such as Bio Dimethyl Ether (DME) from black liquor, tall oil pitch and biomethane upgraded from biogas. High efficiency heat & power generation via thermochemical conversion should also penetrate the market by 2020. Small scale very low emissions combustion installations are expected to be available for commercial applications.

[16] http://ec.europa.eu/energy/renewables/biofuels/flight_path_en.htm

Beyond 2020, liquid and gaseous biofuels produced via thermochemical routes from lignocellulosic feedstock and microalgae and/or macroalgae are expected to penetrate the market. Bio-oil production by flash pyrolysis process, or other processes, from solid biomass/waste feedstock are expected to enter the EU markets. Algae productivity can reach very high yield per unit area and it would be possible to produce algae on non-arable lands thereby avoiding land competition with other crops (although the land would be providing other ecosystem services). Innovative value chains combining thermochemical and biochemical pathways could permit biofuel production from heterogeneous organic residues (via gasification) or directly from industrial gaseous emissions. Beyond 2030, biofuels produced by microorganisms such as bacteria via modified metabolism or biofuels produced via artificial photosynthesis could also enter the bioenergy market. Artificial photosynthesis would enable a high gain of energy efficiency from sunlight to biofuels. Natural photosynthesis has an efficiency of less than 1% from solar energy to the energy in biomass that is grown. Current research developments indicate possible increases in efficiency by a factor of 10 through either modified metabolism or artificial systems and if successful this would reduce the pressure on land use.

Bio-methane from biomass can be a gradually increasing substitute for natural gas. Bio-methane, as long as it undergoes a purification process to comply with the methane grid specifications, can be mixed at any ratio with natural gas avoiding double investment into a parallel bio-methane distribution network.

6.2.2. Wind

EU market and industrial status

Wind power is the renewable energy which has seen the widest and most successful deployment over the last two decades, from 3 GW to 240 GW of global cumulative capacity. In the EU in 2011, the wind energy generation, estimated at the EU average load factor of 21.2 %, was 175 TWh or 5.3 % of the estimated 3 300 TWh of EU electricity demand. The countries with the highest wind share in the electricity mix in 2010 included Denmark (22 %), Portugal (17.1 %), Spain (16.6 %), Ireland (10 %), and Germany (6.2 %). Wind energy will provide at least 12 % of European electricity by 2020, therefore significantly contributing to the 20/20/20 goals of the European energy and climate policy. Beyond 2020, the integration of 50 % wind power into an electricity system is seen as technically possible.

European technology largely dominates the world market although European manufacturers, who used to dominate the world market as well, have seen their shares shrink to 50 %. European technology is now present in US, Chinese, Indian and South American firms through licenses or purchases of European companies. European companies still dominate the offshore subsector of the wind industry.

Costs status and projections

The cost of wind energy depends on factors such as the cost of raw materials; technology options; supply bottlenecks (e.g. there is limited competition in offshore cable supply); market supply/demand balance; administrative barriers, including permits and those caused by NIMBYism; payments for wind electricity, e.g. feed-in tariffs (FiT) and premiums, grants, etc.; and on risks and uncertainties impacting on the investors and lenders. Up to 2004, turbine prices declined, influenced by technology learning and the increasing volumes of production. Supply/demand imbalances and the increase of raw material and component prices pushed up onshore turbine prices to around €1 150/kW in 2009, when the reduction in raw material costs caused by the financial crisis, manufacturing overcapacity and increasing competition pushed down prices to around €950/kW by mid-2011, with the Spanish and Italian markets showing the lowest prices.

The trend for capital investments is for onshore sites to reduce further due to non-technological factors - such as the entry into the competition of Chinese turbine suppliers and the increasing size of turbine blades - playing a significant role, and then to stabilise. Without doubt technology will continue to progress but, as wind turbines are viewed as some kind of commodity, it is likely that non-technological factors will have a stronger influence on the onshore turbine price. Offshore wind costs are expected to remain high until 2015 but there is potential for cost reductions from factors that include technology improvements (e.g. new, cheaper foundations with lower installation costs), learning-by-doing, improved supply chain and increased competition.

Technology trends

Wind energy is among the most advanced renewable energy technologies. The industry targets are to supply 20% of Europe's electricity in 2020, 33% in 2030, and 50% in 2050 with wind power. Major investments in technologies, mass production and deployment will be needed to reach these targets. Onshore wind systems require focus on innovative designs to reduce cost of energy and on solutions for not so favourable conditions such as lower-wind areas, complex terrains and extreme weather. Innovative solutions to ease transport of all components, to shorten the time for on-site assembly and installation and to minimise the external impact in the construction phase are also needed. Improved forecasting tools for wind power generation are necessary to maximise its value on the electricity market. Additional cost reductions have to be achieved by using new control systems and methods for optimisation of operation and reduction of maintenance.

Very large wind turbines, from 10 to 20MW, are required for the offshore sites to compensate for the high cost of support structures, in particular for deep waters. New concepts for multi-service/multi-use floating platforms, as well as new wind turbine designs, such as vertical axis turbines, should be developed, demonstrated and manufactured for commercial deployment. The intelligent use of advanced materials will become increasingly important to enable larger area rotors but also in respect to the shortage of raw materials for the generators. Furthermore, reliable and affordable solutions for assuring grid stability as well as for balancing demand and production in the presence of high shares of wind electricity will have to be developed and demonstrated. Focused technological development and demonstration action for increased availability and reliability for both onshore and especially offshore wind turbines is indispensable to make wind energy fully cost competitive and to maintain important investments in wind energy in the absence of preferential tariff schemes.

6.2.3. Solar photovoltaics

EU market and industrial status

The PV sector has expanded rapidly in Europe with annual growth rates of the order of 40 % since 2000. The total installed capacity of PV systems in the EU in 2011 was 51.3 GWp, representing approximately 6 % of the total EU electrical generation capacity. The electricity generated by PV systems that year was approximately 35 TWh. The annual installation of PV systems in 2011 in the EU reached 18.3 GWp, the second largest amount of newly-built electricity generation capacity after gas-fired power stations. This was due to an exceptional high installation rate in Germany with about 7.5 GW and approximately 6 GWp installed in Italy. According to NREAPs, 26 Member States have set specific photovoltaic solar energy targets, adding up to 84.5 GW in 2020. Over 50 GW is foreseen to come from Germany, but the sun-rich Mediterranean countries which only pledged 24.6 GW now look set to exceed this (by 2011 Italy's cumulative installed capacity of more than 12 GW had was already above the target of 8 GW target it set itself for 2020).

Costs status and projections

Crystalline silicon-based systems are expected to remain the dominant PV technology in the short-to- medium term, but thin films and concentrator PV systems are increasing their market share. In the medium term, PV systems will be introduced as integral parts of new and re-fitted buildings, a market which will also be driven by legal requirements for building energy efficiency. Finally, in the long term, new and emerging technologies will come to the market. It is expected that crystalline silicon, thin films and other technologies will have equal shares in the installed PV capacity in 2030. The cost of a typical turn-key system is expected to decrease from €2.0-3.0 in 2011 to €1 to 2/Wp in 2015, and below €1/Wp in 2030. Simultaneously, module efficiencies will also increase. Flat-panel module efficiencies will reach 20 % in 2015 and up to 40 % in the long term, while concentrator module efficiencies will reach 30 % and 60 % in 2015 and in the long term respectively. It is expected that if these technology developments are realised, the cost of electricity from PV systems will be comparable to the retail price of electricity in 2015 and of the wholesale price of electricity in 2030.

Both crystalline-Si solar cells and the “traditional” thin-film technologies (a-Si:H and its variations based on proto-crystalline or micro-crystalline Si, as well as polycrystalline compound semiconductors) have developed their roadmaps aiming at further cost reductions. These roadmaps are based on growing industrial experience within these domains providing a solid data base for quantification of the potential cost reductions. The Strategic Research Agenda of the European Photovoltaic Platform is one example which describes the research needed for these set of PV technologies in detail, but also points out the opportunities related to beyond-evolutionary technology developments. These technologies can either be based on low-cost approaches related to extremely low (expensive) material consumption or approaches which allow solar cell devices to exhibit efficiencies above their traditional limits.

Technology trends

A broad variety of photovoltaic technological routes will continue to characterise the sector after 2020 depending on the specific requirements and economics of the various applications. Typical commercial flat-plate module efficiencies are expected to increase to 25% in 2030 with the potential of increasing up to 40% in 2050 due notably to wafer equivalent technologies and new device structures with novel concepts. The operational lifetime of photovoltaic modules is expected to increase from 25 years to 40 years. The use of energy and materials in the manufacturing process will become significantly more efficient, leading to considerably shortened photovoltaics system energy payback times. At the same time, affordable materials will replace the expensive ones currently used (e.g. copper instead of silver). Increased R&D is needed to bring thin film technologies to maturity and long term reliability and to create the necessary experience in industrial manufacturing. Beyond 2020, the efficiency of commercial modules could reach more than 20% for CIGS (14% max module efficiency today), 16% for a-

Si, and 15% for CdTe, with new and improved device structures and substrates, large area, non-vacuum deposition techniques, interconnection, roll-to-roll manufacturing and packaging.

Concentrated PV technology is presently moving to commercial-scale applications. Further R&D efforts are required in optical systems, module assembly, tracking systems, high-efficiency devices with the potential of reaching module efficiencies higher than 23%/45%. Emerging PV technologies such as advanced inorganic thin film technologies, organic solar cells, also based on novel concepts like quantum and excitonic structures with their potential for cost reduction and performance improvement will represent an increasing share of the PV deployment post 2020. A relevant R&D work is necessary to capture this potential. For instance, it is necessary to work on the long-term stabilization of the performances of the organic solar cells and improve their lifetime.

6.2.4. Concentrated Solar Power (CSP)

EU market and industrial status

At the end of 2011, CSP plants with a cumulative capacity of about 1.2 GW were in commercial operation in Spain, representing about 70 % of the worldwide capacity of 1.7 GW. The NREAPs forecast an increase in capacity to 7 GW by 2020, mostly located in Spain. The CSP industry association ESTELA is more optimistic, predicting 30 GW by 2020 and 60 GW by 2030.

Within just a few years, the CSP industry has grown from negligible activity to over 4 GW_e either commissioned or under construction. More than ten different companies are now active in building or preparing for commercial-scale plants, compared to perhaps only two or three who were in a position to develop and build a commercial-scale plant a few years ago. These companies range from large organizations with international construction and project management expertise who have acquired rights to specific technologies, to start-ups based on their own technology developed in house. In addition, major renewable energy independent power producers, and utilities are making plays through various mechanisms for a role in the market.

Costs status and projections

Capital investment for solar-only reference systems of 50 MWe without storage was estimated to be approximately €4800 per kWe. With storage, these costs can go up significantly. Depending on the Direct Normal Insolation (DNI), the cost of electricity production for parabolic trough systems is currently of the order of €0.18–0.20/kWh (southern Europe, DNI: 2 000 $kWh/m^2/a$). The Solar Europe Industrial Initiative indicates the potential to reduce costs by 35% by 2020.

Technology trends

The mainstream approach to CSP (oil circulating in trough receivers) appears to have a limited potential for cost reduction. Even allowing for storage and dispatchability possibilities as well as for mass production of components, competitive electricity production costs cannot be assured. More research on advanced concepts (molten salts/solar trough, direct steam/Fresnel, molten salts/solar tower), able to bring technology innovations is necessary. Beyond 2020 substantial increases (above 600 °C) in the operating temperature of the heat transfer fluids are to be expected compared to the current mainstream technology. This will be achieved by studying materials and components which are reliable at very high temperature, developing new heat transfer fluids, more efficient cycles and new system architectures, and optimising the plant control system. Gains in efficiency will be considerable - more than 20% compared to the current state of the art.

In terms of dispatchability, the storage capacity will be improved (above 250 kWh/m^3) due in particular to the study and implementation of ad-hoc thermochemical processes. This will make storage systems more cost effective. With regard to the environmental profile, beyond 2020 a significant reduction of water consumption (below 0,25 l/kWh) can be obtained (in particular through the use of dry cooling systems) while at the same time maintaining the overall efficiency of the plant. As regards multi-purpose plants and hybridisation, beyond 2020 it should be possible to optimise the hybridisation of CSP plants with other renewable energy sources and to efficiently couple the production of electricity with other uses (e.g. desalination).CSP solar power plant exploiting possible efficiencies, cost reduction, performances improvements coming from innovative combined production of electricity and fresh water are strategically and symbolically relevant for exploitation in the MENA (Middle East and North Africa) region.

6.2.5. Geothermal energy

EU market and industrial status

There are three geothermal electricity market segments, two of them based on hydrothermal systems and the enhanced geothermal system (EGS). The first one is the high-temperature hydrothermal market, which accounts for only 910 MW in the EU, of which only 20 MW were installed in 2010. The second segment is low-temperature hydrothermal, exploited through binary-cycle power plant, and which utilises resources that are more widespread in Europe. The plant units are smaller, costs are higher and the efficiency lower. Slowly, this market is growing, supported by high feed-in-tariffs. The third segment is made of EGS technologies, still at an early stage of exploitation, with currently 5 MW installed in Europe and a huge potential, which suggests that this will be an important future market.

The geothermal heat market is divided among heat pumps (GSHP) and direct heat use. The former market is growing faster supported by subsidies to counterbalance the high costs, such as for piping. The European GSHP market was 1.75 GW_{th} in 2009, which is a 6.6 % reduction in annual installed capacity compared to 2008, and suffered a further 3 % reduction in 2010 to reach an estimated cumulative capacity of 12.6 GW_{th} The direct heat market, being surprisingly varied, has much room for growth which is not realised, and this suggests the existence of strong barriers. At the end of 2009, European capacity for direct heat use was 2.86 GW_{th}.

Costs status and projections

A 50 MW conventional geothermal plant with an average production of 5 MW per well requires 1 285-2 285 €/kW in well costs assuming a 67 % success rate. Total plant investment costs vary in the range of 1 600-3 200 €/kW for flash technology, 2 600-4 500 €/kW for binary cycles, and up to 26 000 €/kW for the current EGS demonstration projects. It is expected that costs will reach around 8 000 €/kW in the long term. Cost of electricity is competitive with fossil fuels in high-enthalpy regions (e.g. Italy) at around 50 €/MWh, but can reach 300 €/MWh at low-enthalpy sites using binary plant. Cost of heat depends on whether it is the main product or a by-product of the geothermal exploitation, and the highest cost correspond to EGS exploitations in a range 40 – 100 €/kWh_{th}.

The installed cost of heat pumps varies between 1 000 and 2 500 €/kW for typical domestic facilities of 6 - 11 kW, and between 1 700 and 1 950 €/kW for industrial or commercial installations in the 55 – 300 kW range. Capital costs depend greatly on the ground exchanger layout, whether horizontal or boreholes.

Technology trends

Geothermal energy has the potential to supply 20% of the energy consumption in Europe by 2050, according to the European Geothermal Energy Council. The use of shallow geothermal energy through heat pumps is a proven technology with a potential for expansion to both new and existing residential and commercial buildings, agricultural and industrial applications. Heat pumps combined with underground thermal energy storage are also ideally suited to supply low temperature energy to district heating and cooling systems. Research and development are still needed to increase the efficiency of heat pumps, to develop robust, reliable and low-maintenance systems and to develop products and methodologies for cost-effective retrofitting of buildings.

EGS have the potential for a wide and cost-effective exploitation of geothermal energy for electricity production. The high initial investments in an EGS will be reduced with technology advances such as developing of methods of reliable resources assessment, cheaper drilling, optimisation of stimulation technologies, reducing risk of induced seismicity, advanced reservoir management, control of water losses and water chemistry. The low operating costs and the potential to increase plant efficiency are expected to make geothermal energy competitive with other energy sources and to extend the application potential. The technological advances in binary power plants (using Organic Rankine or Kalina cycles) will further expand the potential to areas with lower enthalpy sources. Advances in material research will help the cost-effective and reliable exploitation of supercritical zones which can deliver very high enthalpy resources.

6.2.6. Marine energy

EU market and industrial status

Most marine energy technologies are in an early stage of development, under demonstration, or have a limited number of commercial applications. Globally in 2011 more than 25 marine energy technology demonstration projects are performed with all of them being in pre commercial stage. Nevertheless, in 2014, 15 projects will be in commercial phase. The main markets in 2020 will be France, Ireland, Portugal, Spain, and the United Kingdom, i.e. the Member States of the Atlantic Arc. UK which is the pioneer in marine energy has 8 devices working at full-scale demonstration stage (5 on tidal energy and 3 on wave energy).

Still and until the mid 2014 the global installed capacity will account for prototypes and demonstration. In 2014 first marine farms will appear and can reach 1GW by 2020 and nearly 10 GW by 2030. Whereas, support for marine energy from policymakers and larger manufacturing capabilities in combination with cost reductions, could lead the marine energy to become cost competitive with offshore wind and thus a part of the energy mix from 2020 onwards. European utilities are moving out of the development learning curve.

Costs status and projections

The levelised cost of energy for wave and tidal is 272 and 194 €/ MWh respectively. The high cost is due to the early stage of technologies. In particular, the present projects are constrained to

10 MW total installed capacity and thus have limited economies of scale. Nevertheless, the total electricity production cost according to ETSAP will decrease from 286 €/ MWh for wave energy to 172 €/ MWh and for tidal from 243 to 172 €/ MWh. Furthermore, the investment cost according to IEA is projected for 2050 to drop to 1500-1750 €/ kW[17].

Technology trends

The seas represent a vast potential of energy, however, marine energy device deployment and survivability in harsh marine environments is challenging and capital costs associated with pre-production prototypes are very high. In the last few years an increasing number of devices are reaching full-scale live testing and proving reliability over sustained periods. By 2020, full scale marine energy systems are expected to have demonstrated their operational performance and survivability in real conditions. Further technological advances would still be needed in the key areas of energy converter and power take-off components, deployment and installation methods, development of design, operation and maintenance of single and multiple device arrays with an objective of technological advancement from R&D to demonstration, pre-commercial and finally to large scale commercialisation.

The deployment, in the sea environment, of large marine energy farms for the electricity generation of tomorrow presents also relevant logistic challenges related to the installation of the devices, the connection to the grid, the continuous monitoring and the maintenance. Strong synergies between off-shore wind, marine and the grid are also expected to be implemented for connection, transmission and distribution.

6.3. Fostering renewable integration

6.3.1. Power storage

EU market and industrial status

After a few years of stagnation in electricity storage capacity, the sector is gathering new momentum through the upgrade and new projects being built in pumped hydropower storage (PHS). The European PHS capacity of around 42 GW has increased mainly in Austria, Switzerland, Germany, Spain and Portugal, and could reach 55 GW by 2020. The other technology capable of utility-scale storage is compressed-air energy storage (CAES). There is however only one installation in Europe but worldwide several projects attempt to demonstrate advanced CAES (i.e. adiabatic CAES). The production of chemical storage (e.g. hydrogen) from renewables is seen as a necessary step in order to achieve a very high penetration of renewables.

Technology trends

Electricity storage is a clear key technology priority for the development of the European power system of 2020 and beyond, in the light of the increasing market share of renewable and distributed generation and the growing limitations of the electricity grid. A cost efficient storage solution would consider different electricity storage technologies at different levels of the grid, and take also additional measures into account, such as an improved demand response, an optimised mix of renewable generation reducing variability, smart grid solutions increasing the resilience of the grid. The technological challenge requires the significant increase of storage

[17] These data according to IEA refer to plants in the United States. Cost data in other world regions are calculated by multiplying these costs by region-specific multipliers for the investment and O&M costs.

capacity over the coming decades. Although recent research shows that there is room for further expansion of pumped hydro storage, it is still necessary to develop, demonstrate and deploy new storage technologies. A wide array of principles - mechanical, (electro)-chemical and physical - is available to store electricity. However, today hydropower plants with storage remain the most common and competitive storage technology at the energy system level. All other technologies are to some extent locked in the development stage facing multiple barriers from technological issues, market uncertainty, regulation and economics.

An overriding priority should be given to research and development in particular on materials and control systems to generate new concepts, to mature and improve the operational characteristics and economics of emerging technologies and to ensure optimum interoperability with the electric grid. This should be complemented by industrial-scale demonstration projects across the EU for near-to-market technologies such as adiabatic CAES and lithium-ion batteries to build industrial capacity and to provide data that can validate their performance and demonstrate their business cases and value to regulators, utilities, and investors. Besides, there are relevant regulatory and market issues at stake. Traditionally, the storage service has been carried out by the vertically integrated grid operators. In today's liberalised and unbundled electricity market, the economics of storage schemes depend on revenues from grid support services and on price arbitrage. It is unclear whether this framework would be enough to foster the necessary future investment in storage schemes or a different regulatory framework will be needed, one which could allow storage to capitalise on its ability to intervene and generate revenues from all the electricity market segments.

6.3.2. Grids

EU market and industrial status

National programmes and projects supporting market deployment of advanced electricity grid technologies have been steadily growing in number in the last decade. To support the trend and to strengthen the effort towards the deployment and market roll out of advanced power networks, the European Electricity Grid Initiative of the SET-Plan has been launched in 2009, with a EUR 2 billion budget, over the period 2012-2018. At the same time, the European Commission grouped together all the relevant stakeholders in power transmission and distribution, creating the "Smart Grids Task Force", with the aim of elaborating advice to the Commission in developing effective policy measures for the Smart Grids deployment up to 2020 according to the provision of the Third Energy Package. The set-up of a common regulatory and market framework for cross-border electricity trade, as provided by the Third Energy Package, is also pushing towards a common EU electricity market. Such a development will drive a significant increase in transmission capacity and efficient allocation mechanisms, requiring both important investments from TSOs and market operators throughout Europe.

National investments that contribute to bridge the gap between the innovation and the market deployment primarily focus on smart meters and system integration, allowing increased integration of distributed generation and demand response. The European industry is at the forefront in the development and deployment of High Voltage Direct Current technology for long distance transmission, with around ten projects planned in Europe in the next decade. Typical investment cost ranges for HVDC undersea cables range today from 1000 to 2000 kEUR/km for the HVDC cable and from 65 to 125 kEUR/MW for HVDC terminals. Flexible Alternating Current Transmission Systems FACTS are also continuously developed in order to improve controllability, efficiency and reliability and ultimately the transmission capacity of existing lines. However, the costs of the power-electronic devices that build FACTS systems are still much higher than mechanical ones, although they represent a concrete development perspective for the European industry. Nonetheless, the increasing deployment of renewable energy generation plants is a driver for the ongoing and planned installation of FACTS devices in Europe. ICT technology, including for data control and system supervision –including Wide Area Monitoring Systems (WAMS) and Supervisory Control And Data Acquisition (SCADA), are also offering the European industry a valuable opportunity to compete worldwide in the power sector. Other markets, such as the storage technologies market, addressed in the previous section, are also expected to contribute and take off with future power grids technologies.

The European power industry is also pointing out the need to remove obstacles, by defining common technical standards and a clear and stable regulatory framework; by fostering social acceptance for new infrastructure as well as customers' engagement in participative programmes. These conditions will contribute to shaping the market deployment pace of future grid technologies.

Technology trends

Electricity grids will need to integrate and connect 34% of total electricity supply from renewable electricity sources by 2020. This percentage is expected to reach 64 to 97% in 2050. Much of the renewable electricity generation will be concentrated in locations far from consumption centres or will be widely dispersed. Future networks for bulk transport of renewable electricity to distant load centres require research and innovation in materials and technologies, as well as in system management and controls. The fluctuation of renewable generation will require enhanced tools to offset this variability with all flexibility options such as active demand, cost effective storage and interaction among various energy networks. Millions of small producers, active loads and flexible grid structures will require equipment and algorithms, policies and standards for sensing, communication and automation of their interaction to ensure security of supply. Grid planning and management will increasingly require a European-level approach, and increasing cooperation among existing players. New players will need to emerge, e.g. to provide energy services.

The infrastructure needs of renewable energy *transport* fuels, covering alternative fuel refuelling stations, common standards and policies and improved management of systems for electromobility are examined in depth in the 2011 Transport White Paper's alternative fuels strategy (White Paper, Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. COM(2011)144 final) and are addressed in the revised TEN_T guidelines (COM(2011)650).

6.3.3. Advanced Manufacturing

The mastery of manufacturing will determine in large parts the capacity of Europe to stay at the forefront of the global industrial competition. High tech manufacturing creates comparative advantages by shifting the price focus from traditional factors such as labour and natural resources to knowledge, a resource in which Europe excels. Manufacturing is a particularly tough challenge that requires a holistic innovation approach. Support should be given to research, development and demonstration activities to develop flexible, multi-product manufacturing systems to shorten innovation cycles and rapidly respond to customer demands and smart assembly systems that integrate effectively skilled workers and automated processes and can open the market for commercially viable small scale systems to be deployed also in emerging markets outside Europe.

6.3.4. Electromobility

Electricity and Hydrogen are energy vectors which can also represent an effective way to introduce renewable energy sources into the transport chain. Battery electric and fuel cell vehicles enable electrification of transport (electromobility), which is a priority in the EU's Seventh Framework Programme for Research and the European Green Car Initiative. Electromobility is a key component of the current EU transport policy ideally suited for densely populated urban areas and which could contribute significantly to reducing CO2 and pollutant emissions from transport. The Green eMotion project financed by the Commission under the Green Cars Initiative connects a range of ongoing electromobility initiatives to compare approaches and promote the best solutions for Europe.

Electric propulsion in road transport could help to optimise electricity and hydrogen production through load levelling and exploitation of intermittent renewable energy sources; excess electricity generated during periods of low demand can be used to produce hydrogen. Furthermore, the use of hydrogen fuelled fuel cell and battery electric vehicles leads to substantial improvements in energy efficiency of vehicles compared to conventional fossil fuelled, internal combustion engine vehicles.

Hydrogen and fuel cell technologies are mentioned in the European Strategic Energy Technology Plan. They were identified amongst the new generation energy technologies that will be needed to achieve a 60 to 80% reduction in greenhouse gases by 2050.