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Progress, barriers, solutions and recommendations for more DER integration in the European electricity supply

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Abstract

The deliverable D4.5 presents an overall and summarizing report of most relevant findings, conclusions regarding the topic of the EU RTD project SOLID-DER, namely “Integration of more DER in the electricity supply of Europe”. It concerns the current position of DER in electricity supply, drivers for more DER and reviews the different technical and economic barriers. But most of it presents the solutions and technical, economic and regulatory changes and policies for increasing the share of DER (RES&DG) in the power supply of all EU countries in the next decades. At the end the report also discusses the most recent developments and issues, i.e. the increasing role of intermittent RES & DG generation and their system impacts that need to be reduced in the future to maintain the reliability levels of the power system. Finally it presents policy measures, regulation and the pending RTD issues necessary to be solved soon to enabling the meeting of the ambitious EU RES targets in 2020 and beyond in all EU countries. The report concerns a review of the:

- Current position of DER in electricity supply
- Drivers and support schemes for more DER in the future
- Technical and socio-economic barriers and recommended solutions for increasing the share of DER (RES&DG) in the power supply of all EU countries.
- Recently upcoming new developments in DER (RES&DG) generation, i.e. the increasing role of intermittent RES & DG generation (wind and PV), and their impacts that need to be tacled to secure meeting EU RES targets 2020.
- Recommendations for policy measures, changes in regulation and RTD priorities, necessary to meet the ambitious EU RES targets in 2020 and beyond in all EU countries.

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Firstly the project coordinator as editor of this final report of SOLID-DER project is particularly in debt to the following persons: Michael ten Donkelaar of Enviros, Pablo Frias and Tomas Gomez both of Comillas, Raul Rodriguez of Labein, Adriaan van der Welle of ECN and other researchers/partners in the project. For more details and background to the final report see the many SOLID-DER reports used for drafting this deliverable. For an overview of all partners and used related projects that have been consulted see listing below.

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Project partners:

- Energy Research centre of the Netherlands (ECN), The Netherlands
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- University of Ljubljana, Slovenia
- University Pontificia Comillas, Spain

This report uses next to SOLID-DER also findings from the following projects:
- DG-GRID project, coordination ECN, finished Sept 2007
- FENIX, coordination Iberdrola, ongoing
- RESPOND, coordination ECN, ongoing
- IMPROGRES, coordination ECN, ongoing
- EU-DEEP, coordination GdF, ongoing
- More Micro-Grids, coordination NTUA, ongoing

The interpretation of the RTD results of other projects is of course the full responsibility of ECN.

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Glossary of abbreviations

ANM	Active network management
AS	Ancillary services
BRP	Balancing responsible party
CHP	Combined heat and power production
DER	Distributed energy resources

DR	Demand Response
DSI	Demand Side Integration
DSM	Demand Side Management
DG	Distributed generation
DSO	Distributed system operator or distribution network operator (DNO) in the UK
ESCo	Energy Services Company
EU	European Union
GCT	Gate Closure Time
HV	High voltage
ICT	Information and Communication Technologies
LV	Low voltage
MS	Member state
MV	Medium voltage
NMS	New member state
PV	Photovoltaic's
RES	Renewable energy resources
RTD	Research and Technological Development
TGC	Tradable Green Certificates
TSO	Transmission system operator
UK	United Kingdom
VPP	Virtual power plant

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Summary

Background

About ten years ago started a new focus of policy makers on the possible benefits of more decentralisation of electricity production, i.e. small size generation connected to the distribution networks, main argument was more efficiently meeting EU policy objectives such as lowering environmental pollution, improving supply security. Therefore the past trend of increasing scale of centralised power production by the national power utilities had to reverse. Particularly the market liberalisation and growing awareness of negative external costs connected with some of the centralised manners of power generation gave the opportunity for developments, away from large scale centralise electricity production by the vertical national monopoly utility and towards small sized environmental friendly power generation. Today what we see in Europe is a large difference of DER (RES-E & DG) penetration on both distribution and transmission level between EU countries. Some countries, mainly the new MS show hardly any contribution of DER to the system, other countries such as Denmark stand out with more than 30% electricity generated by RES & DG (DER).

Drivers and support to promote a much larger RES & DG integration

In 2008 the EC agreed with the MS on ambitious RES targets for 2020 per country. Today however, the gap between the current RES shares and the ones proposed by the EC is very large for most countries. The majority of EU countries, 16 of 27 countries, have to double their renewable energy share in final energy consumption. A large part of this new renewable energy is assumed to stem from new renewable electricity production. So the share of RES-E will have to become event higher, i.e. between 30-50% in 2020. This is also because intermittent RES-E is increasingly adding more capacity than energy production to the system, the capacity credit decreases and renewable electricity production needs to increase even more in capacity terms to reach the target in 2020. As we can see the focus of policy attention for DER has moved towards an increasing of the share of by RES generated electricity, which is more and more also connected to transmission grids and of an intermittent nature. Clearly meeting these highly ambitious RES targets require support schemes for DER. Feed-in and RPS&TGC systems have proved their ability for that purpose. However to financially sustain this support on a massive scale as is necessary by the EU targets for 2020, the support schemes need not only to be effective but also economic more efficient than in the past, for avoiding a too high rise of budgets for this support and costs to society.

Current technical barriers and solutions for more DER

From our RTD in this DER integration field in selected topics, we learn the following.
Interconnection requirements: critical technical issues need solving by RTD, small generators should be released from tedious, expensive and unfair approval/assessment procedures. European connection standards should be developed, subsequently regulatory adjustments for fair treatment of DER is priority.
Interconnection interfaces: future converters should be more DER dedicated and flexible and universal with integrating so called Smart Grid functionalities
Impact of DG in networks: Modification of protection settings, equipment or schemes; effective solutions for ant-islanding are needed; voltage profile control is necessary; monitoring and forecasting techniques are needed; estimation of DG penetration limits without causing disturbance in the grid should be performed
Active network management: the control system needs real-time monitoring and prediction tools; all types of generation, load and storage devices should be controllable and contribute to network voltage and frequency control
Demand Response and Demand Side Management: the elasticity of demand should be enhanced; technology should be improved and made available; electricity cost based price options should be imple-

mented; Demand Response providers should be promoted (aggregators, ESCOs); DR and DSM could bring environmental and economical benefits to NMS; this might be the right time to start thinking about DR and DSM.
DER Energy Market Integration: More focus should be put on the commercial aspects of DER integration projects; beneficial and social effects should be more considered; investment mechanisms for implementation of DER should be part of the RTD activities. This is necessary to secure that really applicable and improved DER technologies are the outcome projects.

Current socio-economic and regulatory barriers and solutions for more DER
For facilitating a take-off of DER, particularly relevant for new MS, key barriers observed are the frequently changing DER support policies, long administrative procedures (special planning construction permission etc), complicated non-standard connection procedures, discriminatory access rules for small generators, DSO refusals to connect because DER is a negative instead of positive contribution to supply loads etc. Most important recommendations are therefore to create "one stop shop system" for project authorisation, secure a stable and transparent support policy system, and standardize connection procedures by DSO. Furthermore regulators should put in place a more fair allocation over DER and DSO of both the costs & benefits of a DER connection etc.

Generally in EU countries the access to Distribution network and electricity markets and use of both by the DER generators the principal findings are as follows. The future increase of DER penetration in distribution networks poses a new challenge for regulators to adapt current DER and DSO regulations. This adaptation should guarantee that all agents receive efficient location and economic signals.
The connection charges paid by DER producers should ensure fair and non-discriminatory network access. On the other hand use-of-system charges should reflect the real impact on costs due to DER production. The participation of DER into ancillary services can improve the operation and planning of distribution networks.
In addition, the integration of DER into distribution networks impacts on the revenue scheme of DSOs. Therefore it is important to neutralize this negative effect, and in case of cost reduction, distribute these benefits among DER producers and DSOs. The incremental costs in new investments (CAPEX) and operation (OPEX) due to DER connection should be compensated to DSOs. Moreover, the operation paradigm of distribution networks should change from passive to active management, in order to efficiently use DER to provide ancillary services and then improve performance indicators, such as quality of service and energy losses reduction.

Impacts on power system by high variable RES & DG shares
However recently some countries already now have more than 30% of electricity generated by (intermittent type) of RES & DG, i.e. Denmark, Spain and this share is expected to grow vastly in other EU countries up to around 2020. This poses a new challenge for regulators and network operators to adapt the current DER and DSO regulations to guarantee economic efficient power systems in the future too.

As become clear from recent power market studies in Denmark, Spain, and Germany by EU and IEA, the rapid growth of (intermittent) RES and DG generation, if rising above certain shares (10-20%) of generation capacity in a country, starts to cause technical system impacts. It requires extra measures to compensate for declining generation, balancing and market flexibility and network control, and that will push the overall system costs upward. This endangers the meeting of the EU RES targets for 2020 and therefore needs to be resolved soon. Below follows a brief summary of those measures and options proving the additional need for market and balancing market flexibility and network controllability.

Demand for more *flexibility* in the system drives up peak prices and gives generators the opportunity to achieve a higher rate of return by deploying more flexible generation technologies like hydro and gas based generators in the generation mix. Investing in more *flexible generation and storage* capacity or supplied by other countries by traders through contracting interconnection capacity are cost enhancing. But also investing in network enforcements and *interconnections* are costly for the system

Another options that are able to mitigate (part of) the increase of the *demand for balancing* (by the increasing variable RES-E supply by wind turbines and PV) are possible if using demand response, provision of balancing services by DER, improvement of wind power prediction models and extension of (available) interconnection capacity. The *Demand response* is a concept that seeks to lower demand during specific, limited time periods, by temporally curtailing electricity usage, shifting usage to other time periods, or substituting another resource for delivered electricity (such as self-generation), focusing on when energy is used and its cost at that time. With application of demand response the increased demand of DER for balancing can be met, without endangering system operation.

Finally reduced *network controllability* may be enforced by implementing *active network management* and (related) options like flexible deployment of DER, demand response and storage. In summary all these compensating measures increase or will increase in the future the overall system costs.

Policy and regulatory changes for coping with large variable RES & DG shares

All recommended measures both on support policies, system rules and regulation are focused on creating new system conditions that promote the economic efficient development of RES & DG, while securing sufficient market, balancing and generation flexibility and network control in the short and long run.

For increasing *generation & market flexibility* an efficient dispersion of renewable production over countries is necessary. Furthermore *support schemes need to be more market prices related and different schemes should become more harmonised* between the different EU member states. At least to an extent to facilitate that RES & DG, i.e. wind turbines are deployed optimally across Europe. Also the introduction of a single *European market for tradable guarantees of origin* is of the utmost importance for steering investments in an efficient way to countries with the highest resources or potentials to meet the EU renewable targets for 2020. Improved *coordination between TSOs,* while capacity allocation can be enhanced by using market based mechanisms like implicit and explicit *auctions for cross-border trading*. For the day-ahead and intraday time frames implicit auctions are most efficient and therefore have to be promoted.

Measures to *increase balancing market functioning* are the introduction of *balancing responsible parties (BRP)* is advised to limit the size of the imbalance between scheduled and real production and demand. Consequently, the TSO has to dispose of less balancing power to fulfil his system balancing task. Also give *DER balancing responsibilities* for their imbalance by giving them an incentive for taking into account the effect of their operations on the system. Furthermore use the potential for balancing available through *demand response*. Add balancing services *by DER through VPP* is already the case in some member states (Germany, The Netherlands) and expected to be a valuable option for other countries in the near future. However, the required minimum size for provision of balancing services differs a lot between countries.

Improvement of wind power predictions can be furthered by BRP as well as by shortening the gate closure time (GCT) of the day-ahead market. Through implementation of balancing responsible parties, generators and suppliers receive an incentive to improve their wind power predictions and limit their imbalance exposure. Reduce *the gate closure time of the day-ahead market* is also strongly advised to limit the demand for balancing services due to intermittent generation.

Measures to increase *network controllability* are to implement for distribution networks (DSOs) *active network management* i.e. higher visibility of distribution networks components, generation and load, and consequently steering of distribution network flows will reduce system integration costs of DG in most cases. In the short term, monitoring and controlling of a part of distributed generation and load seems to be enough in most countries to reduce system integration costs. Implement regulatory rules enabling *DSOs to be indifferent* between new investments and i.e. deployment of DG for network planning. Take into account the impact of unbundling on the development of *other flexibility enhancing options like storage* for flexible network operation, when separating networks from commercial activities, i.e. unbundling. Apply the different *congestion management methods* for allocation of cross-border capacity, currently applied across Europe. Create *more coordination between TSOs* for cross-border congestion management in order to increase the efficiency of the allocation and foster the integration of RES generators. Legal provisions need to be implemented on a European level. Apply *time-of-use network pricing* for both large generators and load is advised for maximising the use of the existent network capacity, thereby limiting the system integration costs of renewables.

Recommended RTD on pending DER integration issues
From our in SOLID-DER conducted research and discussions with stakeholders in conferences and National seminars we conclude on the following RTD priorities. The most pending DER integration issues, which are requiring more RTD today, are in the area of providing in time "DER integration solutions" that facilitate and secure the power system to accommodate really large volumes of variable type of RES-E generation and supply in 2020 and beyond. Most of this technology options are also mentioned in strategic documents of EU Smart Grids Platform.

The priority lies on solving *real-time monitoring and control* issues because nearly all RES & DG and loads will have to be able to contribute to the steering and controlling of network flows by the DSO and consequently thereby contribute to a lowering of the costs of network integration of renewables and DG. Need for *demonstration projects* in that field and changes in the network regulation, i.e. to include (incentives for) *network innovation by DSOs* and supporting the market actors to market conform behaviour (investing & operating).

Real steering of load requires furthermore the *installation of systems at households to curtail* upon request some load automatically when prices are high. This asks for new communication infrastructure between DSOs and loads, extensive use of ICT and high data handling capacity of DSOs. Small scale demonstration projects are needed to get more insight in potential problems and to determine more precisely benefits and costs of real time network pricing. RTD on the different *storage options* for distribution and transmission network load management should be pushed.

Advanced regulation for and implementation of Smart Metering of demand which is a strong prerequisite for implementation of real-time pricing, peak pricing etc requires also much extra research efforts. This is urgent for the installation of smart meters which show data for short time intervals (for example for each quarter) for enabling automatic meter reading by DSOs for frequent informing and billing of consumers etc and consequently support a more flexible consumer response to variable supply loads and electricity prices.

Final recommended is also RTD on the improvement of *wind power prediction tools, i.e. models, methods and data* to improve the load flow analysis and management by TSOs. On a European level improving the efficiency of load flow analysis is important as input for European transmission model for maximizing interconnection capacity available for market parties etc.

1. Introduction

In European member states, in the last decade the public goal of developing a more sustainable energy system and liberalisation of electricity market in EU promoted. The main policy idea behind it was that decentralised and close to the consumer operating generation plants could better, more cleaner and efficiently (lesser transport costs etc), so against competitive costs supply the customer with electricity. This was a reaction on the continuously increasing scale of centralised electricity production per site location that took place in the last decades. During the last ten years the policy support for small scale power generation has also driven the growth of distributed energy resources (DER), connected to the distribution networks, see Figure 1.1. Recently however the increasingly generous support schemes in several EU countries, i.e. Denmark, Spain, Germany, did also promote the building of many wind energy, PV and CHP plants, connected to both the distribution and transmission network, leading to technical system impacts that raises the overall system costs in these EU countries.

The overview of DER penetration in power systems of 25 European member states in 2005, see Figure 1.1, demonstrates furthermore the large differences in DER penetration between countries.

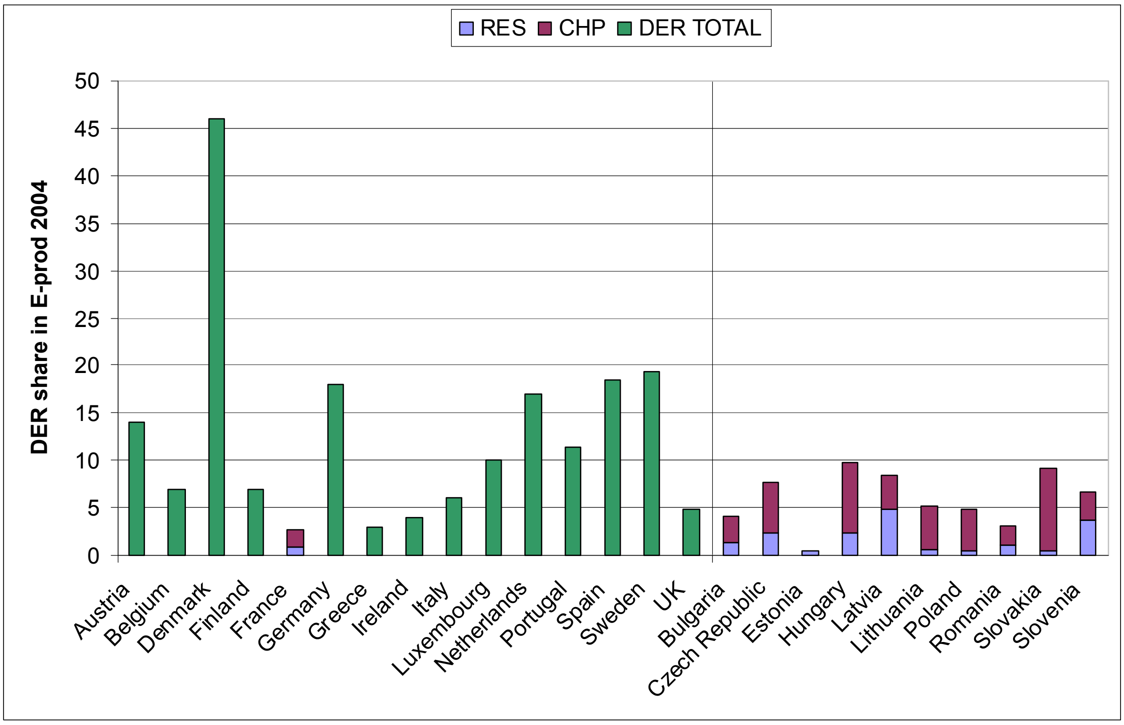

Figure 1.1 *DER share in total electricity production in 2004*

For calculating the DER penetration figures only sources which are connected to the distribution network are taken into account (this definition of DER, which is consistent with the EU Electricity Directive 2003/54/EC, has also been followed in phase 1 of the SOLID-DER project. Therefore large-scale sustainable generation, i.e. offshore wind, onshore wind connected to transmission networks, co-firing biomass in coal power plants, large hydro (> 10 MW_e) and large CHP (> 50 MW_e) is excluded from Figure 1.1. The figure shows that seven countries have a combined DER and CHP share in total electricity production above 10%, but only one of them above 20%. Differences between member states can be explained by different potentials for RES and CHP and from different energy policies in the past. The DER share in electricity supply has the potential to increase rapidly in the future, see next chapter 2 on the EU policy objectives and drivers for more renewable energy and energy efficiency (20% in 2020).

Because of the great differences in the contribution of DER per country today and for simplicity of arguments, for analysing the barriers and recommending solutions for pushing the DER penetration in the EU, we distinguish between two different DER integration phases in a country. A first phase in which DER faces barriers that hinder a simple take-off of DER and a second phase in which the shares of RES and DG have risen above 5-10%, requiring changes in network regulation and DER support policies to secure efficient operation of the power system.
Finally we distinguish a system situation where a increasing larger part of the RES & DG generations consist of intermittent type of those RES & DG sources. Only few countries experience this situation today but almost all EU members will near that situation around 2020 when EU target are met. The so caused increasing reliability and safety concerns in the power system, require compensating measures causing an overall rise of system costs instead of lowering it.

These cost impact is of course also depending on specific type of DER technology, power system conditions etc, characteristics which are different per country and network, see Scheepers et al (2007). The declining system efficiency is mostly caused by a penetration shares of more than 10-20% of more intermittent type of RES & DG in the system, particularly wind power and photovoltaic's (PV). One could consider these increasing system cost impacts a "new barrier for a further large scale DER deployment" in the electricity supply system. Already today for some EU, but in the future for all EU countries an important issue to solve (in meeting EU RES targets 2020).

The structure of the report is as follows. In the next chapter 2 the current drivers for even more integration of DER (RES & DG), the EU policy objectives including the current support schemes that are pushing much more DER to connect are discussed. Next in chapter 3 the current technical barriers and solutions are reviewed for more DER integration. In chapter 4 the current socio-economic and regulatory barriers and their solutions are presented that hamper connecting more DER to the networks. Furthermore in chapter 5 the system impacts, both technical and economic caused by increasing generation of electricity by variable type of RES & DG are summarised.
In chapter 6 the recommended regulatory and policy changes (including the necessary improvements of support schemes) that are needed to secure also a more efficient large scale integration of (intermittent) DER in the future are presented. Finally, in chapter 7 follows an overview of RTD suggestions for solving the pending issues hampering a large DER integration in 2020 and beyond in Europe.

2. Drivers for more RES&DG integration

2.1 Current Policy drivers

Last years the importance of the EU goal of developing a more sustainable energy system has been increased resulting in the formulation by the EU and Member States of concrete policy objectives for RES shares in MS, reduction of CO_2 emissions and energy efficiency targets in 2020. In this context, the importance of an effective and efficient support policy and network regulation for overcoming pushing more RES and CHP in the power systems of EU countries has again a high priority.

As the EU policy goals are defined in terms of a RES share of energy consumption originating from renewable energy production connected to both distribution and transmission networks, it is also important to take into account the large scale renewable energy sources directly connected to higher voltage networks. Moreover, since the electricity production of (offshore) wind parks is increasing, which are directly connected to transmission networks, only considering distributed renewable energy sources in our analysis is not longer sufficient. Therefore, in Figure 2.1 renewable energy sources connected to both transmission and distribution networks are taken into account. The figure shows the part of final energy consumption that is met by energy production[1] from renewable sources in two sectors: electricity generation, heating and cooling for EU-27 countries. In this case renewable electricity generation includes hydro, wind and biomass-waste fired generation connected to all network voltage levels.

The Figure 2.1 clearly shows the large gap between the current RES share and the by the EC proposed energy share from renewable sources for most countries. The majority of EU countries, 16 of 27 countries, have to double their renewable energy share in final energy consumption. A large part of this new renewable energy is assumed to stem from new renewable electricity production. Since intermittent RES is increasingly adding more capacity than energy production to the system, the capacity credit decreases and renewable electricity production needs to increase even more in capacity terms to reach the target in 2020.

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[1] By definition, energy consumption has to be equal to the sum of energy production plus energy imports minus energy exports. We suppose that trading of renewable energy remains limited given the current draft EC directive.

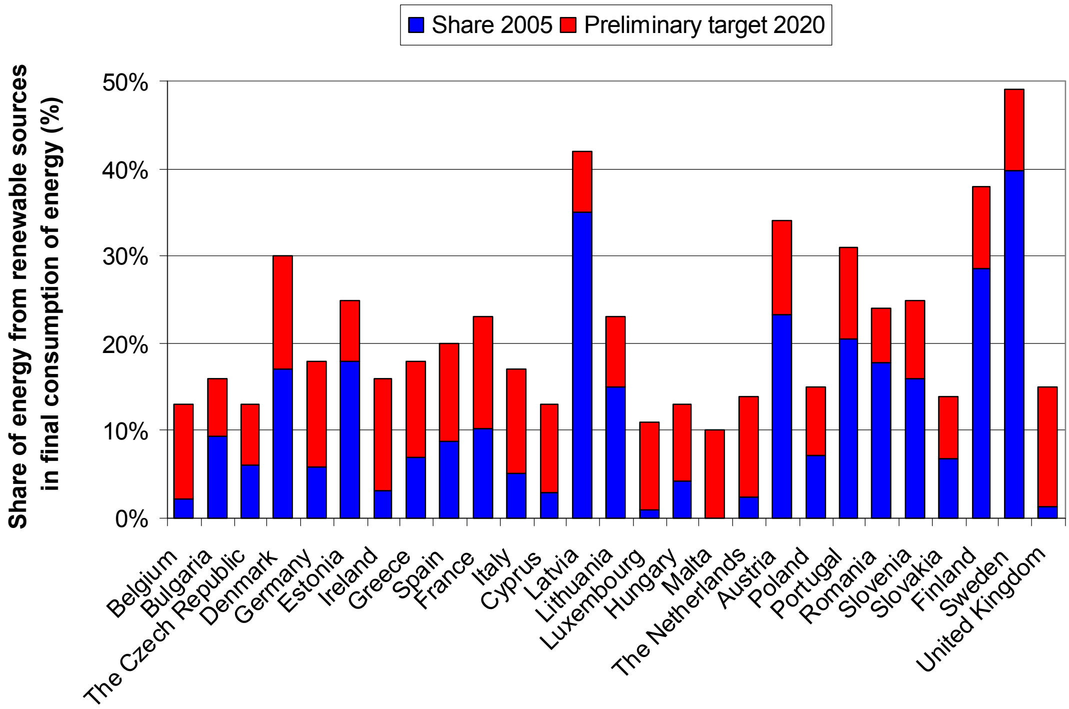

Figure 2.1 *Share of energy from renewable sources in final consumption of energy in 2005 and preliminary EC target for 2020 (source EC, COM 2008 (19) final)*

To meet the ambitious EU RES targets for 2020 the different national support schemes in EU countries play a key role. These DER support schemes have been studied by SOLID-DER and the main findings are presented in the next section.

2.2 Support Schemes for implementing EU policy targets

Currently different policy support schemes and instruments are available in the EU countries for increasing the deployment of the more expensive renewable energy technologies like investment or production subsidies, soft loans, tax exemptions and other support schemes. Subsidies can take different forms like feed-in tariffs (FIT), feed-in premiums (FIP) and renewable portfolio standards (RPS) with tradable green certificates (TGC).[2] Besides, network regulation influences the deployment of renewables in the power system through requirements to generators for connection and system use.[3]

In order to meet the increasing EU goals in the short time (i.e. targets 2020), effective and economic efficient support policies are an important instrument. Different kind of support schemes have been developed during the last decade in different EU countries, of which FIT and RPS&TGC are the ones mostly adopted. This gives rise to two kinds of issues:

- Production support schemes are often not in line with efficient system design, as in the design of these schemes no attention is devoted to the network and system integration costs due to a higher penetration of DER in the system. The support schemes are optimised to their production impact instead of their impact on the system as a whole.
- In systems with a relatively large penetration of DER in the system (say 15% or more), feed-in tariff system is overall becoming economically less efficient if considering the overall socio-economic cost/benefits to society. During the latest decade, the feed-in schemes were very successful as they result today in large shares of RES & DG in Germany, Denmark and Spain. However at the same time the overall system efficiency has also declined

[2] In SOLID-DER report (Donkelaar M ten, et al., 2008) the different production subsidy schemes are described.
[3] In SOLID-DER report (Cossent et al., 2008) network regulation is analysed.

in several countries as the deployment of DER coupled with high feed-in tariffs has increased the cost burden for end consumers for two reasons.

- First the efficiency gains are not passed on to consumers in the form of lower electricity tariffs and
- Secondly large shares of often DER generation of a intermittent supply nature needs extra measures to secure the reliability and safety of the power system and supply.

Therefore, a call for more efficiency is heard from many experts (see for instance IEA, 2007).[4] On the other hand, several countries with alternative fully market-based support schemes like RP combined with TGC need additional measures to assure to meet the national RES targets in the EU agreed for 2020.

Conclusion is that for meeting the ambitious EU targets of renewable energy supplies (RES) and combined heat and power (CHP) aimed for by the EC and individual MS in 2020 the effectiveness and efficiency of the policy support schemes and market and network regulation in place plays a decisive key role. Conclusions is clear failures in having in time in place in EU countries the appropriate market and network regulation and taking account insufficiently the environmental externalities and inefficient support schemes might lead to an insufficient deployment of RES and CHP in the electricity market. So therefore timely and appropriate other related measures and actions are also necessary, see as discussed below.

For an overview of recommendations to improve the economic efficiency of the current support schemes for promoting more RES-E and DG into the power systems in all EU countries, see chapter 6. A more extensive overview and analysis of all support schemes in the different EU Member States can be fond in the SOLID-DER report D1.3-Part B (M ten Donkelaar et al., 2008).

4 IEA (2007), 'Energy policies of IEA countries – Germany 2007 review'.

3. Current technical barriers and solutions for more DER

Since the current contribution of DER into energy supply differs highly between member states, the barriers and challenges to more DER integration are not the same for all EU-25 countries. Therefore it is useful in the analysis to make a distinction between barriers that even hinder a small DER contribution or the connection of a limited number of RES-E and DG generators to the grid and those "barriers" that emerge when more and larger amounts of often intermittent type of DER generation have to be integrated in the country power system. In the latter situation the system costs may rise instead of decline at a certain number and capacity connected to the distribution networks. And if these RES & DG shares are mainly consist of intermittent type of RES & DG technologies the system cost can even rise strongly instead of lowering (which is mainly due to lowering of network losses), implying a decline of the overall economic efficiency of the power system with penetration of DER in old traditionally functioning power systems. Some experts suggest, depending on the specific power system characteristics, that this critical point is reached if the share of intermittent supply is around 10-20% of total supply.[5]

In this chapter we discuss the technical barriers and their solutions. These are mostly occurring in new MS, but also valid for EU-15 countries. The barriers and solutions regarding the situation emerging thereafter, are more complex and focus on facilitating more DER while reducing the increasing system costs otherwise resulting. In the chapter 5 the impacts caused by large scale penetration of (intermittent) DER are discussed. These issues are also the focus of our formulation of RTD priorities for securing more RES-E and DG in the next decades.

3.1 Current technical barriers

Note that before joining the EU, the candidate countries from Central and Eastern Europe had to implement many EU-directives.[6] Furthermore, many other additional commitments regarding electricity system were made by governments of diverse new member states, like the shutdown of old nuclear power plants (Bulgaria and Lithuania) and the decrease of large emissions from coal plants and phasing out of coal mines. So, the pre-liberalisation organisation of the current power system and its structure are responsible for part of the barriers for DER today in new MS. At the same time new MS have to meet push the integration of DER into the power supply according to the RES EC Directives, which is a real challenge to their current technical power system structure.

In the past fifty years the current electricity networks have been developed and designed for supporting the connection of large-scale centralised generated electricity to the higher voltage levels. Therefore, the power flow is largely through transmission to distribution networks, and then on to end consumers via a series of voltage transformations i.e. unidirectional. Renewable generators are only present to a small extent and connected to lower voltage levels, with PV units mainly connected to the LV distribution network while onshore wind turbines and biomass units are connected to either MV or HV distribution networks. Figure 3.1 below shows the network architecture in the power system as a whole.

Some NMS do have a quite low share of distributed generation at the moment and therefore are not facing major problems with integrating DG in the system (Lithuania, Bulgaria and Slove-

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5 This critical point not only depends on penetration but also on the proportion of generation and load connected to the different network nodes ('location'). A large imbalance between production and consumption increase the demand for network and supportive system services.

6 In 2004, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia entered the European Union, followed by Bulgaria and Romania in 2007.

nia), while in other countries the share of DG is steadily increasing (Poland, Hungary). In the latter countries, in general three types of technical barriers for DER can be distinguished: (1) shortage of flexibility in the power system, (2) shortage of balancing power, and (3) lack of network controllability.

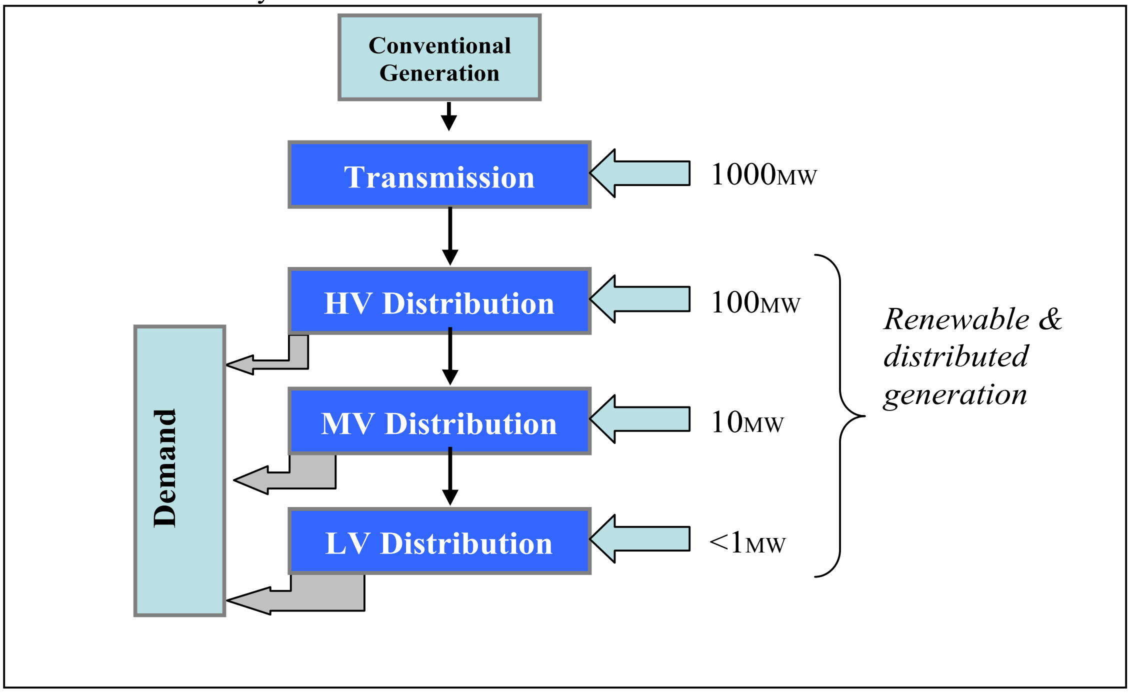

Figure 3.1 *Connection of various forms and sizes of distributed generation to distribution networks (HV: High Voltage; MV: Medium Voltage; LV: Low Voltage).*
Source: RESPOND, D4 report: Ramsay et al. (2007), adjusted.

The first is due to generation characteristics, such as domination of coal and nuclear power plants (Bulgaria, Czech Republic, Poland and to a smaller extent Hungary). A lot of base load generation means lesser peak load generation capacity and consequently a less flexible power system. Such a power system makes it difficult to absorb intermittent renewable generation, since a shortage of peak capacity may evolve which is needed to back-up wind generators especially during hours of less wind. Also fast ramping up and down of generators for being able to follow DER power fluctuations is not possible with nuclear generation, and only to a limited extent with coal power plants. Besides, part loading of coal power plants will lower efficiency and increase emissions of polluting substances. Finally, the shortage of flexibility in the system is demonstrated by the lack of balancing power, mainly downward regulating power in some countries.

Mainly due to shortage of balancing power, system operators tend to set upper limits to the allowed new DER generation (for instance Hungary for wind power units: a maximum of 330 MW[7]) or are considering to do that (among others Czech Republic, Lithuania).

Lack of network controllability is due to weaker grids in some countries that currently need to be adapted to rapidly increasing electricity demand due to high economic growth. These weak grids may pose many DSOs for technical integration problems related to voltage rises, harmonics and increase of fault currents when DER is connected to the system (Bulgaria, Poland, Lithuania)[8]. Also the use of national interconnection requirements which are stronger than really necessary may create an extra burden and so a barrier for DER units to be connected.

[7] See task 1.2, p. 11.
[8] Part of the country-specific impacts are derived from Blazic et al. (2008), SOLID-DER WP 2.

Although NMS probably experience stronger effects of these barriers, the existence of these three types of barriers is not limited to countries with a relative low penetration as will be shown in the next section.

3.2 Solutions to overcome the technical barriers

Below follows an overview of main RTD conclusions and recommendations being a result of collecting the latest findings in different on-going national and EU projects, country level questionnaires and discussions with stakeholders in the EU countries at the national seminars organised by SOLID-DER.
The objective and approach of the work was to monitor and assess the technical breakthroughs, innovations and findings in meeting the Research & Development needs in DER interconnection, the optimal management of networks and the integration in energy markets. Four priority RTD areas selected were:
- Interconnection Requirements and Interfaces
- DER integration and Active Networks Management
- Demand Response and Demand Side Management
- DER Energy Market Integration

A great number of international, EU and national projects deal with DER integration, each from different points of view. Nowadays, it seems that the presence of DER in the electricity networks of the future is widely accepted. In relation with this, many efforts are carried out currently to figure out how networks of the future will look like. Concepts as Smart Grids, active distribution networks, etc. are deployed and studied. All of them assume the existence, in harmony, of distributed generation, storage, demand response, power electronics and communication, together with the already existing big central generation plants and transmission networks. According to this, the network of the future will be, on the one hand, more complicated but, on the other, more flexible and efficient.

In the SOLID-DER project many of the ongoing and already finished projects on integration of DER in electricity supply in Europe are used for updating and providing the latest insights and RTD developments useful for other institutes and market actors to know. The Table 3.1 summarises the main topics studied in SOLID-DER for a better integration of DER into the network and supply. Table 3.1 also shows some of the important aspects analysed in the different RTD areas/topics and some of the presently ongoing or recently finished EU projects dealing with it.

Table 3.1 *Overview of research topics and projects on fostering the increase of DER penetration into the electricity supply*

TOPICS	ASPECTS	PROJECTS
DER Interconnection to the network	Standards, Power electronics (interfaces). Regulation	Solid-der, DER-Lab, Dispower, DGFACTS, Microgrids…
Active Networks	ICT, storage, forecast, power electronics, dispatch centres, network cells	Solid-der, Crisp, Microgrids, More Care, Reliance, Danish cell project…
Demand Response and Demand Side Management	Raising awareness of consumers, incentive types	Solid-der, EFFLOCOM, EUDEEP, CRISP…
Microgrids	Islanded operation	Microgrids, More Microgrids
Virtual Power Plant	Technical and economical management of resources	FENIX
DER support to the network	Ancillary services	FENIX
Network Balance	Storage, CHP + wind, DSM/DR	INVESTIRE, DESIRE, RESPOND
DER impact into the grid	Hosting capacity	EUDEEP
Network planning	Based on probabilistic approach,	ELEP

	hybrid energy hubs	

From these topics, four most important were selected for a more in depth analyses in SOLID-DER. Below the main findings are summarized.

3.2.1 Interconnection requirements of DER

A focal point in this RTD area was to review and analyse the interconnection requirements in Europe, with the aim to identify possible inadequacies and discrepancies and to formulate some recommendations. The main concern was set on the technical aspects for interconnecting DER to the power network, with an objective to validate and refine the conclusions presented in previous works (result of other EU projects), as well as to extend the analysis to EU-27 and the USA. The final objective was to identify the major problems related to interconnection requirements and to raise the awareness of stakeholders involved in the development of standardisation work and a second objective was to assess the status and progress of developments of interconnection interfaces.

Conclusions

Regarding Interconnections are important:
-*Absence of an European interconnection standard* for DER: USA experience (IEEE 1547) and pre-normative work could be positive
-*Inadequate documents,* or the information is not always transparent or easily accessible
-Some documents reflect *lack of experience* with DER, e.g. inverter based DER
-Few documents provide explanation and assessment examples
-Significant interpretation margin is left for some of the technical issues

Regarding Interconnection Interfaces the main conclusions are:
-*Next generation* power converters will enhance competitiveness through lower cost, higher reliability and better performance
-*Innovative topologies* will contribute to performance improvement
-The use of new *materials for semiconductors (SiC)* and *magnetic components* should increase the performance

Recommendations

Regarding interconnection requirements is important:
-These critical technical issues should be further investigated through pre-normative work (e.g. EU Network of Excellence DERlab)
-Small generators should be released from a long and expensive assessment procedure. Availability of certified equipment could reduce costs and the interconnection procedure
-A European interconnection standard should be developed: dealing with all technical aspects related to interconnection
-Regulatory adjustments are necessary and should help technical and organisational measures

With respect to interconnection interfaces:
-Future converters should be DER-dedicated but flexible and universal: they should be able to work with various DG sources (fuel cells, photovoltaic, small wind…)
-DER converters will have to integrate smart grid functionalities, also combined with storage

3.2.2 Integration and Active Network Management

Traditionally, the electrical power system consisted of the transmission system supplied by large power plants and the distribution power systems delivering the electrical energy to connected

consumers. The pressure to change the power system structure began with the introduction of the liberalisation of the electricity market, increasing environmental concern and the availability of new technologies. This resulted also in the advent of Distributed Energy Resources (DER) characterized by a large number of relatively small energy sources. Fuel cells, wind turbines, gas turbines, batteries, photovoltaic arrays and other types of energy sources are becoming an important part of distribution systems that were not designed to accommodate energy production. Also difficulties with controlling of a large number of different sources (e.g. a large number of wind turbines) are asking for reconsidering the so far viable way networks are operated and regulated.
In the RTD area "Integration and Network management" a study and report were executed on "Techniques for DER integration and active networks management", in which both subjects are addressed. It addresses the technical aspects of the impact that DER has, or may have, on today's electrical networks and the question of network topology and control which would facilitate an efficient integration of a large DER shares in electricity supply.

Conclusions
With respect to "The technical impact of DG on networks" are important:
-Impact of DG on the *protection scheme* and *unintentional islanding*, which can endanger the safety of people and equipment involved.
-*Network voltage profile* voltage levels may vary on some feeders and even go beyond defined limits
-*Intermittency of RES,* especially wind power makes it difficult to balance energy production and consumption and also diminishes the overall system stability
-Power quality and network operation *problems already occur* in some countries systems by large volumes of DG integration in some EU countries, i.e. Spain, Denmark, Germany. Network operators are forced sometimes to limit a further DG penetration. The mitigation of these problems is an urgent issue, because it is a threshold to permit a higher penetration.

Concerning "Active network management" the conclusion is:
-The main technical challenge is related to the ***control*** of a large number of DER plants
-Substantial investments will be needed in distribution networks
-The introduction of "distribution system automation" will be slow and gradual

An Active Network must pose the following functionalities:
-It can be divided into local control areas (connected or autonomous operation)
-It must enable voltage and frequency control by means of controllable power sources, loads and energy storage and by means of power electronics, communications (ICT) etc

Recommendations
With respect to the "Technical impact of DG on network" suggestions are:
-Modification in protection settings, equipment and/or schemes
-Anti-islanding protection: effective solutions are needed
-Control over voltage profile is necessary
-Monitoring and forecasting techniques are needed for the mitigation of the intermittency of some renewable energy sources
-Estimation of DG penetration limits without causing disturbances in the grid

Regarding "Active network management"(ANM) characteristics should be:
-Real-time monitoring and prediction tools for consumption, production and electricity prices
-All types of generation, load and storage devices should be controllable and contribute to network voltage and frequency control:
-DG should provide fault ride through capabilities
-Storage devices should maintain energy balance during emergency
-Power electronic will operate standalone and as part of controllable devices
-ICT (Information and Communication Technologies) are an important part

3.2.3 Demand Response and Demand Side Management

The definitions of Demand Response (DR) and Demand Side Management (DSM) are unclear and change from country to country. CIGRE adopted the Demand Side Integration (DSI) term to include all the initiatives trying to influence the electricity consumption. Within SOLID-DER project, the following classification was considered for all initiatives included under these terms:
-*Indirect initiatives* that encourage consumption efficiency increase and demand reduction, e.g., financing of energy efficient lighting, devices…
-Initiatives based on sending *price signals* to customers. Electricity cost is different at different times of the day and this should be reflected by its price
-*Indirect load control* initiatives that force or encourage customers to reduce their consumption during certain periods, e.g., interruptible contracts. Customers must execute the reduction themselves
-*Direct load control* programs where DSO, TSO or programme operators disconnect part of the customer's load. Direct communication is needed.
-Initiatives or *market structures* that allow the participation of the customers offering load reductions in exchange for certain price

Conclusions
The *USA* is the country where DSI measures have been more widely deployed: their power system is over-stressed in some areas. However, the *UK* and Northern countries in Europe are catching up recently and the main reasons to launch DSI initiatives are:

-*Encourage energy efficiency* and demand reduction to reduce environmental impact of energy consumption
-Alleviate *local grid constraints*, which may improve grid *reliability* levels
-*Defer investments* associated to grid reinforcement
-Improve *grid balance mechanisms*

In the EU there exist still a lot of barriers for DSI implementation, among others the reluctance of customers to modify their electricity consumption habits, the lack of information, many restrictive requirements to participate in such markets or initiatives, an immature technology, a lack of profitability due to high initial upfront investment; electricity price structure in the country (retail prices); lack of well organised provision of DSI services.
Particularly for new EU members an assessment of the DSI potential suggested that, among others the following conclusions:
-At the present *safe operation margins exist* in most of the countries but things are changing. -Good quality of supply exits in general but it is poor in some areas
-DSI would bring *environmental and economical benefits* due to fuel dependence and could defer investments in the network
-Now is the right time to start thinking about DSI

Recommendations
Proposed is the following:
-*Enhance the elasticity* of demand with incentives to customers (public and/or private support is important) and raising their awareness (more information)
-*Technology improvement and its availability*, i.e. appropriate type of metering (smart meters), information and communication technologies (ICT), internet based solutions.
-*Price based DSI options* implementation, i.e. the electricity tariffs should reflect the marginal cost of electricity and information should be available for customers
-*DR services providers* should be promoted (via aggregators, ESCOs etc)

3.2.4 DER Energy Market Integration

The focus in this task was to analyse the contribution of public Research and Development to the DER industry. According to the *European Paradox* (Green paper on innovation by the EC, 1995), European scientists were producing world-class science but this was not reflected properly in European economic performances. According to this report, one of Europe's weaknesses lies in its *inferiority in terms of transforming the results of technological research and skills into innovations and competitive advantages.*

Conclusions

Analysis carried out in SOLID-DER project highlights the following conclusions:
-*The "European Paradox" is confirmed:* 40% of the considered RTD projects did not think of the future exploitation of results. The European Commission is making efforts to link research projects and market.
-*Barriers* to the market introduction were, among others, the lack of regulatory visibility and need to improve the DER technology.
-Existence of great gaps between *Research community and Industry* in several key EU projects.

Possible markets for DER technologies and knowledge**,** in the present and near future, are shown in Table 3.2.

Table 3.2 *Market introduction of DER related technologies*

Today	**From now up to 5 years**	**From 5 up to 10 years**
DER prediction tools DG units with additional functionalities	Micro-grids New or improved DER components DER monitoring tools	Distributed network management Energy management systems LV and MV converters for grid support DG output trading methods

Recommendations

Recommended as important for future RTD projects is:
-More focus on the commercial aspect of projects is necessary
-The beneficial social effects of these technologies should more stressed
-More efficient and effective investment mechanisms for DER are needed
-Electricity quality and safety problems should receive more attention

3.2.5 Final conclusions

The studies developed within SOLID-DER work package on Technical and System Constraints for DER integration resulted in sets of conclusions and recommendations addressing the existing barriers for the widespread integration of DER in Europe. Clearly concluded was that a substantial DER contribution needs the technical, engineering and system improvements in several areas at the same time, i.e. Standardisation, Technology, Education, Market implementation, take up of New services.
In fact, a change in regulation would particularly modify the landscape on the way towards a much larger DER integration in the electricity supply and networks. However the elimination of technical and standardisation barriers is a first and necessary step to accomplish a much larger penetration of DER in the energy supply. The elimination of the identified barriers through some of the recommendations presented should, either directly or indirectly, support the increase the role of DER systems in the electricity supply and networks of the EU in the future. See for a extensive and complete analysis the different SOLID-DER reports, i.e. by Rodriguez, Raul et al (2008).

4. Current economic barriers and solutions for more DER

4.1 Current economic barriers and solutions for DER take-off

In countries which did move only recently to more market based regimes, spurs from the past are still visible in their power systems. For instance, the power systems of the Czech Republic and Bulgaria are still for a (large) part state-owned, which may suppress competition on generation markets since governments are losing revenues when they introduce more competition oriented rules. Also generation mix choices (for example, for nuclear energy) taken in the past holds down prices and impedes market access for DER. Furthermore, receiving approval for new production sites is hindered by planning and environmental objections. The effects of DER on other generators, network and system operation are often not taken into account by current support policies, since the kind of support policies usually are feed-in tariffs which are independent of market conditions (Bulgaria, Estonia, Lithuania, Slovakia, Slovenia).

The main network access barriers seem be, next to the lack of rules for DER to be connected to grid, the lack of streamlining of rules and the compliance of all rules by all parties. Heavy and very complicated administrative and legal procedures for new connections, e.g. Poland, Czech Republic, Italy, Spain (see OPTRES project and SOLID-DER phase 1 report by M ten Donkelaar et al, 2006) make requests for grid access by new DER operators, time-consuming and costly. Lack of standardisation of network access regulation strengthens this effect. But also simple refusals by authorities and local DSO to give a permit for building a DG generator or/and connecting it to the distribution network are observed. An overview of the different kinds of barriers with regard to DG deployment that are prevailing in the individual Member States are presented in Table 4.1. Simultaneously, it is evident that even though there are major problems which many countries have in common, they also vary a lot from Member State to Member State. Concerning network constraints, some MS are e.g. struggling with connection delays whereas in other MS the main issue may be the limitation in the network's capacity or maintenance problems. Some aspects have to be tackled at the level of the EU but other aspects should be tackled at the national level.

Table 4.1 *Barriers for DER (DG&RES)*

Barrier	
Connection charges	- relatively high - discrimination - lack of transparency
Network constraints	- limitation in network's capacity - connection delays - maintenance - balancing mechanism
Procedural barriers network	- delayed or complex authorization procedures
Lack of unbundling	- problems resulting from previous vertical integration
Lack of incentive for proactive DSO	- lack of opportunity for pay-back of grid investments - no incentives in regulatory system/ DSO's regard DG as additional complexity in their system - securing of own sites by DSO
Market access	- lack of transparency - high trading fees
Entry barriers	- dominant position of incumbents - no direct/ difficult access to wholesale market - trading mechanism for DG not fully developed/ use of "mediator" for market access
Lack of benefit for DG	- uncertainty (support mechanisms) - lack of reward/ revenues for connecting DG

Based on the barriers mentioned above a number of (country)-specific recommendations have been developed:

- In the development of support schemes, take into account their cost-effectiveness in the long-term and the stability it has to create for investors.
- Complete the unbundling process, not only within the legal framework but also in practise for securing transparency in different interests, costs and benefits of connecting DER to the grids.
- Simplify authorisation procedures for spatial planning and construction permits through a "one-stop shop system" for project authorisation.
- Introduce transparent and non-discriminatory grid connection, grid use conditions as well as cost allocation between DER operators and network operators.
- Market access for DER operators should be ensured through simplified procedures for access to wholesale, balancing and ancillary services markets.

Furthermore an in dept research (by national questionnaires) on different network access policy and regulation did reveal that DER integration is also substantially obstructed by insufficient unbundling of production and supply of networks. While the networks are generally legally unbundled, in practise incumbent power producers are still able to (tacitly) influence the DSO network access policy through affiliated companies. See for these and a more in depth analysis of current market and network access regulation in all different EU countries and its role for more access of DER to the distribution networks and energy markets section 4.2.

4.2 Barriers and solutions for more DER integration

This section analyzes some of the topics related with the access to markets and distribution network of DER producers. Among this topics connection and use of system charges of DER will be first studied. Then, the participation of DER into the energy markets is analyzed. Other important topics such as DSO unbundling are not address in this paper but can be found in the SOLID-DER project report D1.3-Part A by Cossent et al., 2008.

4.2.1 Network access

The incremental costs resulting from the connection of DER in distribution networks is recovered through the network charges. Generally, two different network charges can be identified: connection charges and use-of-system (UoS) charges. A correct design of UoS charges and connection charges is a key issue to ensure fair and non-discriminatory network access.

DER connection charges

Connection charges are used to compensate for the costs of connection of DER into distribution networks. These costs are paid just once, when the network access is approved. Two different kinds of connection charges can be distinguished: shallow and deep charges. Under the deep connection charging DER should pay for all the network reinforcement costs both at the transmission and distribution level. On the other hand, shallow connection charges will only pay for the direct costs of connecting the DER producer to the distribution network. In some cases so called "shallowish connection charges" are used, being these an intermediate approach between deep and shallow charges. The connection charging approach can be of great relevance for DER producers trying to participate in the market.

Table 4.2 *European review of connection charges of DER*

Connection charges for DER	Countries	Structure of connection charges	Guidelines
Deep charges	Czech Republic, Slovakia, Romania, Lithuania[1], Spain, The Netherlands (>10MVA)	Charges are subjected to DSOs or TSOs intervention	Implement shallow charges
Shallow charges	Austria[2], Germany, Slovenia, Bulgaria, Poland, Hungary	Total amount depends on DSOs calculations	Evolve to regulated charges
	The Netherlands (<10MVA), Denmark	Regulated and published charges	Evaluate current scheme

1-Shallowish charges are sometimes used
2-Negotiated lump sums may be added to these charge

According to the review carried out in the SOLID-DER project, half of the analysed countries have implemented shallow connection charges. For instance in Czech Republic, Slovakia, Romania and Lithuania DER must pay for all costs of their connection to the grid, including the necessary upgrades. In Slovenia, Bulgaria and Hungary DER only pay for direct connection costs, and in Poland plants less than 5 MW have to pay for half of the actual connection costs.
There is a trade-off between providing incentives for the optimal and cost-reflective siting of new generation (deep connection charges) and facilitating entry for small-sized DER operators (shallow connection charges) for whom these charges may otherwise be a major barrier. In order to improve the access of DER to distribution networks, avoiding discriminatory behaviours and conflicts, it is recommended that some rules for connection are defined, avoiding negotiations between DSOs and DER promoters. In addition those countries with deep connection charges for DER should migrate to shallow connection charges. Finally, countries applying

shallow charging schemes should define transparent rules in order to establish regulated charges.

DER use of system charges
The UoS charges are periodically paid by all network users, including end-consumers and generators, so that DSOs can recover their allowed revenues. UoS charges should try to (i) reflect the cost incurred to provide the network user with the network service, and (ii) ensure full recovery of the DSO's total acknowledged costs.
According to the European review carried out in the SOLID-DER project in most countries DER do not pay UoS charges (see Table 4.3). Moreover, in those countries which do apply UoS charges for DER, these charges are uniform, making no distinction on location, time of use, etc. For example, in Slovakia, UoS fees are similar to all network users, including costs related with transmission, distribution and system operation. In Romania, UoS charges are differentiated in three voltage levels and eight distribution companies.
Efficient signals should be given to DER according to its real impact on the distribution network operation costs, which are settled by the UoS charges. For this purpose, UoS charges ought to include differentiation per location (voltage level, urban/rural area), and time of use. Moreover, according to cost-causality criterion UoS charges for DER can be either positive or negative, since DER can reduce distribution costs due to energy losses reduction, or investment deferral. Finally, UoS charges should be consistent with the electricity regulatory framework, such as the specific support mechanisms.

Table 4.3 *Use of system charges for DER*

UoS charges for DER	Countries	Structure of UoS charges	Guidelines
No	Czech Republic, Slovenia, Bulgaria, Poland, Lithuania, Hungary Denmark, Germany and Spain	N/A	Implement UoS charging mechanisms.
Yes	Slovakia Austria, The Netherlands	Uniform charges	Structure UoS charges, according to voltage levels, DER size, time of use and power plant location.
	Romania	Differentation by voltage level and location	

4.2.2 DER participation into energy markets

Technically, DER units are able to provide different ancillary services and other network services that can lead to a more reliable and economic efficient operation of the distribution network. For instance, a flexible operation of controllable DER can save investment or defer network reinforcements. In addition, DER can reduce the impact of network outages on customer supply interruptions if islanding operation is implemented in distribution network. Finally, DER under local control or following system operation orders can provide voltage support or flow control when needed by the DSO. Therefore, the quality of the electricity service provided DSO can be improved.
According to the European review different levels of participation in the provision of Ancillary Services can be found among the countries, as presented in Table 4.4. For instance, some countries allow DER to participate into the reactive power control and energy balancing. However, in most countries there is still a non-existent or very low contribution of DER to the provision of AS. In some countries like Lithuania, although DER is allowed to provide ancillary services, its real contribution is still very low. In Romania DER are obliged to provide ancillary services including reserves, voltage control and islanding operation. In Slovakia DER also actively participate into ancillary services, where DSOs can make attractive contracts with DER to provide network support.

Table 4.4 *DER participation in the procurement of ancillary services*

DER participation in ancillary services	Countries	Services	Guidelines
NO	Lithuania, Poland, Bulgaria, Slovenia, Czech Republic	None	Include DG into ancillary services
	Austria, Denmark		
YES	Romania, Slovakia	Reactive power control, balancing market and reserves	Improve the contribution of DG to ancillary services
	Germany, Netherlands, Spain, UK		

As DER can positively contribute to a more reliable and efficient operation of distribution networks, specific schemes should be designed to incentive the participation of DER into the ancillary services. Moreover, the future large penetration of DER may be limited by security constraints, mainly associated with balancing and reserves management. For this purpose the contribution of DER will become a key issue, and should be recognized and compensated by commercial arrangements between the DSO and DER.

4.2.3 Impact of DER on DSO regulation

The connection of DER has changed the traditional scheme of planning and operation of distribution networks, and also in its business model. Under the incentive remuneration scheme for DSOs calculates benefits as the regulated asset base (including demand increase and price index) plus certain performance incentives minus capital costs (CAPEX) and operational expenditures (OPEX). It is clear that the connection of DER into distribution networks modifies the different terms of the DSOs benefits equation, and as DSO is a regulated wire business, it is quite important to study the impact of DER into the DSO remuneration scheme.

4.2.3.1 Incremental costs due to DER connection

The connection and operation of DER clearly impacts on the costs of the distribution activity. The impact of DER on DSOs costs depends on the level of DER penetration in the network (the energy generated by DER locally with respect to the total energy consumption) and the concentration of DER capacity (the physical location of DER units inside each voltage network level). DSOs generally do not benefit for DER, except for cases where DER penetration is low, i.e. below 20%, and for low concentration of these units in the network.

The connection of DER into distribution networks requires in the short-term additional network investments, reinforcements and new equipment. In the long-term the adequate modulation of DER production can help peak load demand management, and therefore postpone network reinforcements. The impact of DER into the operation costs clearly depends on the operation scheme of the DSO. Most countries still operate networks under passive management, with no control of DER unit production. Therefore some costs may arise mainly associated with the higher complexity of the network, and with the increase in the transaction and data management. However, active network management benefits from the contribution of DER to the network ancillary services, and can reduce the total operation costs.

How the incremental OPEX and CAPEX are considered in the accounting of the DSOs depends on the regulatory alternative: cost of service or incentive regulation. Cost of service regulation considers the incremental costs associated with DER connection. However, specific mechanisms should be designed for the incentive regulation scheme, which is the case of the majority of the European DSOs.

According to the review carried out in the SOLID-DER project (see Table 4.5), most countries under incentive regulation have not specific mechanisms for incremental compensation of CAPEX and OPEX, which is the case of Slovenia, Poland, Romania and Slovakia. However in some countries, like Lithuania and Bulgaria, new investments due to DER not covered by connection charges are compensated as any other CAPEX. Finally, in Czech Republic and Hungary all incremental costs due to DER connection in distribution networks are remunerated after the approval of the regulatory authority.

Table 4.5 *Treatment of incremental OPEX and CAPEX due to DER*

Type of regulation	Countries	Incremental OPEX and CAPEX due to DER	Guidelines
Cost of Service	Germany	YES	Migrate to incentive regulation
Incentive regulation: Price or revenue cap	Slovenia, Poland, Romania, Slovakia Denmark, Austria, Spain, The Netherlands (>10MVA)	NO	Explicit mechanisms to take into account CAPEX and OPEX due to DER
Incentive regulation plus incremental CAPEX	Lithuania, Bulgaria The Netherlands (<10MVA)	Only CAPEX	Consider OPEX
Incentive regulation plus explicit mechanisms for OPEX and CAPEX	Hungary, Czech Republic Denmark	YES	DER performance

It is recommended that countries with incentive regulation should implement specific mechanisms to take into account incremental costs due to DER when calculating DSO's allowed revenues. There are several options to include these costs in the revenue formula, for instance include incremental costs in the asset base at the beginning of the regulatory period, or considering DER as an additional cost driver.

4.2.3.2 Impact of DER on performance indicators

There are two main signals used to valuate DSOs performance, which are the quality of service and energy losses. These indicators are used in the DSO revenue formula under the incentive regulation [8].

Quality of service

Quality of service in distribution networks is characterized by continuity of supply (frequency and duration of supply interruptions) and by the voltage and power quality (voltage disturbances). The connection of DER on distribution networks can positively contribute to improve the continuity of supply. However, in some situations DER may produce some problems in the power quality, such as harmonics injection or flickers.

According to the European review, several countries where DSOs are not compelled to accomplish certain quality of service levels yet. Moreover, DER are seen by most DSOs as a potential source of problems rather than a help for network management and quality improvement. That is mainly due to the lack of monitoring and controllability of these sources, together with their frequent disconnections in case of network disturbances.

Recommendations on this topic are in line with the promotion for the participation of DER into the network Ancillary Services. In addition, the efficient contribution of DER to network quality requires a deep transformation of current passive to an active management.

Energy losses

Active energy losses in distribution networks are clearly affected by DER [9]. For low DER penetration levels usually DER would reduce network energy losses with respect to the refer-

ence situation with no DER, as that generation is nearer to the load and electricity circulates through a shorter part of the network. On the other hand, high DER penetration levels would increase energy losses when local generation exceeds local demand and power flows reverse. This effect normally depends on the period of the day.
The impact of energy losses variation on DSOs final revenue depends on how energy losses are treated in each regulation. In the European review carried out in the SOLID-DER project, four different methodologies to treat energy losses have been found (see Table 4.6). Most countries have implemented some way to promote DSO to reduce losses, however none of them take into consideration the influence of DER, thus DER are not rewarded nor penalized for energy losses variation. Some good practices have been reported, such as the Czech Republic, where energy payments to DER are higher at lower voltage levels, which compensates for avoided losses at higher voltage levels.
It is important that DSOs receive economic signals to operate more efficiently, such as lowering energy losses. Therefore specific incentives for energy losses reduction should be designed, in order to share its potential benefits among DSOs and DER. A simple approach for this purpose is an incentive based on area specific and updated "target losses".

Table 4.6 *Impact of DER on losses reduction incentives*

Incentives for losses reduction	Countries	Impact of DER on losses reduction incentives	Guidelines
Actual losses	Austria, Germany	Not considered	Implement specific incentives
Upper limit	Lithuania, Slovenia	Not considered	Incentives beyond the limit value
Buying losses at the market	The Netherlands	DER effect on losses is not considered	Compensate DSOs for incremental losses due to DER, or share benefits
Regulated targets	Czech Republic, Slovakia, Romania, Lithuania, Slovenia, Bulgaria, Poland, Hungary Spain, Denmark	The impact of DER on losses targets have not been considered	Compute targets including DER impact

4.2.4 Conclusions

The future increase of DER penetration in distribution networks poses a new challenge for regulators to adapt current DER and DSO regulations. This adaptation should guarantee that all agents receive efficient location and economic signals.
The connection charges paid by DER producers should ensure fair and non-discriminatory network access. On the other hand use-of-system charges should reflect the real impact on costs due to DER production. The participation of DER into ancillary services can improve the operation and planning of distribution networks.
In addition, the integration of DER into distribution networks impacts on the revenue scheme of DSOs. Therefore it is important to neutralize this negative effect, and in case of cost reduction, distribute these benefits among DER producers and DSOs. The incremental costs in new investments (CAPEX) and operation (OPEX) due to DER connection should be compensated to DSOs. Moreover, the operation paradigm of distribution networks should change from passive to active management, in order to efficiently use DER to provide ancillary services and then improve performance indicators, such as quality of service and energy losses reduction.

Market access

Generally, energy companies are not longer state-owned, or only to a small extent. More competition between generators gradually diminishes large plant margin (overcapacity). For budget reasons (e.g. concern of rising electricity prices to consumers), in the future countries are probably also move gradually on to more market oriented support schemes for DER and balancing. Consequently, the effects of DER production on production of other generators are increasingly taken into account. With the increasing penetration of DER also the contribution of DER to system operation (balancing and ancillary services) becomes important option. However, often DER does not have access to markets due to so called minimum size requirements and grid codes which are prohibitively strong nowadays. However, note that sometimes many administrative barriers for new DER sightings are still in place (environmental, spatial planning etc.), see chapter on barriers for take-off.

Network access

In latter phases of DER integration, grid access and operation procedures and rules are more streamlined and regulated. Since conventional generators in most member states only have to pay shallow connection charges (ERGEG, 2008b), charging deep connection charges for DER generators distorts the level playing field of RES/CHP with conventional generators. Therefore, the majority of countries seem to have implemented shallow connection charges. The remaining costs of grid connection for the network operators can be remunerated by Use of System charges. As this is not yet the case, it is a major barrier for DSOs to connect DER in a lot of countries today.

Network access policy is slightly less obstructed by insufficient unbundling of production and supply of networks compared to the case of lower DER penetration, since more advanced forms of unbundling are already or will be implemented in some countries in the near future (i.e. functional unbundling, ownership unbundling). This might somewhat diminish the probability of incumbent power producers to (tacitly) influence the DSO network access policy through affiliated companies. Question remains, whether this form of unbundling is strong enough for enabling easy connection of independent DER (not owned by former affiliated companies of DSOs) to the grid. The main conclusions and findings on current market and network regulation and required changes of it in EU MS can be find in Cossent, R., Frías, P. and Gómez, T. (2008), "Current state of and recommendations for improvement of network regulation for large-scale integration of DER into the European electricity market, D1.3-Part A, SOLID-DER project phase 2.

5. Impacts on power system by high variable RES & DG shares

Clearly and almost certainly the ambitious European target for RES, CO_2 and end-use efficiency for all MS for 2020 and with the support schemes and policies in the member states in place for implementing them will push a large scale penetration of RES-E and DG generation technologies mostly of an intermittent nature in most of the country's power systems in the next decades. Below we discuss the expected technical impacts and their consequences for the overall system costs for most countries. These conclusions are based on already in other countries, i.e. Denmark; Spain etc experienced effects but also several ongoing and recently finished EU studies.

5.1 Technical impacts on the power system

In some EU countries, such as Denmark, Spain, or Germany, already today a massive increase of DER in their electricity systems has taken place. And in the near future this also will happen in other EU-25 countries, see EC objectives for 20% RES (implying shares of RES-E being around 25 or 35% of power generation) in energy consumption. This will likely result in increasing system costs and subsequently decreasing socio-economic benefits of these much larger (intermittent type of) DER shares if the power system architecture of the past is not adapted to the new RES dominated generation-mix expected in next decades. Consequently it is useful to anticipate on this situation in time by analysing the (likely) impacts and their nature and developing market based cost-effective response options to reduce these negative cost impacts for the system. In general, three main types of technical impacts can be distinguished with regard to a much higher (around 30% or more, depending on the power system characteristics at hand) penetration of mostly intermittent type of DER technologies for generating electricity.

5.1.1 Need for more flexibility in the power system

A higher share of intermittent DER in the system implies that the total supply of electricity will become more variable, unpredictable and more uncontrollable. Consequently, a shortage of system flexibility is created by necessitating other system participants to offer more flexibility to compensate for the higher variability and uncontrollability of DER generation. Given that supply has to equal demand and demand currently cannot provide flexibility, controllable generators with high ramping up and ramping down abilities (gas and hydro based generators) are considered necessary for providing the required additional flexibility. Additional flexibility often implies additional generation capacity for critical load times, while DER is also providing energy during 'normal' system conditions. Therefore, DER displaces the energy of conventional generators but not an equivalent amount of their capacity. This decreases overall generation efficiency, not only because the needed additional investments in generation capacity, but also because of increased part loading of existing plants and increasing cycling of generators (more start-ups and shut-downs). As part of this transition, base load conventional plants are shifted to the margins and may see a reduction in their profitability with increasing penetration of RES and DG. This may affect system security negatively since low profitability does impede investments in generation capacity and a shortage of generation units may arise which must also provide necessary flexibility and required system services.

The shortage of flexibility of generators due to more intermittent DER has also important consequences for prices on spot markets (trade). In a system with a lot of wind generation, through the low operational costs of wind, wind enters early in the merit order of generation and generally will be dispatched when available. Therefore, the supply curve of the system will shift to the right, resulting in a decrease of the market clearing price and a decline of profitability of conventional generation as the most expensive units drop out of the merit order during times of high wind generation. However, since wind generation is nearly uncorrelated with peak demand conventional units for generating electricity are still needed for times of peak demand. Hence, these units have to earn a higher rate of return on their investments during the remaining hours to get their investments back. Consequently, power prices during peak hours are higher. As a result, lower prices during off-peak hours are compensated by higher prices during peak hours and overall price variability of generation rises, making the generation sector as a whole a more risky business for investors. In the end, generation investments have to be higher remunerated, ceteris paribus.

5.1.2 Need for more balancing power

Through the increase of intermittent DER production also the need for more balancing power may rise. First of all, emergency situations caused by unexpected RES and DG plant outage may happen more often, e.g. large wind farms trip off the system during system faults causing large imbalances. Moreover, the need for frequency regulation and reserves will increase with higher penetrations of intermittent sources, making the system facing increasing balancing costs. Balancing costs consist of costs for primary, secondary and tertiary reserves. The additional cost of primary reserves or frequency regulation is considered to be small. In case wind power penetration increases with 20%, the demand for secondary reserves is expected to increase –ceteris paribus- with 3-7% of peak load or capacity in the Nordic countries (Holttinen, 2004), see Figure 5.1. This percentage is highly dependent on the kind of system under consideration, especially security of supply requirements of system operators and differences in gate closure times between power exchanges. Generally, the demand for secondary reserves is expected to grow with a higher percentage of peak load when wind power penetration exceeds 20-30% of gross demand. The demand for tertiary reserves will rise in the same proportion as the demand for secondary reserves.

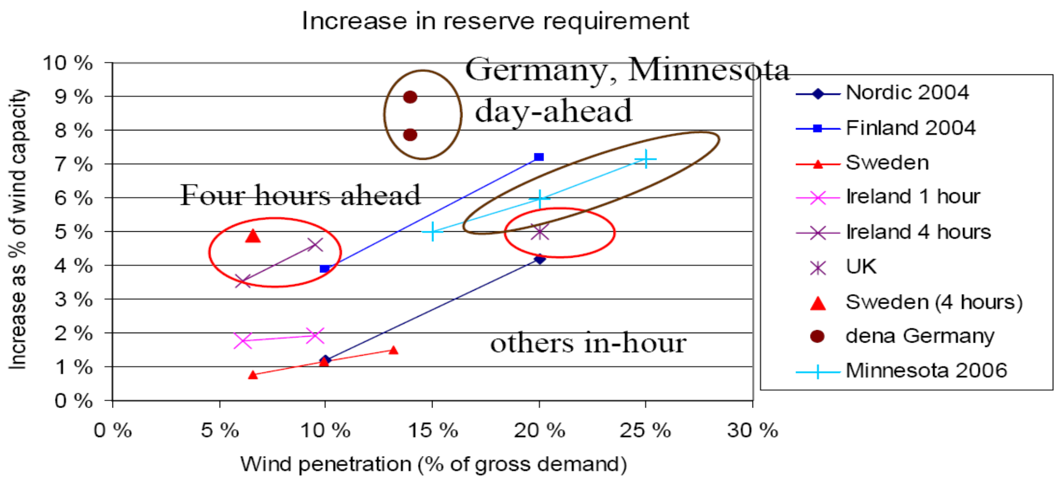

Figure 5.1 *Increase in reserve requirement with higher wind penetrations*
Source: Presentation IEA task 25 by H. Holttinen, GreenNet 2007

5.1.3 Need for more network controllability

A rising penetration of intermittent generation due to high RES targets and concomitant support schemes has important impacts on the networks in many EU member states and hence makes new demands on the power systems in those countries. This is mainly due to the inherent characteristics of intermittent generation, which by definition is uncontrollable, variable and unpredictable. Through incorporating more RES and CHP production in the system, DER intermittency is passed through from production to network operation which has effects on both the short and long term (Holttinen et al., 2007) and on distribution and transmission networks. In the following, the focus is first on the effects on the distribution networks since most DER is connected to distribution networks. Next the impacts of RES on transmission networks will be discussed.

5.1.3.1 Distribution networks

Short term effects

In the period from seconds to minutes maintaining voltage and frequency within narrow bands is an important task of the (distribution) system operator in order to supply customers within the required voltages. Furthermore, system interruptions have to be prevented by reducing the number and duration of system faults below the safe maximum.

Connection of DG has an impact on both voltage profiles and system fault levels. A higher penetration of RES/DG may cause:

- Voltage rise problems in rural networks. These problems occur when the production of DG is high at the end of a circuit and there is insufficient local load to absorb the whole production, resulting in power flows in reverse direction. Hence, voltage levels sometimes rise to a too high level and exceed voltage limits.
- An increase of fault levels in urban networks. A higher penetration of DG increases the power current, which implies more difficulties in discerning fault currents from normal currents making the localisation of the position of faults to repair them more challenging (Meeuwsen, 2007; Ramsay et al., 2007).

Long term effects

In longer time scales, ranging from hours to years, power flows may change as the system architecture changes considerably; with higher penetrations of DG, a large number of renewable generators are connected to all distribution voltage levels instead of mainly a small number of large generators connected to higher voltage levels. This has important consequences for the reliability and security of the electricity system as it influences both the direction and magnitude of the power flows on the network.

On the one hand, since more power is supplied to distribution levels, less power has to be transferred from the transmission level downwards in the chain to the end consumer. On the other hand, a higher penetration of DG implies that power supply from intermittent generation sometimes exceeds the local load and therefore needs to be exported to other regions. Consequently, the excess of power needs to be transferred from distribution networks to the transmission network and upward flows will occur. So while the magnitude of top-down power flows reduces, reverse power flows may occur and the direction of power flows may alternate between top-down and bottom-up. The latter is shown in the Figure 5.2 below (compare to Figure 3.1.)

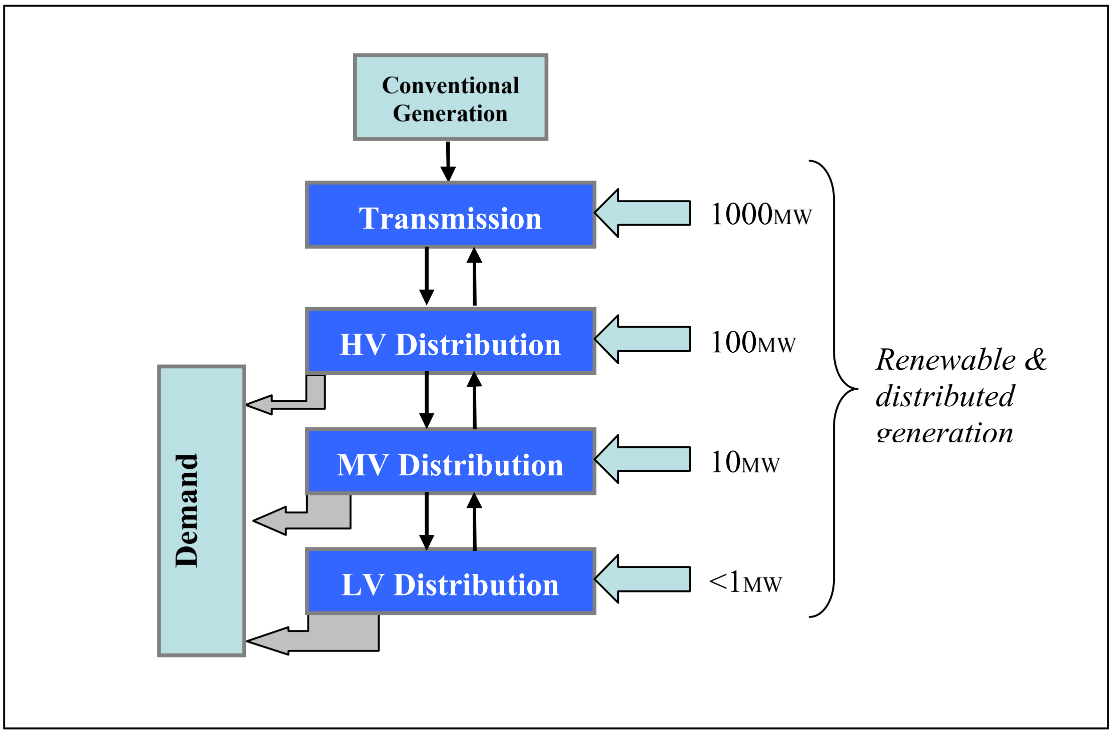

Figure 5.2 *Connection of various forms and sizes of distributed generation to distribution networks (HV: High Voltage; MV: Medium Voltage; LV: Low Voltage)*
Source: RESPOND, D4 report: Ramsay et al. (2007), adjusted

The change in magnitude of power flows implies that both less transmission network capacity and less transformer capacity on the transmission-distribution boundary are needed on the precondition of a small distance between generation and load. Also energy losses are likely to be reduced at lower DG penetrations due to the decrease of power flows. However, the effects on network capacity and energy losses may change if the direction of power flows reverses or more fluctuating flows do occur due to the variability and unpredictability of DG production. As a consequence, more network capacity is necessary for being able to handle those flows, especially flows originating from forms of generation which depend on the availability of natural resources, for instance wind. Wind generation is located far away from load in a lot of cases and therefore necessitates more network capacity investments (transformers, overhead lines, network cables). By definition energy losses are a quadratic function of the size of the network flow. Initially flows and thereby losses may be reduced with more DG, while with higher penetrations of DG placed far away from load losses are expected to increase. As a consequence, the network operator has to deal with a higher number of different and extreme situations in network flow management.

5.1.3.2 Transmission networks

The transmission network has always been used to deal with transporting electricity to the different distribution networks, cumulating in load flows dependent on supply and varying demand. Moreover, the main system services are arranged and controlled by the TSO. Therefore, real time network control is already used for a long time by transmission network operators. Consequently, the transmission networks are better suited to deal with the variability effects of wind (including offshore wind parks which will be installed directly to these networks) and other renewable energy sources compared to distribution networks where the network control usually is resolved in the planning phase.

Nevertheless, due to the strongly increasing contribution in some EU countries, i.e. Germany, Denmark, the variability of RES has increasingly important impacts on the transmission network, both on the short and long term.

Short term
Voltage dips caused by a fault may result in disconnections of a large amount of wind power (depending on the type of wind turbines applied) and endanger the system stability. Therefore, at present fault ride through capability is required from the wind turbines by connection rules part of the grid codes.

Long term
First of all, reverse power flows coming from (rural) distribution networks with surplus of power need to be transferred to areas with shortage of power. The transmission network therefore not only receives power from large scale generators but also has to deal with these additional flows. For including these flows in the network some additional network reinforcements may be needed.

Without reinforcement of the network, at some locations network congestion may occur. This congestion can change the physical flows of electricity through the transmission network and increase the load on networks of surrounding countries ('loop flows'). These loop flows deteriorate the stability of the network and decrease the cross-border network capacity that can be used for energy trading. The latter distorts market functioning leading to higher prices.

5.2 Increasing system costs

The consequences of the above summarised technical impacts on the power systems are a reduction of generation and balancing and market flexibility, network and demand controllability. The compensating this impact by extra measures and investments to compensate these reductions require and imply small extra system costs, which at the end have to be paid by the customer.
The costs of these compensating measures, while still operating in the environment of a traditionally power system framework, lead to rising overall system costs that might be reduced, if in anticipation and in time, sufficient and proper technical, institutional as well as regulatory measures are implemented to change the power system in its operating conditions to cope economically more efficiently with the increasing shares of intermittent type of power generation in the EU. Consequently, in order to avoid a situation where these rising system cost might become a prohibitively too "high cost barrier" for connecting more and more wind and PV generation to the grids, institutional, technical and regulatory changes are urgently necessary in some EU countries as Denmark, Spain, Germany etc. Below in Figure 5.3 the different cost impacts in the system are summarised.

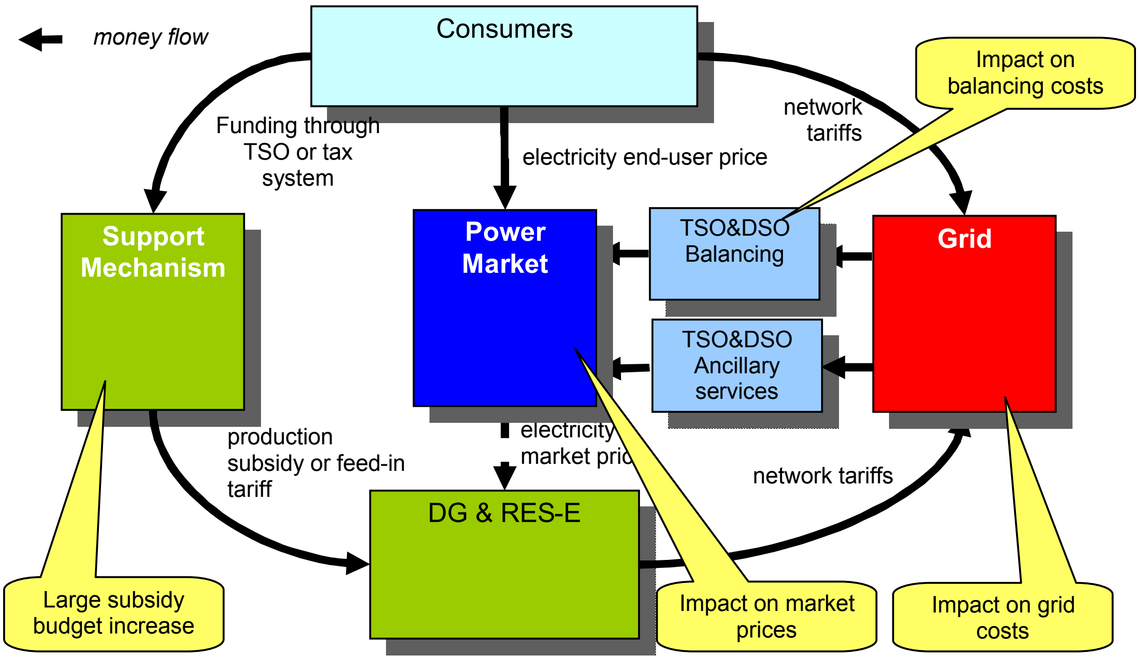

Figure 5.3 *Increase of system costs through large scale connection of RES-E & DG*

For example these costs concern the costs caused by a need for more extra load balancing measures and ancillary services for networks, a much greater volatility of electricity market prices making investments in more generation quicker obsolete or unprofitable, need for extra capacity of the grids etc and finally the steeply increasing RES & DG supporting cost that sometimes serve to compensate or overcome the earlier mentioned system impacts. See for a more elaborated analysis of impacts and cost for example reports by Jacobsen, H et al (2008), Ramsay, C et al (2007) and van Oostvoorn, F and vd Welle, A (2008).

6. Policy and regulatory changes coping with high variable RES & DG shares

As became clear in the preceding chapter, the rapid growth of DER will surely causes impacts that will increase the overall system costs. Particularly if an increasing share of DER is composed of intermittent type of technologies such as wind and PV, a situation already is occurring in Denmark and Spain today and other countries in the next decades if EU RES targets are or will be met in the electricity markets. Consequently these impacts have to be resolved soon. The system impacts can be reduced by a number of technical and institutional "response measures" which also need system conditions (market and network regulation) that stimulate the development of those "response options. In "several recently conducted or ongoing related EU projects (RESPOND, SOLID-DER, DG-GRID, FENIX, EU-DEEP, More Micro-grids) these issues and their solutions are addressed. Thereby is the focus of studies on increasing market flexibility, network controllability and available balancing power. Particularly the work and results of the RESPOND project (see also a chapter in the SOLID-DER report D1.3 Part-C by F van Oostvoorn and A vd Welle, 2008) is relevant.

This chapter presents a brief summary of required institutional and policy and regulatory measures and changes that can promote the implementation of a number of technical and institutional measures to secure a sustainable, flexible, controllable and cost-efficient power system. In this context we start however first with a note on the Improvement of the current DER support mechanisms in the EU countries, based on the SOLID-DER report D1.3 Part B, by Donkelaar et al (2008).

6.1 Improving the economic efficiency of Support Schemes

After a take-off of DER, one should start to remunerate the production of renewable production partially due to market circumstances instead of a standard amount of money. A standard amount of money takes away the incentive to withhold their production at times of low demand (for instance during an early Sunday morning). However with an increasing penetration of DER, FIT gives rise to increasing problems and extra associated network and system costs. More market based schemes like *feed-in premiums* and renewable portfolio standards with tradable green certificates may solve this problem for a large part. Furthermore DER should also be rewarded for the lower energy losses at some locations, avoided network reinforcements, possibilities for DER to solve network congestion and provision of ancillary services. Equally, negative contributions of DER to system operation should be discouraged. A precondition for rewarding the contribution of DER to other markets is a higher level of automation of the power system. Transaction costs of participation of DER in markets and the provision of system services might also be lowered by aggregating DER in *virtual power plants*.

A more efficient exploitation RES (for instance wind or sun) in Europe can be achieved by an EU wide harmonisation of support schemes. Hence, a call for harmonisation today is heard from many recognised experts (Jansen et al., 2005). However securing a fair trading of RES-E guarantees of origin is an important means to implement this. Further promotion of trading possibilities for guarantees of origin through removing restrictions of member states as well as further development of the trading system are another key for meeting the EU goals without much opposition from the consumer side and therefore as efficient as possible.

In summary different types of production support schemes are available now and currently implemented in the last years in the EU member states. However with increasing shares of DER the overall efficiency of the different schemes and their implications for other actors in the power system do not receive sufficient attention which is required for also securing an efficient overall power system operation. Feed-in tariffs and tradable green certificate schemes have led to a high penetration of renewables but without take into account the impacts of DER on the networks and the system operation costs as a whole. Also budget concerns and opposition of consumers against too high tariffs for consumers due to inefficient support schemes are expected to become an issue in several countries. In order to overcome these expected disadvantages, type of support schemes have to be promoted which take into account the specific conditions in the system as a whole. If support schemes like feed in premiums and renewable portfolio standard with tradable green certificates are implemented, DER is (partially) subject to market conditions (like wholesale and balancing markets). Consequently, both easy and difficult system conditions are reflected in prices, which govern the production of DER. As a consequence, part of the DER integration costs for network operators is avoided, consumers have to pay relative lower prices and opposition against (barrier to) more DER is prevented from taking further grounds.

6.2 Institutional and regulatory changes for enhancing market flexibility

Since investment decisions regarding generation and trade are generally left to the market, new investments cannot be directly influenced by government initiatives, but what the government can do is changing institutional setting and boundary conditions influencing (profitability of investments in) DER integration.

Flexible conventional generation
The government may promote *investments in flexible generation units* through changing institutional boundary conditions like access to markets and networks by policy and regulation. Market access can be promoted for instance by constructing a gas network which covers the main (potential) locations for gas powered electricity plants. Furthermore the amount of support that DER is receiving directly or indirectly by subsidies and other regulations (for instance priority network access), implicitly determines investments in conventional units as investors select the type of generation investment on basis of the rate of return of different generation technologies. The rate of return of sustainable generation technology will rise when favourable policy and regulatory decisions for renewables are taken by the government inducing more investments in renewable generation. Consequently, the need for investments in flexible conventional generation will increase at the expense of less flexible generation sources. This effect of support policies on conventional generation needs to be also taken into account when drafting support policies for renewables, see section 6.1 above.

Furthermore, planning procedures and building permits for hydro and gas power plants have to be organised as efficient as possible, given certain democratic legitimacy. This will make market and network access for new generators as easy and cheap (i.e. cost-efficient) as possible. Other possible options are creation of a competition authority with enough power to overcome objections of incumbent power generators and creation of a network regulator with enough power to reduce network access barriers like interconnection requirements and unfair, non-standardised connection charges, among others.

Storage
Many storage technologies are still in the demonstration phase and are too costly for wide scale application yet. The government might stimulate the development of these technologies, but the choice for investment in storage or another flexibility option should be left to the market. In determining the amount of subsidy for this development should be put in a broader perspective of

other options like flexible conventional generation and interconnections. Also should be taken into account, i.e. not to distort the level playing field between options.

Interconnections
In addition to bilateral agreements between different TSOs from neighbouring countries for expansion of interconnection capacity, the construction of interconnections is furthered by the priority interconnection plan of the European Commission to improve market integration. More interconnection capacity favours the development of renewables due to better dispersion of renewable production over countries if countries' generation portfolios are not highly correlated and policy regarding building permissions for new lines and subsidy schemes is not very divergent. The development of renewables therefore calls for some policy harmonisation concerning subsidy schemes. Nowadays with higher market prices of electricity, the subsidy schemes of some countries distort the economic efficient incentives for investment in new renewable generators (type of technology and location) where the largest most cost-effective potentials are in EU or MS. Along with a limited number of new wind turbines that can be installed due to production limitations, this results in main geographical inefficiencies in reaching the renewable goals for Europe as a whole. See for more information about efficiency and other characteristics of subsidy schemes report of Donkelaar et al. (2008).

Furthermore, *power exchanges* are increasingly used for cross-border trading of capacity and/or energy for yearly, monthly, day-ahead as well as intra-day purposes. Since exchanges replace relative non-market based mechanisms like pro-rata allocation and first-come first-served allocation of capacity and energy, they make available more capacity and/or energy to the market.
Exchanges can take different forms: both explicit and implicit auctions are deployed for allocation of physical transmission rights. Under explicit auctions only the network capacity is auctioned to the market, independently from the trading of electricity. In contrast, implicit auctions auction both capacity and energy. The latter are considered to be more efficient, at least for intraday and day-ahead purposes, as the capacity always is provided in the direction of the energy flows, while capacity sometimes is contracted in the opposite direction of the price differential in case of explicit auctions. Furthermore, explicit auctions often imply under-utilisation of capacity when price differential exists (ERGEG, 2008b). Nowadays auctions generally are organised in the explicit form while at the same time there are many plans to introduce implicit auctions in different evolving regional markets in the EU (ERGEG, 2008a). This shift to implicit auctions is also highly recommended for enabling a better integration of RES in the power system.

6.3 Institutional and regulatory changes for enhancing the functioning of the balancing market

Implementing options like demand response and giving DER access to the balancing market, increases competition for provision of balancing power and therefore may lower balancing costs. This may decrease the market power of existing parties supplying balancing power and therefore increases the efficiency of the market. As a result, the balancing costs for wind generators are reduced and the integration of RES in the power system is enhanced.

Provision of balancing services by demand response
Application of demand response can be increased in a lot of countries by changing the balancing market design. There are roughly *two kind of balancing systems*: on the one hand a system in which TSOs are responsible for processing the whole imbalance between scheduled and real production and demand; on the other hand a system with balancing responsible parties (BRP) that are responsible for processing the imbalance of their own generation and demand portfolio. In the latter case, (distributed) generators and suppliers have an incentive to reduce their imbal-

ance as far as possible by own measures like implementing demand response measures to limit the effect of imbalance on their own revenues.[9] Then the TSO only has to solve the imbalance balancing responsible parties are not able to reduce themselves and costs of balancing will decrease considerably.

In a system with balancing responsible parties DER can also easily be made balancing responsible and therefore stimulated to reduce its imbalance as far as possible. However, since the imbalance of DER usually is larger than the imbalance of conventional generators, usually DER has to be compensated for the competitive disadvantage through subsidy schemes (only for efficient costs). In this manner, DER can both assist in achieving lower balancing costs for the system as a whole, as well as remain its competitive position. Therefore, in several MS, including Denmark, the Netherlands and UK this kind of system have already been implemented.

Different *demand response measures* can be implemented: real-time pricing, peak pricing, end user pricing based on hourly day-ahead prices and interruptible contracts (see for a description of these measures below). Out of these measures, only interruptible contracts are useful for balancing since very fast reactions of demand are necessary to be able to participate in the balancing market. The other demand response measures (with the exception of peak pricing) require a lot of communication infrastructure (smart metering) between system operators and demand (consumers), which is currently not in place.

Interruptible contracts can be used to withhold a part of the demand of the market during high need for lower system demand. In some countries[10], large consumers are currently able to take part in the balancing market by signing interruptible contracts with the TSO, since they already dispose of smart metering and necessary control equipment. Net revenues of this option are relatively high as large industrial consumers in practise show the largest demand response while only some kind of standardized contracts are needed between producers and system operator. For other groups of consumers first smart metering needs to be implemented and new ICT systems need to be developed to enable the TSO to deal with the large data amounts of smart metering. Besides, curtailing these customers delivers lower benefits due to the generally higher value of lost load for this customers group.

Provision of balancing services by DER

Virtual power plants may provide DER balancing market access. A virtual power plant (VPP) is defined as follows: a VPP aggregates the capacity of many diverse DER, it creates a single operating profile from a composite of the parameters characterizing each DER and can incorporate the impact of the network on aggregate DER output. A VPP is a flexible representation of a portfolio of DER that can be used to make contracts in the wholesale market and to offer services to the system operator (Pudjianto et al., 2008). When DER participates in a VPP transaction costs of DER are reduced, it is made visible to the system operator and therefore may gain access to the balancing market. Current regulation or requirements of system operators still may impede DER from taking part in this market by requiring a minimal size of generators that are allowed to provide balancing services. Of course such blockades should be removed out of regulation if these are not justified by clear technical reasons. Country practices with respect to DG access to balancing markets are described in Cossent et al. (2008).

Improvement of wind power prediction

Wind power predictions can be improved for balancing market use with two policy or regulatory measures. Firstly, in a lot of countries predictions will improve by changing the design of

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9 From a system point of view, one central balancing organisation instead of different organisations might level out the different imbalances of the whole area better (more geographical dispersion). However, in that case market parties do not have an incentive to decline their imbalance as far as possible. The latter effect is much stronger than the former effect; therefore, implementation of a system of balancing responsible parties throughout whole Europe is recommended.

10 See Cossent et al. (2008), section 4.8.

the balancing market to the already mentioned system with balancing responsible parties (BRP). In that case market parties like generators and suppliers are incentivised to search for further improvements of their wind power predictions in order to limit their exposure to expensive imbalance settlement.

Secondly, the accuracy of wind power predictions are also influenced by the gate closure time of the day-ahead market.[11] At a predefined moment of time trading on the day-ahead market for physical delivery between market participants ceases and intended production schedules cannot be changed to a large extent. The time between gate closure for a period and the start of that period, known as settlement period, varies between countries. The shorter the time between gate closure and operating hour the better wind power predictions will be, since wind power prediction models are better able to predict wind production in shorter time frames. However, the gate closure time cannot be unlimitedly reduced, because some time is needed for the dispatch of some conventional generators with large start-up times. Nevertheless, a reduction of the current gate closure time of 12-36 hours in many countries to 5-7 hours seems possible (since a coal-fired power plant has a start up time of 4-6 hours). Consequently, balancing responsible parties including producers will have to pay less imbalance charges.

Extension of interconnection capacity

More interconnection capacity gives more possibilities for cross-border balancing. Cross-border balancing may diminish balancing costs for DER as balancing reserves between countries can be (partly) shared. Balancing reserves consist of primary, secondary and tertiary reserves. The scope for sharing of tertiary reserves is widest (ETSO, 2006), since primary control is deployed automatically and secondary control is at least partially contracted by the TSO beforehand. Currently, in several regional market integration initiatives cross-border balancing is considered or even planned to be implemented in the short term for promoting a more efficient European electricity market (ERGEG, 2008a) and in the end the creation of a single Internal Electricity Market. Integration of balancing markets is considered necessary for reducing the large variations in balancing market design that currently exist and which are perceived as an important barrier for the developing common electricity market.

6.4 Institutional and regulatory changes for options enhancing network controllability

6.4.1 Distribution network

Active network management

The institutional setting heavily influences the adoption of active network management by network operators. As the networks are natural monopolies, the regulator has to supervise the network operators in order to guarantee an efficient and secure network operation and an efficient extension of the networks, among other objectives. However, it depends on the chosen type of network regulation, cost of service[12] versus incentive regulation, whether or not DSOs are given sufficient incentives for an efficient network expansion. In the first case, network investments are remunerated with a certain rate of return. Therefore, the DSO does not receive an incentive to consider alternatives to network reinforcement like the deployment of DER or demand. In the second case, a revenue or price cap is applied which sets an upper limit to the allowed costs. Generally, this implies that DSOs have an incentive to reduce their costs and so to diminish

[11] Also gate closure times of the intraday and balancing markets are of importance. Since the day-ahead market is most ahead in time when predictions are more uncertain, reducing gate closure time of this market will have larger effects on wind power predictions than reducing gate closure times of the intraday and balancing markets.

[12] Also known as “rate of return regulation”.

their investments in network reinforcements. DSOs thus receive in nearly all countries (see Cossent et al., 2008, for an overview of country practices)[13] an implicit regulatory incentive to look for alternatives to network reinforcements and consequently to apply active network management (see Jansen et al., 2007, for more details about regulatory practices). In Germany at least a shift from cost of service to incentive regulation is needed before network operators will consider active network management as an alternative. This shift is announced to take place in 2009.

However more substantial additional regulatory efforts to accelerate the implementation of active network management by DSOs are needed. First of all, DSOs can be stimulated to perform demonstration projects with active network management. Secondly, network innovation can be encouraged through remunerating DSOs for cost savings through implementation of active network management (see also Cossent et al., 2008).

Besides network operators, also distributed generators and demand can be given incentives to lower costs of the management of network flows and to participate in system operation (see also Cossent et al., 2008).[14] The variation in magnitude as well as the change of direction of power flows due to DER can be limited through implementing *network user tariffs that differ according to time and location*.[15] Consequently, the complexity of controlling network flows may be reduced and lesser parts of the network need to be automated compared to a situation with fixed network tariffs.

Flexible deployment of DG16

At present, payment for flexible deployment of DG is generally not permitted as an option for DSOs to control network flows in current legislation and/or regulation due to priority rules for renewable energy production, which only allow DSOs to consider production adjustments in emergency situations. Changes in legislation and/or regulation therefore are needed to enable production adjustments of DG, for which DG receives a payment on a more frequent but temporal basis for network planning purposes.

Furthermore, the currently applied regulatory regime sometimes impedes flexible deployment of generators as an alternative to network reinforcement by remunerating all investments (cost of service type of regulation) instead of setting a cap to them (incentive regulation). The latter stimulates DSOs to perform more efficient investment policy, and therefore better network planning by taking into account all options to remove network capacity shortage including flexible deployment of DG. By temporally deployment of DG, DSOs will obtain more time to assess whether a certain development is only temporally or structural. Such a long term investment approach diminishes the risk of carrying out many small incremental network investments while it may be economically more optimal to invest a smaller amount of money at once and (temporarily) resolve the remaining problem by DG or another network congestion management method.

Deferring or even cancelling investments may deliver large benefits for DSOs. DSOs should be encouraged to share this benefit with the involved (distributed) generators by a contractual arrangement between themselves and generator. Preferably a regulatory rule should arrange and/or simplify the accomplishment of these contracts. In that way, both the DG operator is remunerated for lost revenues due for not being able to provide energy to the grid and a higher ef-

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13 Cossent et al. (2008), section 4.2.

14 Cossent et al. (2008) elaborate in section 3.2 on the different country practices.

15 Cossent et al. (2008) elaborate in section 4.1 on the different country practices.

16 This might be interpreted as curtailment by some people. However, there are two fundamental differences between flexible deployment of DG and curtailment: (1) flexible deployment of DG is connected to network *planning*, instead of network operation. Therefore in this case production adjustments are well known in advance, while curtailment is only known at real-time or afterwards; (2) it is argued that flexible DG deployment always should be compensated, while curtailment is not compensated for in many cases, for instance ‘force majeure’ cases.

ficiency and security of supply for the power system as a whole can be achieved, cumulating in higher welfare for society.
Finally, deployment of generators for network planning purposes may be limited through implementing location and time dependent pricing in regulation. These types of pricing stimulate the location of generators nearby load and equalize production to demand of the (part of the) distribution network at hand.[17] Implementing *ICT and smart metering* are preconditions for introducing these advanced forms of pricing. Therefore, additional legislative and regulatory efforts may be needed.

Demand response18
Adaptation of demand can be realised by implementation of different institutional and regulatory measures promoting demand response (Jacobsen H et al., 2008)[19] [20]:

- *Real-time pricing.* A strong prerequisite for implementation of real-time pricing is the installation of smart meters which show data for short time intervals (for example for each quarter). These meters enable automatic meter reading by DSOs for frequent informing and billing of consumers. More advanced smart meters dispose of bidirectional communication between metering party (usually DSO) and customer's premises for enabling adaptation of automatic load control appliances like electrical heating, air conditioning and washing machines during peak demand. Automatic load control appliances may be necessary to obtain real benefits of smart metering. Costs of a large scale roll-out of smart metering and concomitant ICT costs of transferring large amounts of data may be relatively high compared to revenues. Estimates of net effects differ a lot between studies.
- *Peak pricing.* Usually customers pay a time of day price and a high peak price at times when it is important to reduce demand. Customers are alerted for these tariffs by a red light on their meter one day before the peak period begins. The costs of this option seem to be small, while benefits for the system as a whole are considerable.
- *End user pricing* based on hourly day ahead prices. Large (industrial) consumers may directly demand power of power exchanges instead of suppliers, or use a supplier only as intermediary to pass through wholesale prices. Hence, they are directly influenced by price changes and will change their behaviour. This kind of pricing is a subset of real time pricing as it is limited to large consumers. Revenues of this option are relatively high as large industrial consumers in practise show the largest demand response, while costs are relatively limited as they can be spread out over a large power quantity.
- *Interruptible contracts*. These contracts are used to withhold a part of the demand of the market during high price conditions. As a rule, only large consumers are currently able to sign such contracts as they already dispose of smart metering and necessary controlling equipment. Revenues of this option are relatively high as large industrial consumers in practise show the largest demand response, while only more or less standardized contracts are needed between producers and system operator.

Storage for network services
At present, the revenue possibilities for storage of providing system services and postponement of distribution network investments are limited due to the current institutional architecture and network regulation.

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17 Another possibility is the introduction of more market-oriented production support schemes, since these can force DG to produce on times of sufficient load, for instance by coupling the support level to market prices.
18 Country practices with regard to time of use pricing, interruptible consumers and smart meters are outlined in Cossent et al. (2008), Section 4.8.
19 Time of use pricing is an already implemented measure in many member states, but is too rough (too little differentiation between hours of the day) to provide flexibility.
20 See also Cobelo et al. (2008).

First of all, this institutional architecture does not promote deployment of distributed generation, demand and storage in network operation ('active network management') in many countries due to insufficient network planning and inaccurate investment incentives. The current institutional stance is also visible in the absence of separate markets for different system-wide ancillary services like regulation, reserves and emergency power (Jansen et al., 2007).

Another issue potentially hindering the use of storage by system operators, is the separation of commercial activities like trading from regulated network activities in order to guarantee non-discriminatory network access to all generators ('unbundling'). Therefore DSOs are not permitted to perform commercial activities like trading by use of storage and hence have to deploy a storage facility wholly for their own, or to hire certain storage capacity from an independent storage facility. It depends on the extent to which storage is used by the network operator whether the former or the latter option is most profitable.

In case of an independent storage facility, the facility operator needs to decide to which market parties it will provide storage services. Therefore the benefits and costs of providing storage for distribution network purposes have to be traded against the benefits and costs of providing storage services to traders, producers and/or transmission network operators. Supposing that the available storage capacity is large enough and divided between DSO and other market parties, also the complementarities of the different services is a relevant factor to consider since demand profiles for services of DSO and other market parties like traders can be opposite to each other; while the DSO may have a daily pattern to shave peak demand, the trader could have a longer time pattern and therefore for instance may prevent deployment of storage capacity during evening peak hours to be able to provide power to the balancing market in the next morning.

Finally, providing storage services to the distribution network will be only attractive if the storage facility is sufficiently remunerated for providing services during peak network demand for services and/or during network constraints. Therefore, storage services should be higher remunerated during these restrictive situations than during off-peak situations without network constraints, provided that storage offers a solution for this constrained situation.[21] This implies that implementation of time- and location variable network pricing is necessary. Use of system charges should be lower for storage devices which contribute to reliability and firmness of the network during network constraints and peak situations.

6.4.2 Transmission network

Network reinforcement/interconnections

The traditional approach to transmission planning is building capacity according to the sum of peak outputs from all connected generation. All generators want to generate during times of peak demand in order to obtain the highest profits. However, this approach is not appropriate for systems with high levels of wind generation, for which output is correlated to weather conditions instead of peak demand. Furthermore, systems with high levels of wind generation demonstrate higher generation margins, implicating peak demand is exceeded considerably with high wind levels. Consequently, it seems highly inefficient to maintain the current approach to transmission planning and therefore sharing of network capacity was proposed (Ramsay et al., 2007). In case not all physical flows can be accommodated at all times by the transmission network, congestion management is necessary. Congestion management is not only applied on a national level, but is also common for cross border interconnections.

In the EU, congestion management for cross-border interconnections is organised by Regulation 1228/2003 and Congestion Management Guidelines 2006/770/EC. One important aspect yet to be analysed and assessed is the efficiency of the congestion management (CM) methods. In

[21] If the congested network node cannot be influenced by the storage facility, for instance if the necessary capacity of the transformer falls short, also locational pricing cannot provide a solution for this congestion problem.

most cases explicit auctions are used, which are less economically efficient for short term capacity allocation than implicit auctions (see Section 0). Efficiency is also affected by the use of counter-trading and re-dispatching by TSOs to alleviate congestion, although it is unclear to which extent counter-trading and re-dispatching are currently used in MS. Another relevant issue is maximising capacity on current cross-border interconnections, which depends on the treatment of curtailment and firmness of transmission capacity, among others.

In summary, promotion of more efficient congestion management requires implementation of implicit auctions in short term frames (especially day-ahead) as well as a better evaluation of the current CM mechanisms in place. For the latter point, it is important that both national regulators and TSOs coordinate there efforts more at a regional level. The legal provisions for that are presently not yet in place.

Storage

At present, the revenue possibilities for storage of providing tertiary reserves and power quality are limited due to the current institutional architecture and network regulation.

First of all, this institutional architecture does generally not promote deployment of storage in network operation in many countries. Providing storage services to the transmission network will be only attractive if the storage facility is sufficiently remunerated for providing services during peak network demand for services and/or during network constraints. Therefore, storage services should be higher remunerated during these restrictive situations than during off-peak situations without network constraints, provided that storage offers a solution for this constrained situation. This implies that implementation of time- and location variable transmission network pricing is necessary. Use of system charges should be lower for storage devices which contribute to reliability and firmness of the network during network constraints and peak situations.

Secondly, issues like unbundling and non-complementarily of services when a (independent) storage facility is operated for both generation, trading and network purposes may prevent transmission network operators to consider storage as an option (for a more elaborate discussion see Section 0).

Improvement of wind power prediction

It is unclear to which extent TSOs currently do consider improvements of wind power predictions for easier and better load flow management. Better forecasts not only will improve load flow management but will also assist to maximise network capacity. The latter may be not of direct interest for TSOs but is a clear advantage for the society. Since the advantage for the system as a whole from better wind predictions is larger than the advantage for the TSO, a kind of incentive scheme seems justified to motivate TSOs to improve their wind power predictions and therefore to maximize network capacity.[22] A possible output-based incentive scheme could be to reward TSOs for the maximum interconnection capacity available during a year, given the maximum line capacity (total transfer capacity) and some standardised transmission reliability margin or, alternatively, reliability margin based on load flow analysis in a common transmission model. Benchmarking of the capacity calculation performance of TSOs can enlarge the incentives for TSOs even further and limit the necessary budget for implementation of such an incentive system.

[22] ERGEG is currently considering the different alternatives for building such a kind of incentive mechanism (ERGEG, 2008b).

6.5 Conclusions

The following measures are recommended in order to increase the ***market flexibility*** for dealing with the integration of large volumes of intermittent RES-E generation in power systems:

- Since EU generation markets are liberalised intervention of the government in the market is minimised. Therefore, policy makers are advised to take into account (unintended) *effects of support policy on conventional generation's* profitability and investment.
- For efficient dispersion of renewable production over countries *support schemes need to be harmonised* between EU member states, at least to some extent, to secure that RES, i.e. wind turbines are deployed optimally across Europe. In this respect, also the introduction of a single European *market for tradable guarantees of origin* is of utmost importance for steering investments in an efficient way to countries with the highest resources or potentials to meet the EU renewable targets for 2020.
- Improvements in capacity calculation and allocation of interconnection capacity enable better dispersion of renewable production across regions. *Capacity calculation* can be improved by *better coordination between TSOs*, while *capacity allocation* can be enhanced by using market based mechanisms like implicit and explicit *auctions for cross-border trading*. For the day-ahead and intraday time frames implicit auctions are most efficient and therefore have to be promoted.
- Besides, *more interconnections* need to be built to enlarge the interconnection capacity available for improving dispersion of renewable production over countries.
- Planning and environmental procedures for building flexible conventional power plants (gas-fired power plants or hydro power) have to be concise and limited in time. A *one-stop shop approach for obtaining licenses* and running through all administrative procedures is highly recommended.

Measures increasing the ***balancing market functioning*** are:

- *Introduction of balancing responsible parties (BRP)* is advised to limit the size of the imbalance between scheduled and real production and demand. Consequently, the TSO has to dispose of less balancing power to fulfil its system balancing task.
- Nowadays, DER is not balancing responsible in many countries. It is highly recommended to make *DER balancing responsible for their imbalance* by giving them an incentive for taking into account the effect of their operations on the system. This will limit the additional balancing power required for dealing with a higher penetration of renewables and further the integration and acceptance of DER by other system participants and consumers.[23]
- It is advised to use the potential for balancing available through *demand response.* Usually the TSO (and in some systems also balancing responsible parties) can enter into *interruptible contracts with large customers.*
- *Provision of balancing services by DER through VPP* is already the case in some member states (Germany, The Netherlands) and expected to be a valuable option for other countries in the near future. However, the required minimum size for provision of balancing services differs a lot between countries. Hence, TSOs should explain why their requirements differ to each other and try to harmonise them. The minimum size of generators that are allowed to provide balancing services should not deviate from or higher than technically effective/reliable in the system.
- *Improvement of wind power predictions* can be furthered by BRP as well as by shortening the gate closure time (GCT) of the day-ahead market. Through implementation of balancing responsible parties, generators and suppliers receive an incentive to improve their wind power predictions and limit their imbalance exposure. Since wind power predictions are better the shorter the prediction period, *reduction of the gate closure time of the day-ahead*

[23] Making DER responsible for its own imbalance does not necessarily mean that balancing is decentralised and efficiency of balancing market is lowered, since DER can still be allowed to transfer balancing responsibility to a balancing responsible party against some costs.

market is also strongly advised to limit the demand for balancing services due to intermittent generation.

Measures to increase the ***distribution network controllability*** are:

- Implementation of *first phases of active network management* i.e. higher visibility of distribution networks components, generation and load, and consequently steering of distribution network flows will reduce system integration costs of DG in most cases. In the short term, monitoring and controlling of a part of distributed generation and load seems to be enough in most countries to reduce system integration costs.
- Implementing regulatory rules which *make DSOs indifferent between new investments and other less costly measures* like deployment of DG for network planning. For instance, incentive regulation with due allowance for both capital and operational expenditures can make this independent stance more likely.
- Take into account the impact of unbundling on the development of *other flexibility enhancing options like storage* for flexible network operation, when separating networks from commercial activities, i.e. unbundling.
- *Priority network access and dispatch* is with increasing generation shares not economic efficient so should be gradually be replaced by more market based instruments and regulation to reduce the negative implications for network operation which ultimately limits the integration of much more renewables in the grid.

Following measures are recommended to increase the ***transmission network controllability*** are:

- Accurate *capacity calculation and allocation of TSOs* is important for facilitating *cross-border markets* (day-ahead, intraday and other time frames). Both maximising the network capacity available as well as an efficient distribution of this capacity (i.e. congestion management) are of utmost importance for enabling a higher share of renewables in the power systems of Europe.
- *Security policies* need to be evaluated and assessed on the basis of their **economic value** in order to prevent unduly *restrictive security policies and therefore a smaller interconnection capacity availability. Benchmarking the capacity calculation* performance of TSOs will reveal policies which guarantee a high security of supply and at the same time a high efficiency. A need to be implemented throughout Europe for a better integration of renewables.
- Different *congestion management methods* for allocation of cross-border capacity are currently applied across Europe. Therefore, *more coordination is required* for cross-border congestion management in order to increase the efficiency of the allocation and foster the integration of RES generators. Legal provisions need to be implemented on a European level.
- *Time-of-use network pricing* for both large generators and load is advised for maximising the use of the existent network capacity, thus limiting the system integration costs of renewables. This kind of pricing may also promote the provision of storage services to the transmission network. Equally, network pricing can give locational signals to large generators and load and in that way accelerate the usage of generators, load and storage by network operators.

Note that some of these options have already been implemented in some countries or do have a low value since other institutional and regulatory measures are already in place. Therefore, it is recommended to survey the different country-specific situations and the whole range of options to be applied on the country level and different SOLID-DER final reports.

7. RTD on some pending DER integration issues

Manny of the SOLID-DER solutions and recommendations in the previous chapters require more research, pilot tests before these can be applied on commercially scale to restructure the current traditional power system into a so called "DER integration friendly power system" in terms of incentives, functionality and its way of operating economic efficiently and able to cope with much larger amounts of (intermittent type) renewables and DG to supply electricity than today. For some EU countries with already today or very soon having to deal with more than 25% shares of wind power (Denmark, Spain etc) these system changes, options and regulatory changes are already necessary today, but for other countries these changes and options need to be available in the next years up to 2020. These system improvements having priority concern mostly options to enhance the *market flexibility* and **network controllability**. Part of the technologies or systems options providing that need urgently more RTD, testing in pilot projects to become a "proven technology or option" and to become economically more competitive and/or technically reliable and safe enough to apply them commercially. In summary for being commercially widespread applicable (standardisation etc) in the eyes of investors/stakeholders in the next ten years is assumed:

- The technology deployed must be sufficiently proven.
- Investments must be commercially viable.
- Regulatory context that is required to support these options need to be in place.

So the below addressed recommendations for more RTD, in the field of different disciplines such as policy and regulation, focus on technology development primarily intended to reduce the expected increasing power system costs to be caused by a substantially increasing share of power generated by intermittent type of RES & DG technologies in the near future in Europe.
The recommended RTD options are mend to push the technology development or breakthroughs, i.e. lowering considerably the investments (including that of enabling technologies) and put in place in time the necessary DER integration facilitating complex regulatory regimes (changes in current ones). Below the RTD recommendations are grouped according to areas of urgent application, I.e. for facilitating the:

- Generation and market flexibility
- Balancing market flexibility
- Distribution network and demand controllability
- Transmission network controllability
- Demand controllability

RTD options to increase the **generation and market flexibility** for integration of intermittent generation in medium and longer term are:

- **Additional research** has to be done into the influence **of generation portfolios** with common characteristics (for instance a lot of wind) on both sides of the border **on the usage of interconnections** and the dispersion of renewables EU wide.
- RTD on a **stricter harmonization of support schemes** is necessary for optimisation of deployment of RES technologies on a European perspective, instead of optimisation of the technology deployment for each separate member state. Consequently, a larger amount of the European RES potential can be harvested by more economic coordination between member states.
- Different **storage options** for different applications **need urgently RTD** for technologically a further developed enabling substantial cost reductions. In the meantime, the regulatory framework should be developed enabling the usage of one storage facility for several purposes, i.e. for trading, balancing and network controllability, through the establishment of an independent storage facility.

Different storage technologies are available since there doesn't exists a universal storage technology. The storage capacity and discharge time are clearly dependent on the kind of storage technology deployed: small-scale or large scale. Technologies like batteries, super magnetic energy storage (SMES), super-capacitors, flywheels and hydrogen fuel cell storage system (HFCSS) can be deployed for short time periods up to a few hours, while compressed air energy storage (CAES) and pumped storage have longer discharge times up to a day[1] (Jacobsen H et al., 2008; Mariyappan et al., 2004; Meeuwsen, 2007). As a rule only CAES and pumped storage are used for price arbitrage by energy traders.

To increase the **balancing market flexibility** for integration of much more intermittent generation in medium and longer term **RTD and pilot** actions are recommended on:

- S**mall customers in interruptible contracts** with the TSO/DSO through some kind of virtual agency or supplier need to be investigated and demonstrated in research programmes.
- Implementation of cross-border balancing, which has important advantages for the costs of renewable integration. Therefore, harmonisation of a large number of **technical codes and market rule**s with regard to balancing is strongly needed.
- Extension of interconnection capacity enables deployment of interconnections for cross border balancing purposes, besides trading purposes.

To increase the **network** and **demand controllability** for integration of much more intermittent generation in medium and longer term **RTD** is recommended on:

- Extension of **real-time monitoring and control** to (nearly) all distributed generation and load will contribute in steering and controlling of network flows by the DSO and lower the costs of network integration of renewables. For enabling real-time monitoring and control, first **demonstration projects** are needed and innovative network regulation frames, including (incentives for) **network innovation by DSOs,** need to be developed and tested.
- Real steering of load requires development and installation of **smart metering systems at households** to curtail upon request, some **load automatically**, when prices are very high or low. This asks for new **communication infrastructure**s between DSOs and loads, extensive use of ICT and high data handling capacity of DSOs. Small scale **demonstration** projects are needed to get more insight in potential problems and to determine more precisely benefits and costs of real time network pricing.
- RTD on is advised time and location network tariffs since more cost reflective tariffs induce generators and load to system-supportive behaviour and consequently help DSOs to steer and control network flows. This requires implementation of **genuinely smart metering** i.e. smart meters that are also of use to network operators, as well as using prices as input for automated systems at households (HAN).
- Again hereto RTD to increase the feasibility of using **storage technologies** for distribution network purposes (load management) responses) sis a high priority. See also section 5.1 for technology options overview.
- Vital for coping with large load fluctuations is to increase the **demand Response**. And again **advanced regulation and Smart Metering** is a strong prerequisite for implementation of real-time pricing, peak pricing etc is the installation of smart meters which show data for short time intervals (for example for each quarter).
- Finally to increase the **transmission network controllability** for integration of large volumes of intermittent power supplies **storage** technologies for transmission network purposes should be researched, tested etc. This and **improvement of wind power predictions** will improve load flow analysis of TSOs and are therefore high RTD priorities.

Crucially important is the timing of the commercial availability of the different RTD solutions and breakthroughs, because the majority of them are interlinked or/and depending on each other availability on a commercial scale.

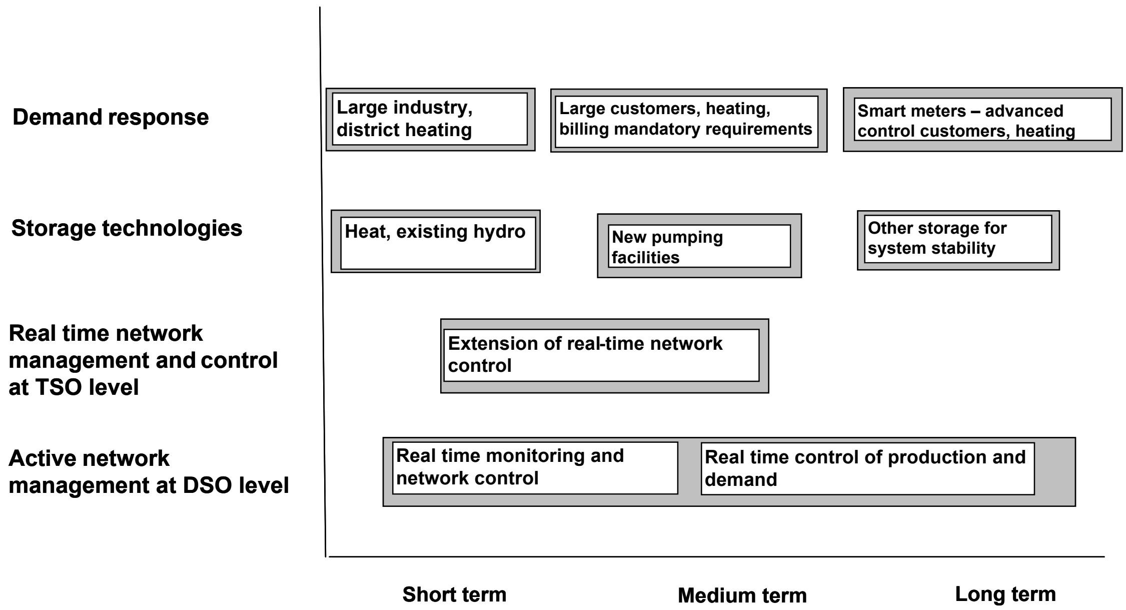

Figure 7.1 *Tentative time table for the application of different system innovations*

In Figure 7.1 above a very tentative “time table for the application need” is also implicitly an indication of timing for commercial availability of RTD results. Notice that short term is defined as available before 2020, medium term as available around 2020 and long term as available close after 2020 up to 2030 or so. Of course this time table is very depending on the specific power system needs, e.g. the share of intermittent type of RES generation technologies in a country’s system.

Finally note that much of the barriers, solutions for them and new developments in EU countries in the field of promoting the contribution of DER in the energy supply have been extensively discussed at two series of national seminars in the different EU MS, see final report D3.4, by Hudcovsky S at al (2008), “Report on Results of National Stakeholders seminars”. As well as discussed in two large conferences of which the last one was held on 25/26 September 2008 in Warsaw, see final report D3.5, by Jarzemska M et al (2008), entitled Large scale integration of RES and DG into the European electricity supply for meeting the EU RES targets of 20% for 2020.

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Appendix A Definitions OF DER

During the last decade the new energy sources, now called DER, have been described in different ways: decentralised generation, embedded generation and distributed generation. DER stands for Distributed Energy Resources. These resources are generally connected to the distribution network and therefore can be considered as an alternative notion to Distributed Generation (DG). Both terms are generally considered as interchangeable. According to the EU Electricity Directive DG are all power plants connected to the distribution system. Each different type of distributed generation has, however, its own technical and commercial characteristics and makes a distinction between large and medium/small-scale RES and CHP supply technologies. The medium and small scale-units of both RES and CHP sources are considered as distributed generation. Three characteristics distinguish DG from centralised large-scale generation:

- Distributed generation is connected to the distribution network (usually at voltage levels of 110 kV and lower) and is often operated by independent power producers, often consuming a significant share of power themselves. The large-scale units are connected to high voltage grid levels and operated by incumbent utilities (sometimes a joint venture with a large industrial consumer). DG has, as it is connected to lower voltage networks, to cope with a number of specific network issues that are of less relevance to centralised generation capacity.
- A second distinction is the location of the electricity supply. DG is usually generated close to the source and not so close to the demand site. Especially wind power is usually generated remote from the more populated regions. The consequence is that wind power plants are connected to weak (low voltage) electricity grids, i.e. grids with low consumption, having all kinds of impacts on the functionality of the distribution grid. Combined heat and power (CHP) is usually connected closer to the customer but often primarily sized to local heat demand and not to local electricity demand.
- A third aspect is the intermittent nature of electricity supply from RES and CHP. In contrast with electricity supply from conventional large power plants the electricity supply from wind and PV installations is far less controllable due to direct dependency of output on weather conditions. But also the controllability of power supply from CHP and small hydropower might be limited, because of the high dependency on heat demand or water levels or flow respectively.

Finally one should noted that although in SOLID-DER the main attention is on DER implying a focus on electricity distribution level, it is clear that recently formulated EU RES targets enlarged the focus of or analysis and finding solutions also towards the transmission level were more and more RES is connected for meeting these policy target in the EU in 2020.

Table A.1 *Categorisation of Sustainable Electricity Supply Technologies*

	Combined Heat and Power (CHP)	Renewable Energy Sources (RES)
Large-scale generation	• Large district heating* • Large industrial CHP*	• Large hydro** • Off-shore wind • Co-firing biomass in coal power plants • Geothermal energy
Medium/small-scale generation (Distributed Generation)	• Medium district heating • Medium industrial CHP • Commercial CHP • Micro CHP	• Medium and small hydro • On-shore wind • Tidal energy • Biomass and waste incineration/gasification • Solar energy (PV)

* $> 50\ MW_e$
** $> 10\ MW_e$