S U S T E L N E T

Policy and Regulatory Roadmaps for the Integration of Distributed Generation and the Development of Sustainable Electricity Networks

POLICY AND REGULATORY ROADMAPS FOR THE INTEGRATION OF DISTRIBUTED GENERATION AND THE DEVELOPMENT OF SUSTAINABLE ELECTRICITY NETWORKS

Final Report of the SUSTELNET project

August 2004

ECN

M.J.J. Scheepers

Acknowledgement

Support of the European Commission

The SUSTELNET project is supported by the European Commission under the 5th RTD Framework Programme within the thematic programme 'Energy, Environment and Sustainable Development' under the contract No. ENK5-CT2001-00577.

This document or any other document produced within the SUSTELNET project does not represent the opinion of the European Commission. Neither the European Commission, nor any person acting on behalf of the Commission, is responsible for the use that might be made of the information arising from the SUSTELNET project.

SUSTELNET project partners in EU Member States:

- Energy research Centre of the Netherlands (ECN), Petten, The Netherlands (co-ordinator)
- University of Warwick, Coventry, UK
- Öko-Institut, Freiburg, Germany
- Fondazione Eni- Enerico Mattei (FEEM), Milano, Italy
- Elsam Engineering, Fredericia, Denmark
- Institut für ZukunftsEnergieSysteme (IZES), Saarbrücken, Germany
- ECON Analysis, Centre for Economic Analysis, Copenhagen, Denmark

SUSTELNET project partners in Newly Associated States:

- Enviros, Prague, Czech Republic
- The Polish National Energy Conservation Agency (KAPE), Warsaw, Poland
- Hungarian Environmental Economics Centre (MAKK), Budapest, Hungary
- EGU Energy Institute, Bratislava, Slovakia

Other organisations contributing to the SUSTELNET project:

- Eindhoven University of Technology / Foundation for the History of Technology, Eindhoven, The Netherlands
- Eltra, Fredericia, Denmark

For further information:

- www.sustelnet.net
- Mr. Martin J.J. Scheepers
  Energy research Centre of the Netherlands (ECN)
  Phone: + 31 224 564436
  E-mail: info@sustelnet.net

Abstract

The SUSTELNET project has been created to identify criteria for a regulatory framework for future electricity markets and network structures that create a level playing field between centralised and decentralised generation and facilitate the integration of RES. Furthermore, the objective of the project was to develop regulatory roadmaps for the transition to a sustainable electricity market and network structure. This report summarizes the results of the project. These results consist of: criteria, guidelines and rationales for a future electricity policy and regulatory framework, an outline for the development of regulatory roadmaps and nine national regulatory roadmaps (for Denmark, Germany, Italy, the Netherlands, United Kingdom, Czech Republic, Poland, Hungary and Slovakia), recommendations for a European regulatory policy on distributed generation and a benchmark study of current Member States policies towards distributed generation.

CONTENTS

EXECUTIVE SUMMARY

Electricity generation from renewable energy sources (RES) and decentralised generation (DG) in the European Union is increasing. A transition towards a more sustainable electricity supply may be expected in the coming years due to strong energy policies, new technological developments and introduction of market liberalisation. However, inaccurate economic regulation of liberalised electricity markets can hinder the deployment of RES and DG. Today, often the economic values DG and RES generate for the electricity system (e.g. for distribution system operator and system balancing) are insufficiently recognized and not correctly valued and allocated. Although rewarding RES and DG through support schemes can overcome this barrier, this will result in economically inefficient solutions and will keep DG and RES from becoming mature power generation sources.

In the SUSTELNET project a group of 11 research organisations from 9 European Member States, including four new Member States, studied the long-term dynamics of electricity systems, analysed the current electricity policy regulatory framework in the participating Member States and analysed the technical options and boundaries of integration of DG/RES in electricity networks. The aim of the SUSTELNET project was to develop a tool for a regulatory strategy to be used in the transition process towards an electricity market and network structure that creates a level playing field between centralised and decentralised generation and facilitates the integration of electricity from renewable energy sources. Therefore, the project team identified criteria for a regulatory framework for future sustainable electricity markets and developed regulatory roadmaps that set out a regulatory strategy for individual Member States for the medium to long-term.

During the project a participatory process was initiated. This process brought electricity regulators, policy makers, distribution system operators and supply companies together, as well as representatives from other relevant institutions. In soundboard meetings and workshops, these actors reviewed and debated the criteria for an adequate future regulatory framework and the proposed regulatory roadmaps. In addition, a study was performed in which current regulation of the participating Member States was benchmarked against the criteria and guidelines for the 'adequate' future regulatory framework developed in the SUSTELNET project. Key findings of the SUSTELNET project were compared with the current EU legislation and possible additional EU policy, regulation and initiatives were identified that can help Member States in developing future economically efficient and sustainable electricity supply systems.

The results of the SUSTELNET project are:
- Criteria, guidelines and rationales for a future electricity policy and regulatory framework.
- An outline for the development of regulatory roadmaps and nine national regulatory roadmaps (for Denmark, Germany, Italy, the Netherlands, United Kingdom, Czech Republic, Poland, Hungary and Slovakia).
- Recommendations for a European regulatory policy on distributed generation.
- A benchmark of current Member States policies towards distributed generation.

OBJECTIVES AND STRATEGIC ASPECTS

The European electricity sector is reshaped by liberalisation and internationalisation of electricity markets, and decentralisation of electricity technologies and services. Medium-term EU targets for the penetration of RES and GHG emissions reductions strengthen the trend towards decentralisation. More ambitious RES and GHG targets can be expected after 2010. The provision, pricing and regulation of transmission and distribution network services is already crucial to the penetration of distributed generation in the current EU electricity market. The role of distribution network services is likely to become even more pivotal as the electricity system becomes more decentralised, and the pressure from distributed generators rises to participate on a level playing field in the internal electricity market. On the transmission level the initiative to harmonise transmission pricing for cross-border electricity trading through the Florence Regulatory Process seeks to enhance the integration of the EU electricity market. On the distribution level hardly any regulatory initiatives exist on the EU level that consider the pricing and regulation of distribution services, its relation to centralised and distributed electricity supply and its role in the internal market. A clear view on the role of distribution regulation is needed for distributed generation to participate in and advance the internal market in electricity, and to achieve EU RES and GHG targets in the medium-to-long term. The SUSTELNET project provides the analytical background and organisational foundation for a regulatory process that satisfies this need. The underlying principle is that there should be no bias towards centralised or decentralised generation and network development.

In May 2004 the European Union was enlarged with new Member States. In accordance with the EU acquis communautaire the liberalisation of the electricity market in these countries has started before that date. The past situation of the electricity sector in these new Member States has been very different from most of the other EU countries. The consumer tariffs in the formally state controlled power sector were heavily subsidised in case of some consumer groups (e.g. households, agriculture) and did not reflect the production costs of electricity. Before liberalisation could be possible, electricity tariffs to consumers, particularly households, had to be increased to cover costs of production and supply and enable power companies to make a reasonable revenue on the deliverance and to stop cross subsidies between various consumer groups. This adaptation of consumer tariffs and prices has been one of the basic differences with the power sector in EU countries where consumer prices already were cost-reflective.

Another recent development is that the costs of electricity production by renewable sources decreased and came closer to its alternative, the fossil fuel based electricity production. Although still relatively expensive compared to traditional large-scale fossil fuel based power generation, price differences have decreased substantially in recent years. Nevertheless, the situation for RES generation is still not really favourable, recently enhanced by the uncertainty created by the liberalisation of the electricity markets. Also policies and regulation regarding the level of feed-in tariffs and distribution tariffs are still unclear or absent in many countries and little can be said about the impact it will have on RES and DG if implemented.

Socio-economic objectives and strategic aspects

The objectives of SUSTELNET are to:

- Analyse the long term technical, socio-economical and institutional dynamics that underlie the changes in the architecture of the European electricity infrastructure and markets.
- Develop medium-to-long term transition strategies/roadmaps for network regulation and market transformation to facilitate the integration of RES and decentralised electricity systems.

- Lay the foundations for and map out a regulatory process on the regulation of distribution networks in the EU, involving distribution and supply companies, national regulators and national and EU policy makers.
- Lay the foundations for and map out a regulatory process on the regulation of distribution networks in NAS[1] and their integration with EU MS, involving distribution and supply companies, national regulators and national policy makers in NAS.
- Develop a common policy and regulatory roadmap for the NAS towards the integration of DG into the energy system in harmonisation with EU strategies.

Scientific and technical objectives

Specific scientific and technical objectives of SUSTELNET are:

- Identification of the key technical, socio-economical, political and institutional factors and relationships that determine the long term dynamics of European electricity systems.
- Defining the medium-term technical options and boundaries to electricity system development.
- Review of MS network regulatory mechanisms: comparison of the effectiveness and efficiency of the theoretical model and its practical implications.
- Defining roadmaps for electricity regulation and policy on the medium-to-long term: identifying the issues in a dynamic context and delivering policy responses. Roadmaps provide guidance on all the bulleted issues below. Furthermore, they provide benchmark criteria to monitor the development of EU and NAS electricity systems.
- Establishment of operational criteria, guidelines and templates for the design of distribution and transmission regulation on the medium term, focusing on:
    - Interconnection standards, procedures, and the allocation of costs and benefits of distributed generation interconnection.
    - Energy and capacity pricing mechanisms at the transmission and distribution level, with particular attention to peak energy and capacity pricing.
    - Capacity commitment and managing the operation of dispersed generation: economic incentives in market design and the need for regulation.
    - Energy losses and ancillary services pricing.
    - Participation of distributed generation in electricity markets: the role of power exchanges.
    - Electricity network expansion and upgrades.
    - Active network operations using state of the art ICT.
    - Benchmarking MS/NAS regulatory regimes and distribution company practices.
    - Anticipating on the accession of the four NAS to the EU. This will lead to early harmonisation of the electricity regulatory framework and establishing a real European unified electricity grid in the next decades.

[1] In the SUSTELNET project new Member States were indicated as Newly Associated States (NAS).

1 INTRODUCTION

Current energy and environmental policies of the European Union and Member States are aimed at a number of policy targets, among them an increase of energy efficiency, an increase of the energy supply from renewable sources, a reduction of greenhouse gas emissions and securing the overall energy supply. Ambitious policy targets are achieved with technological innovations in the electricity supply systems and with use of financial support mechanisms to overcome economic barriers. Consequently, electricity supply from renewable energy sources (RES) and combined heat and power (CHP) lead to a more decentralised electricity infrastructure. Increasing amounts of electricity are being generated on the distribution network level by so-called distributed generation (DG).

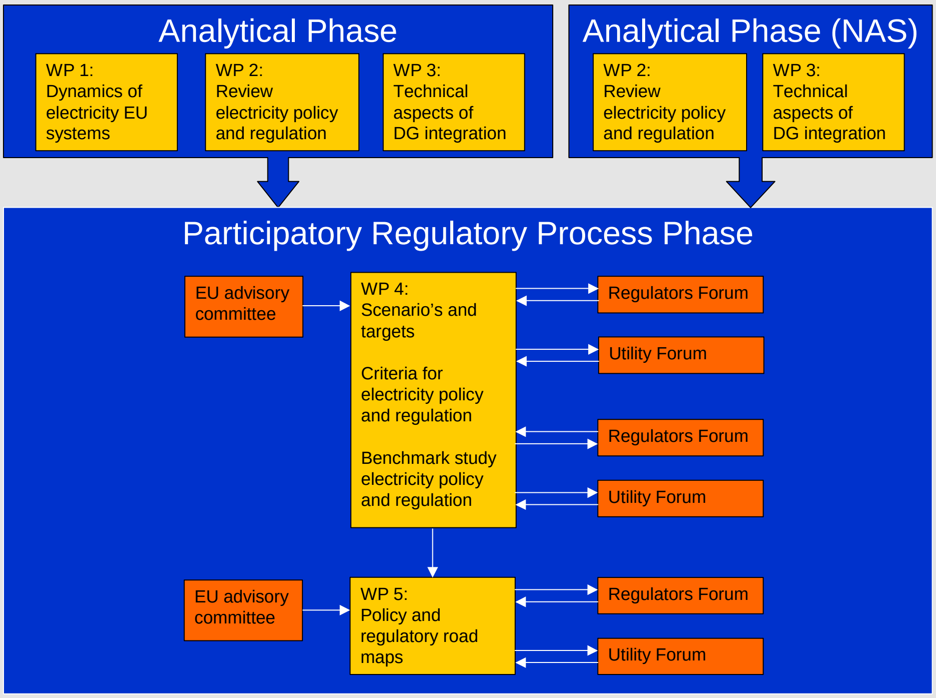
According to the EU RES Directive (EU, 2001), the EU CHP Directive (EU, 2004) and the EU Electricity Directive (EU, 2003a), electricity supply from RES and DG should be considered in the operation and planning of the electricity infrastructure. Furthermore, costs and benefits to the distribution network induced by the various distributed generation technologies should be taken into account in the electricity network regulation. In practice, however, current electricity network regulation often does not consider regulatory mechanisms to ensure effective participation of RES and DG in liberalised electricity markets. Alternatively, governments still use support schemes to ensure that DG and RES are employed and environmental benefits are achieved and thus mitigate the often complex barriers to incorporating DG and RES within economic regulation of electricity networks. In the long run, DG and RES should become fully part of the electricity market, since continuation of market protection could result in much higher infrastructure costs. In addition, regulatory incentives are needed to change the design and operations of distribution networks, enabling the efficient and reliable management of large amounts of distributed supply.

The SUSTELNET project has been created to identify criteria for a regulatory framework for future electricity markets and network structures that create a level playing field between centralised and decentralised generation and facilitate the integration of RES. Furthermore, the objective of the project was to develop regulatory roadmaps for the transition to a sustainable electricity market and network structure. To this end, the project was divided in two parts (see Text Box). The first part, the analytical part, identified the long-term historical and future technical, socio-economic and institutional dynamics that shape the European electricity systems and markets. This increases the understanding of the structure of the current European electricity sector and its socio-economic and institutional environment. To deliver a fully operational regulatory road map, a participatory process was initiated in the second phase of the project. This process brought electricity regulators, policy makers, distribution system operators and supply companies together, as well as representatives from other relevant institutions. In soundboard meetings and workshops these actors reviewed and debated the criteria for an adequate future regulatory framework and the proposed regulatory roadmaps.

The SUSTELNET project anticipated on the enlargement of the EU by extending the project to new Member States[2]. Similar as for the five selected EU MS (Denmark, Germany, Italy, The Netherlands and United Kingdom) the current policy and regulatory framework for the electricity market and the electricity supply infrastructure has been reviewed for four new MS (Czech Republic, Poland, Hungary and Slovakia). For all of these nine countries regulatory roadmaps have been developed.

[2] Partners from four former Newly Associated States (NAS) participated in the project, i.e. from the Czech Republic, Poland, Hungary and Slovakia. These countries are, among six others, Member State of the EU since May 1st, 2004. Approximately 6 months after the project was started, the NAS extension was realised, resulting in a separated work process for these four countries during the analytical phase.

In this final report the results of the SUSTLNET project are summarised. In Chapter 2, first a short introduction on DG/RES is presented, its impact on the electricity system and the required technical and institutional transition. Subsequently, the DG/RES drivers and an introduction to possible problems raised by the liberalisation of power markets are described in Chapter 3. Chapter 4 outlines values created by DG on distribution networks, while discussing the desirability and feasibility of creating a level playing field between small and large-scale power generation. Chapter 5 investigates the rationales and principles of current and future economic regulation. Benchmarking of the current regulation of electricity markets against this ‘adequate’ future regulatory framework is discussed in Chapter 6. The introduction of a new regulatory approach in electricity network regulation requires a regulatory strategy. The SUSTELNET project proposes the use of a ‘regulatory roadmap’ as a tool to map out the regulatory strategy. The development and use of regulatory roadmaps is explained in Chapter 7. Key findings of the SUSTELNENT project were compared with the current EU legislation. Chapter 5 identifies possible additional EU policy, regulation and initiatives. Finally, in Chapter 9, some conclusions and observations are presented. Reports on the different activities, including the regulatory roadmaps of nine EU MS, are published on the SUSTELNET website (www.sustelnet.net).



The diagram provides a schematic overview of the SUSTELNET project. The analytical phase consists of three activities (work packages): the long-term dynamics of EU electricity systems (WP 1), an overview of current electricity policy and regulation in selected MS/NAS (WP 2) and an overview of the technical options and boundaries for the integration of distributed generation in electricity networks (WP 3). The regulatory process consists of the following activities: WP 4 develops criteria for network regulation. Consequently, a benchmark and improvement study of MS distribution regulation and management is conducted. WP 5 develops medium to long-term policy and regulatory road maps for participating EU MS and NAS. Each activity during the regulatory process phase involves extensive input and review by an EU Advisory Committee, a Regulators Forum and a Utility Forum.

2 DISTRIBUTED GENERATION

2.1 What is Distributed Generation?

Generally, power generation that is connected to the distribution network and has a capacity up to a certain limit is considered to be distributed generation (DG). It appears however difficult to pin down DG on specific numbers because this is country specific and relates to characteristics of the centralised power system. Co-generation (or Combined Heat and Power; CHP) and electricity generated from renewable energy sources (RES) are often considered as DG. However, as it is shown in Table 2.1, only a part of CHP and RES can be considered as DG.

What is considered as large-scale power generation and DG in a specific country can be determined from existing network regulation. Often distinctions are made in electricity network regulation on the basis of network level and generation capacity, for example regarding connection costs, system balancing, system reserves and auxiliary services. How these distinctions are made can implicitly create a non-level playing field between large-scale generation and DG. This will be further discussed in Chapter 4.

Table 2.1 *Characterisation of Distributed Generation*

	Combined Heat and Power (CHP)	Renewable Energy Sources (RES)
Large scale generation	• Large district heating [a] • Large industrial CHP [a]	• Large hydro [b] • Offshore wind • Co-firing biomass in coal power plants • Geothermal energy
Distributed Generation (DG)	• 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)

[a] typically > 50 MW_e
[b] typically > 10 MW_e

2.2 Development of DG in centralised electricity systems

To understand the structure and use of current electricity supply systems and to lean about possibilities and the barriers to changing these systems Verbong and Van der Vleuten (2002) analysed in Work Package 1 the historic dynamics of long-term electricity supply systems. They observe that, in a long-term historical perspective, the current concern or critical problem for creating a level playing field for distributed and centralised generation is remarkable. This concern seems completely opposite to the dominant critical problem in the 1950s and 1960s, which was to reduce the contribution of distributed generation to public electricity supply as much as possible, in order to achieve advantages of scale. It is no surprise therefore, that current systems have an intrinsic bias towards centralised generation. Arguments for large scale power generation during the era of scale increase and expansion (see Figure 2.1) were economies of scale, construction of (coal) power plants located near mining sites and integrated with hydro, investment savings on back-up units and avoiding over-capacity[3]. Later on in many countries the introduction of nuclear power plants lead also to centralised generation. Due to the increasing availability of natural gas in many countries, environmental concerns and technological development (such as; availability of competitive smaller generators) scale increase and siting of power generation locations became of lesser importance. As a result, in the 1970s and 1980s electricity systems in some countries[4] started to develop from central systems in the direction of 'hybrid systems' hosting centralised as well as decentralised generation units in one and the same system. The possibilities (barriers, opportunities) for DG in the current socio-technical electricity supply systems are conditioned by characteristics of the system developed in the era of centralisation and how actors since the 1970s have been dealing with these.

In parallel to national electricity systems, a European electricity supply system has developed (see Figure 2.1). Although the European network was more and more intensively used, until the1990s national boundaries provided barriers for international co-operation in production and transmission. This completely changed with the implementation of energy market liberalisation and creation of an international electricity market. More recently, efforts have been made to harmonise transmission pricing and to improve congestion management[5]. The impact of the development of the European grid is uncertain. On the one hand, large scale introduction of distributed generation, both co-generation and renewable energy sources, could push for balancing demand and supply of electricity on a lower level, reducing the role of high voltage transmission grids. On the other hand increasing exchange of electricity, exploiting differences in the availability of resources, economies of scale and favourable market conditions (e.g. cheap base load from nuclear power stations during the night) could be a factor, pushing for sustaining and expanding the European network.

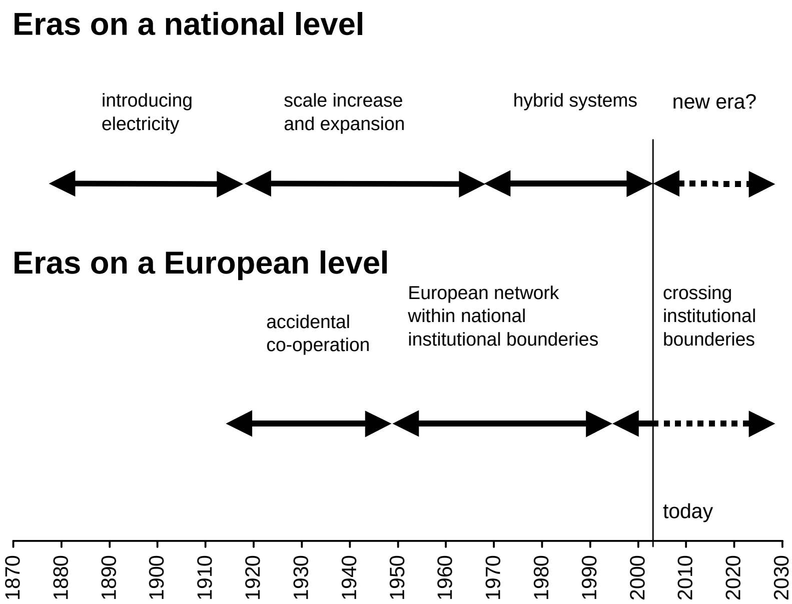


Figure 2.1 *Eras in the development of electricity supply systems (Verbong and Van der Vleuten, 2002)*

---

[3] In the first part of the 20th century Georg Klingenberg, professor at the polytechnical school of Berlin and head of the German company AEG, put forward these four arguments for large integrated electricity networks.

[4] There are considerable differences from country to country. A co-evolution of centralised and decentralised systems can be observed.

[5] The Electricity Regulatory Forum of Florence addressed issues on cross border trade of electricity, in particular the tarification of cross border electricity exchanges and the allocation and management of scarce interconnection capacity.

2.3 Technical options and constraints

In some countries the level of DG in the electricity supply is already remarkably high. For instance, in the Netherlands approximately 15% and in Denmark approximately 25% of the power (on a yearly basis) is supplied by DG.[6] These 'hybrid supply systems' were developed before the electricity markets were liberalised. The opportunities for distributed generation were created by changes in the institutional framework.

In Work Package 3 Nielsen (2002a) reviewed technical options and constraints for integration for distributed generation in electricity networks. The review is based, to a large extent, on a case study of large-scale DG deployment in the Western part of Denmark. In this area 1621 MW of local CHP and 1900 MW of wind turbines have been introduced in a system with a minimum demand load of 1150 MW and a maximum demand load of 3800 MW (see Figure 2.2). Although, it appeared technically possible with such a high DG penetration in a conventional grid, strong international connections were necessary to balance the system. The risk of serious network failures has increased since. The mixture of production and consumption in the same local networks has made the operational tasks more complicated, particularly under emergency conditions.

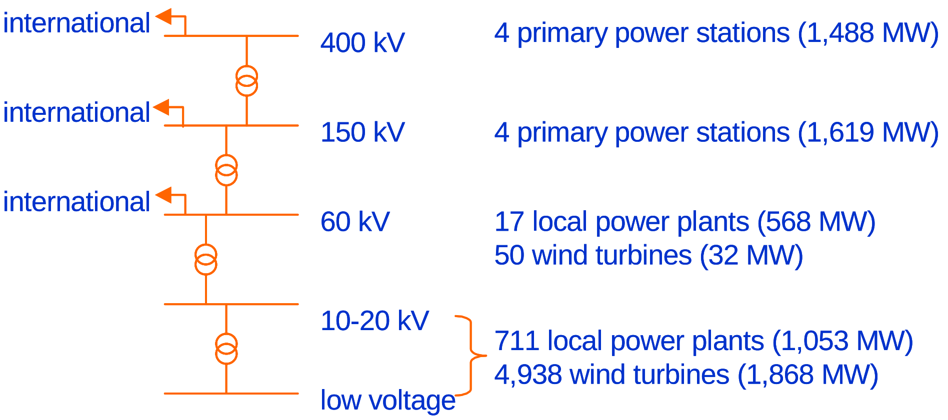


Figure 2.2 *Production capacity at each voltage level in the Western part of Denmark (Nielsen, 2002a)*

In present electricity systems control structures are still based on a division of networks into two parts: a distribution network connecting end-users to the electricity supply system and a transmission network connecting power plants and cross-border lines to major users and to the distribution networks. The operational co-ordination between the two networks is limited, both under normal conditions and in emergency situations. To minimise the risk of serious network failures and to be able to improve the economical optimisation of electricity networks it is important to recognise that distribution networks can no longer be considered as passive appendages to the transmission networks. The entire network must be operated as a closely integrated unit. Organising this co-operation will be a major challenge. Furthermore, a number of technical improvements have to be developed and implemented. Several ideas for redesigning electricity networks have been put forward[7], however, practical experience is still limited. In these future electricity networks the role of information and communication technologies (ICT) will certainly increase. Nielsen has also reviewed the role of ICT in network management and market operations (Nielsen, 2002b).

[6] These figures are the annual average for the whole country, which means that level of DG supply will be much higher in some distribution grids and on specific times of the day/year.

[7] Nielsen (2002b) illustrates this with three ideas: 'The Grid', 'Active network' and 'Micro-grids'.

In Work Package 3 (Donkelaar et al., 2003) analysed the possible impact of DG/RES on electricity supply systems in four new EU MS (Czech Republic, Poland, Hungary and Slovakia). Since 2001 the electricity networks in these countries fully comply with the UCTE requirements (i.e. do not differ from networks in other EU MS) and are capable of delivering electricity in a relatively reliable way. Looking at the share of Distributed Generation in total, it shows that in all four countries CHP covers a significant amount of electricity production (between 10 and 20%). So far intermittent DG has a low share in power generation (below 1%) and has therefore a minimum impact on network quality. Generally, no specific technical constraints to DG have been found in new EU MS. However, TSO's and DSO's and not yet prepared to integrate large amounts of intermittent DG. All four countries have a potential for growth for (small-scale) CHP. Other sources with relatively high potential are biomass (in combination with CHP), small-scale hydropower (< 10MW) and wind power (mainly on the Baltic Coast, Poland).

3 DG PROSPECTS

3.1 Drivers for DG

Environmental policy is an important driver for DG. In 1995 the share of CHP and RES in Europe's (EU-25) electricity supply amounted to 31.3% (see Figure 2.3). A baseline scenario developed for the EU-25 shows an increase of CHP and RES up to 36% in 2030 (EU, 2003b). However, the policy targets[8] will not be met in this baseline scenario. It is most likely that enhanced policy measures will be implemented resulting in a higher share for CHP and RES (up to a level of 40 to 50% as indicated in the Figure 3.1) and therefore also a higher share for DG (up to a level of approximately 25 to 30%[9]).

Growth of the RES-share will reduce the dependency of the EU on foreign energy supplies. Also increase of energy-efficiency, e.g. by use of energy efficient CHP units, will contribute to the EU security of supply policy (EU, 2002). Furthermore, the decentralised generation of electricity may contribute to a more reliable electricity infrastructure.

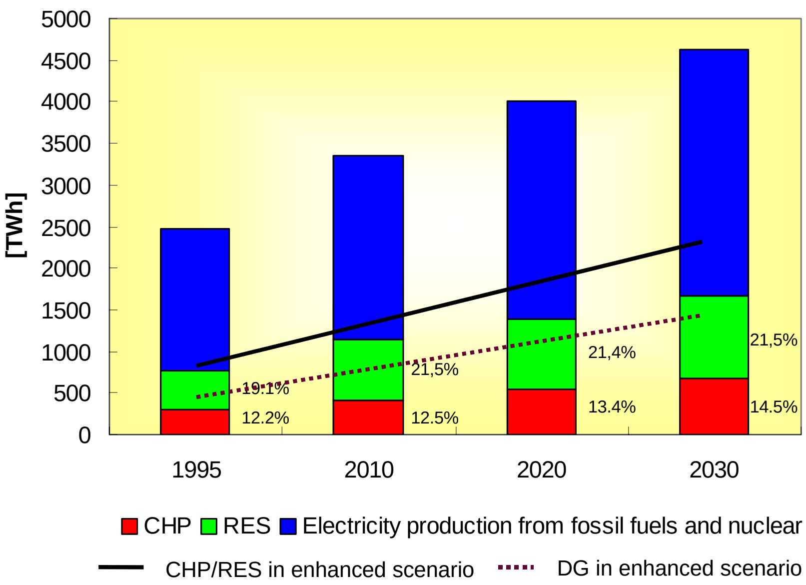


Figure 3.1 *Position of CHP and RES in the electricity supply in the European Union (EU-25)*
Source: EU-25 Baseline Scenario: Trends to 2030/PRIMES & ACE Models.

In summary, in the longer term a continuation in the increase of the CHP and RES share in electricity supply is to be expected, and as a result, the share of DG will also grow, because a significant part of new CHP and RES is DG.

8 A greenhouse gas emission reduction of -8% in 2010 for EU-15, a RES share in electricity consumption of 22% in 2010 for EU-15 and an energy end-use saving of 1% per annum. For EU-15 the European Commission expects with current policy measures only a greenhouse gas emission reduction of -0.5%, leaving a gap of 7.5% (EU 2003c). For the EU-14 the RES share in 1995 was14.8%. With the current policy measures the European Commission expects this figure to rise to 18-19% (EU 2004b), leaving a gap of 3 to 4%.

9 These are European figures. In some Member States national figures will be much higher. High levels of DG supply will in particular occur in local distribution grids.

3.2 Electricity market liberalisation

The liberalisation of electricity markets has also an impact on the development of DG. Although the opening of electricity markets should create opportunities for decentralised power generation, the participation of DG in competitive power markets could affect its profitability. Based on the analysis of the electricity regulation in four 'old' EU MS, carried out in Work Package 2 of the SUSTELNET project, Connor and Mitchell (2002) illustrated that in a liberalised electricity market RES and DG are often not rewarded or insufficiently rewarded for their benefits to the electricity system and are in some cases strongly dependent on non-market based support schemes. It is suggested that support schemes should, however, not be used to compensate the often complex barriers to incorporate DG within economic regulation, as this could keep DG from becoming a mature power generation source.
Electricity regulation that is 'neutral' towards central generation and distributed generation will help to create a level playing field. Connor and Mitchell also state that the current regulation framework tends to favour the centralised production of power and that current systems for incentivising investment by distribution companies reduce the potential options available to network operators by locking them into doing the same thing while trying to reduce associated costs. The pricing and regulation of distribution network services is, therefore, crucial to the penetration of distributed generation in the EU electricity market. The achievement of policy goals on RES, CHP and GHG may become in danger if distribution system operators (DSOs) [10] are not able to adapt their networks or and are unwilling to connect DG. This is dependent not only on whether DSOs are disincentivised regarding DG but on whether regulation allows them methods to actively discourage its uptake.

Wals et al. (2003) reviewed the regulatory framework in four new EU MS and produced in Work Package 2 an addendum to the report of Conner and Mitchell. Due to a more recent start of the electricity market liberalisation process these countries have limited experience with economic regulation of electricity network activities. Furthermore, the electricity sector is still in a restructuring process in most of these countries. Although in some countries the DG share in power supply appeared to be relative high, the regulatory framework can cause similar problems for the deployment of DG as found for the other EU MS studied.

3.3 DG Scenarios

A large number of factors can influence the development of the electricity supply sector. These factors have a different nature (technical socio-economic, institutional) and can be part of the electricity system or be external. For instance, harmonisation in the EU is an important external factor that cannot be influenced directly by the actors in the electricity sector but can have a significant impact on the electricity regulation. The use of information and communication technologies for operation and control of electricity networks is an example of a technology development that can be influenced by the actors in the electricity sector. The uncertainty of the different factors influencing the development of the electricity system makes it difficult to determine the future state. The range of possible future developments of complex systems like the electricity sector becomes even larger if the distance from the present increase.

[10] In other SUSTELNET reports the term Distribution Network Operator (DNO) was used. In line with the wording of the new Electricity Directive (2003/54/EC) the term Distribution System Operator (DSO) is used in this Final Report.

By using a scenario method possible future developments can be described by a set of ‘scenario descriptors’. For the electricity system more than 120 possible descriptors were identified in Work Package 4.1 of the SUSTELNET project. A limited number of these have been selected for a basic scenario layout. By using two independent factors - harmonisation of EU regulation and energy policy (i.e. the incentives for RES and DG) - four different possible futures have been identified (Timpe and Scheepers, 2003). These four scenarios are characterised in Table 3.1.

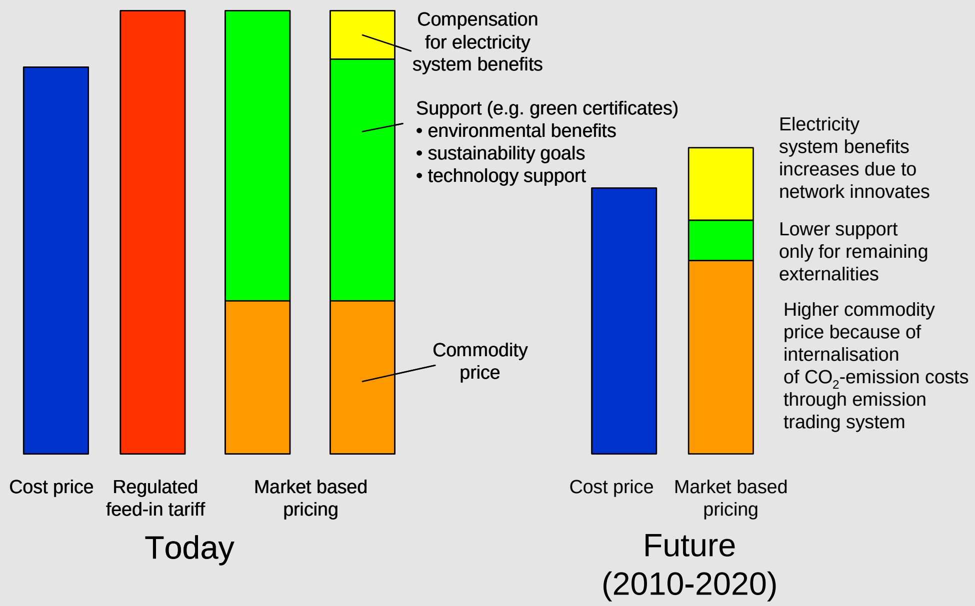
Table 3.1 *DG Scenarios*

	High RES & DG incentives	Moderate RES & DG incentives
	Scenario A	Scenario B
Stronger EU harmonisation policy.	DG opportunities in a fully harmonised EU market. • Efficient regulation (EU Regulator). • Market concentration. • Non-discriminating grid access rules. • Ambitious EU-wide targets for RES & DG. • Strong EU-wide support schemes (tradable certificates).	Difficult times for DG in a fully harmonised EU market. • Efficient regulation (EU Regulator). • Market concentration. • Grid access rules disfavour small units. • Harmonisation of RES & DG support at a low level. • EU wide certification schemes (tradable certificates).
	Scenario C	Scenario D
Reduced EU harmonisation policy.	DG opportunities in national markets. • No harmonised regulation (national focus). • Some MS implement fair grid access. • Ambitious EU-wide targets for RES & DG. • Diversity of national support schemes. • Strong RES & DG support compensates for regulatory deficits.	Difficult times for DG in national markets. • No harmonised regulation (national focus). • No improvements in grid access. • National support schemes partially reduced. • No compensations for regulatory deficits.

4 DG VALUES

4.1 Market incentives

Market incentives and disincentives towards DG are generated basically through regulatory issues and support mechanisms (See also the Text Boxes: *Economics of DG* and *Economics of the DSO*). While the former deals with the regulation of the electricity system - namely network regulation and market access - the latter should be introduced when the pricing system does not internalise all positive externalities created, to support technologies that are in their infant phases and to achieve a determined policy objective. Typically, regulation of current electricity systems favours centralised generation to the detriment of DG and, in many countries support mechanisms are generally introduced to correct this. The use of support measures to correct regulation imperfections is inefficient. The SUSTELNET project departs from the basis that in a liberalised market the existence of a level playing field in the regulation of the electricity system is a *sine qua non* condition to achieve an effective and efficient participation of DG. Support mechanisms, instead, should only be used for the three aforementioned objectives: to compensate for externalities, in support of infant technologies and in the achievement of specific policy objectives. The SUSTELNET project is focused on the area of economic regulatory issues.



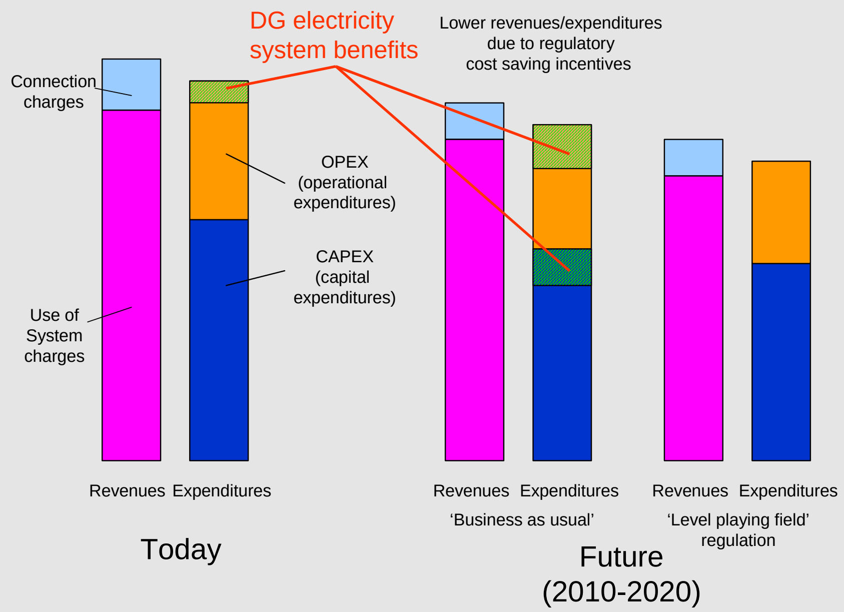
Economics of DG

The figure above shows qualitatively the costs and revenues of the DG operator. Costs can be expressed per kWh (costs price). Depending on policy and regulation the revenues for the DG operator consist of a regulated feed-in tariff or a market based commodity price for the electricity and an additional support tariff. The SUSTELNET project advocates making a distinction between support tariffs (or a 'green' market price based on tradable green certificates) and compensations for electricity system benefits. In the long term the electricity system benefits may become a relative more important source of income for the DG operator since the cost price may reduce (in particular for new DG technologies), the commodity price increases (internalisation of CO_2-emission costs) and the support decreases. An increase of income from system benefits, however, will only happen if the regulatory framework and data exchanges allow a proper allocation and transfer of system benefits to the DG operator.

4.2 Level playing field

It is difficult to provide an exact definition of a level playing field. However, discussions in the SUSTELNET project have yielded valuable insights into what might constitute some of the ingredients of a level playing field. There is general agreement that a level playing field entails markets and regulation that provide neutral incentives to centralised generation versus DG. This requires that all the values of DG are recognised, and that appropriate mechanisms are set up to put a monetary value to these values. Furthermore, incentives should be provided to network operators and generators to exploit these values in the best possible way.

It is recognised that the provision of non-discriminatory incentives and proper valuation of benefits and cost associated with distributed and centralised generation alone may not result in level playing field in the long run. Path dependencies in the electricity infrastructure are likely to create a bias towards centralised generation. It may therefore be granted to temporarily tilt the playing field slightly in favour of DG in order to create a level playing field in the longer run. Thus a level playing field should balance long term and short term benefits and costs of the electricity infrastructure.



Economics of the DSO

The figure above illustrates qualitatively the revenues and expenditures of the Distribution System Operator (DSO). The expenditures can be divided into operational expenditures (OPEX) and capital expenditures (CAPEX). The revenues are resulting from regulated connection charges and Use of System (UoS) charges to consumers and DG operators. The profit DSOs can make is caped by regulatory enactments. The regulatory framework will provide an incentive to DSOs to become more efficient, resulting in lower future network tariffs, i.e reducing the future revenues and expenditures of DSOs. DG can contribute to reducing the network costs. On the short term DG can only reduce operational expenditures, e.g. line loss reduction. In the longer term DG may contribute to a further reduction of operational expenditures (e.g. DSOs purchasing ancillary services from DG locally) and also reducing capital expenditures (e.g. avoiding reinforcements). Initially, the electricity system benefits can be shared between the DSO en DG operators, but due to regulatory mechanisms the benefits for the DSO will be passed on to consumers in the next regulatory period. DSOs may share benefits with DG operators only when new ICT technologies are applied and an active management system is implemented. In the SUSTELNET project it is assumed that the costs of these systems are lower than conventional reinforcements of the network.

4.3 Costs and benefits

When DG connects to the distribution grid, it generates operational and capital benefits and costs for DSOs. However, a number of the benefits or costs they generate are not always considered. In order to achieve a level playing field, all DG values should be recognised, assigned - if possible - a monetary value and be allocated between DG and DSOs. Long-term and short-term values should both be considered.

In Work Package 4.2, Leprich and Bauknecht (2004) presented an overview of benefits and costs DG induces in the electricity system (see Table 4.1). These benefits and costs can generally be separated in two broad categories: those that are network-related (infrastructure) and those that are energy-related (commodity). Within each category and subcategory there can be a range of different benefits and costs to the DSOs, the TSOs, the customers and the society as a whole. Each benefit or cost tends to be highly technology-, site- and time-specific; they do not necessarily apply equally or at all to every individual DG case. Especially with respect to the energy related benefits one has to differentiate between intermittent and controllable DG contributions. The more controllable they are the higher their economic value is.

For both the network-related and the energy related benefits it is crucial to differentiate between short-term and long-term benefits. In the short term some of the mentioned ‘benefits’ may actually be additional costs to the system. There may be a need for additional grid capacity because of DG entering the market; there may also be a need for additional balancing power because of the intermittent character of wind power or PV. And if the reliability of the system is already very high the possibility that DG will improve this situation is very low. But in the long run a more decentralised system has the potential to be superior to a centralised system in economic terms, and therefore the long-run benefits must already be considered today in some way.

Table 4.1 *Costs and benefits for the electricity system induced by DG*

	DG can create benefits to the electricity system:	DG can create costs to the electricity system:
Network related	• *Distribution capacity cost deferral:* the development of small-scale DG facilities near a load can postpone necessary investments in additional distribution and transmission capacity absolutely or temporarily. DSOs can benefit from these new DG facilities as it can reduce their investment costs in upgrading or extending the distribution network. The costs of distributing electricity differ from location to location, and placing DG facilities in 'high-cost areas' may reduce costs for DSOs. • *Operational cost savings:* distributed generation can reduce costs for operation and maintenance of the distribution system. Values regarding engineering costs include: - reduction of losses, - voltage support, - reactive power support equipment life extension. • *Congestion relief.* • *Reliability improvement*: through grid relief and therefore a lower probability of blackouts or brownouts.	• *Connection costs:* the connection of the DG plant to the distribution network incurs expenses regarding connection lines and grid upgrade, depending on the location of the DG facility. When choosing the location of a DG facility close to an existing grid may reduce connection costs. • *Metering costs:* metering of DG production presents a cost that is allocated outside the network, and can be attributed to the DG operator. The costs for a management and control system that collects automatically metering data and provide control signals to the DG plants should, however, be attributed to the DSO. • *Costs for network upgrade and extension:* induced by DG plants. • *Costs for additional planning efforts.* • *Transaction costs* (e.g. administration costs etc.)
Energy related	• *Contributions to (peak) load reduction*: to backup capacity and to balancing power. • *Flexible option values* (e.g. short lead times for DG, contribution to balancing power, etc.) • *Improvement of security of supply* (e.g. through ICT systems and/or better forecasts) • *Avoidance of overcapacity*: avoidance of overcapacities or at least reduction of reserve margins compared to more centralised systems. In traditional power systems an increasing demand of electricity was solved by installing a new 'central' power plant. In todays market environment, over-dimensioning of power plants may be a risky investment. Small-scale DG plants are better equipped to respond to short-term demand changes. • *Less lumpy generation investment.*	• *Reserve costs:* when installing a large capacity of intermittent DG sources (e.g. wind and PV generators) a certain backup of power needs to be available. This can be another DG source (illustrating that DG can act as reserve capacity also) or centralised source. DG that is 'controllable', such as CHP plants that can be operated independently from heat demand, can contribute to reserve capacity. • *Balancing costs:* there might be a need for additional balancing power because of the intermittent character of some DG sources (such as wind or PV systems). Generally, the ability to balance the distribution system depends on the way that a DG generation facility is controllable and can present a burden or a benefit to the distribution system. • *Costs for additional system services.* • *Control costs:* in the case of controllable DG plants.

5 RATIONALES AND PRINCIPLES FOR A FUTURE REGULATORY FRAMEWORK

When restructuring electricity markets, all activities - production, transmission and distribution and retail - are unbundled. While in the first and last activities competition is introduced, the second activities remain regulated due to their natural monopolistic characteristics. As market conditions cannot be created in the network sector, regulation should, on the one hand, provide incentives for DSOs to undertake efficient investments and operation of the network while complying with consumer interests of quality levels. On the other hand, regulation should also guarantee the economic viability of the business. The regulator has the power to influence the DSO through regulation incentives.

Before going into details of the regulatory framework Leprich and Bauknecht (2004) pointed out some general rules on which regulation should be based on with respect to the allocation of the benefits and costs of DG. These general rules should especially give guidance to the political and administrative framework and will therefore be more pragmatic than scientifically exhaustive:

1. Do not try to consider system benefits or costs of DG plants if they are too small or too complex to calculate. This means that they should not be allocated to the DG plants, which in consequence means that they will stay with the DSOs.
2. Assume that the DSOs have to become ‘active’ facilitators possibly through licenses and incentives. This means that DSOs have to (see also Table 5.1.):
   - allocate the *short-term network-related benefits* to the DG plants individually or as a group wherever they can be determined,
   - consider the *long-term network-related benefits* in their network charges,
   - enable the DG plant operators to self-market the *short-term energy-related benefits* wherever markets exist,
   - consider the *long-term energy-related benefits* in their network charges,
   - bear the *short-term network-related costs* and charge the individual DG plant operators in those cases where the costs can be clearly attributed to them; the charges should give right signals in order to optimise the system in the long run. If the costs cannot be clearly attributed to individual DG plants they should be socialised through the network charges,
   - bear the corresponding *long-term network-related costs* which are necessary to optimise the system in the long run and socialise them through their network charges,
   - bear the *short-term energy-related costs* and charge the individual DG plant operators in those cases where the costs can be clearly attributed to them; the charges should reflect the corresponding market prices. If the costs cannot be clearly attributed to individual DG plants they should be socialised through the network charges,
   - bear the *long-term energy-related costs* which are necessary to optimise the system in the long run and socialise them through the network charges.
3. Bias the benefit/cost allocation temporarily in favour of DG in order to make up for biases towards centralised power plants if they really can be shown. This could mean that for example the short-term energy-related costs like balancing costs should also be socialised.

Table 5.1 *Benefit and cost allocation of DG plants*

	The short-term B/C should be allocated to the	The long-term B/C should be allocated to the
Network-related benefits.	DG operator; individually or as a group.	Active DSO
Energy-related benefits.	DG operator; (market products).	Active DSO
Network-related costs.	DG operator; (if they can be attributed to them individually).	Active DSO
Energy-related costs.	DG operator; (if they can be attributed to them individually).	Active DSO

Besides physical access to the network, DG should also have access to the power market, i.e. day ahead, balance and ancillary services markets. The organizational forms of restructured markets does not usually take into consideration the presence of DG; still it is possible to foresee an efficient and profitable integration given some necessary modifications both in the market design and the structure of supply.

A necessary requirement for any type of generator in order to participate successfully in trading activities is to have good knowledge of several kinds of information such as bidding rules, fuel prices, weather conditions and operational procedures. The costs of acquiring this information are largely fixed, giving an advantage to larger firms; they can also often determine the minimal profitable size for new entrants[11]. It is straightforward to realize that such an issue could have a negative impact on DG; still the natural barrier of large transaction costs is a characteristic, which does not rule out the profitability of DG. As a matter of fact the possibility to aggregate resources can solve the problem and allow DG to be competitive with respect to large generators: the principle is to have a single operator controlling multiple plants.

Given this general idea the next step would be to point out what type of institution could be appointed to such a task. There are several solutions, which could range from the DSO to an energy broker, but there cannot be a general recommendation since the choice should depend on the initial conditions of each market and the regulatory framework. One principle, which is important to take into account, is the possible separation of operational control and ownership. It is not necessary that the two coincide: it can be the case that the operator offers a contract to a DG owner in order to exploit its plant. In such a set up there is an efficiency improvement: the operator has superior information about markets and can use the flexibility given by coordinating multiple units.

The principle of unbundling may play a role here, since vertical integration is not only associated with ownership but could duplicate some of the anti-competitive effects. What should be analysed is the type of contract between the operator and the owner to foresee the effects[12] [13]. The role of aggregation is important also in demand, since through consortia it is possible for relatively small customers to participate directly to wholesale markets. The main recommendations from this are:

- To set up rules which facilitate aggregation of resources. These should concern dispatch and market bidding. There is a need of creating a framework for the interaction of the controller with the TSO (dispatch) and the Power Exchange (bidding). These developments should be in line with the use of active networks and a new protocol of exchange of information.

[11] This statement considers the degree of complexity introduced by the increasing use of financial derivatives contracts.

[12] This could be the case for a standardized set up proposed by the regulator to structure the arrangements between the controller and the owners.

[13] The role of control of generating capacity is being used in wholesale markets to divest generating capacity without changing ownership (Virtual Power Auctions).

- To establish a market for ancillary services where the network operator could not discriminate against a specific generating technology, but should just request neutral performance standards. This is especially important for the balancing and reserve markets. Through aggregation DG can act as a large generator and possibly improve the degree of reliability of supply, which is extremely relevant in emergency conditions.

5.1 Regulatory approach

In the SUSTELNET project the DSOs are seen as key actors for a fair market access of distributed generators. Therefore, the incentives for DSOs, which are usually closely connected with their revenue streams, are identified that hinder DG dissemination in the existing regulatory framework. These incentives should be neutralized wherever this is possible in order to create an economic level playing field. The key issues with respect to the incentive structure of the DSOs are the method of charging the connection costs and the method of calculating the use of system charges.

Connection charges

To create a level playing field between centralised production and DG (no bias towards or against DG), DG must be given market access. In this context market access for DG plants means:

- Network access for selling electricity in the wholesale and retail market.
- Access to markets for reserve power, reactive power and balancing markets (ancillary service markets).

The DSOs must provide the technological opportunities for such access. In case that the DG plant operators are allowed, but not prepared to participate in the markets, an 'active' DSO might be an intermediary between DG operators and the markets. Such participation should be an opportunity for the DSO - and not an obligation. Up to a certain market share of DG it seems to be reasonable to give priority dispatch to DG plants as the European directive for the liberalisation of the electricity market stipulates (EU, 2003a). DG units can be too small to pay the transaction costs of going to market, and if DG penetration is low, no third party will act as an intermediary and aggregate many DG plants before taking them to market. However, this does not automatically mean that DG has a better chance in the market because the prices still have to be competitive.

Whether the prices of DG plants will be competitive relies on one hand on the capital and operating costs of the plants. On the other hand the connection costs may also be an important factor, especially in cases where the DG utilises natural resources that are not located in the near of load centres. To discuss connection charges, we need to differentiate between *shallow* and *deep* connection charges:

- Shallow connection charges include only the cost of connecting the customer to the nearest point in the distribution network.
- Deep connection charges include any cost of reinforcements of the existing network that has been induced by the DG plant.

It is generally agreed that *shallow* connection charges (connection only) do not create a level playing field from a strict economic point of view. When the full cost of connecting DG is not charged to the DG investor, economically inefficient investments in DG may be made. In addition, shallow connection charges do not give DG operators the right signal as to where to locate a new plant, and it might discourage DSOs from connecting DG.

With *deep* connection charges every new entrant is treated individually and will face actual marginal cost of connection. In theory this will give correct signals for investment. However there are some severe problems with this theory:

- *Economies of scale and first mover disadvantage:* The initial investment in grid reinforcement is usually large, but any later DG entrants will not induce any further investment cost. Therefore the first mover must not be charged for the entire investment, which would be prohibitive for him in most cases and hence undermine optimal economic solutions.
- *Meshed grids:* Any grid reinforcement in meshed grids induced by DG may also benefit other customers. It may be argued therefore that such reinforcement costs should not be included in deep connection charges. However, if they are completely left out, DG investment could induce more reinforcements than are economically optimal.
- It has also been argued that it will be difficult, or impossible, to determine the deep costs *correctly*, and that they should therefore be left out. But then it is still possible to include deep costs in cases where they can be determined.

It should be noted that deep connection charges might be negative in cases when the DSO can postpone or avoid network reinforcements by connecting DG instead.

In the UK it has been proposed to use shallow connection charges plus an 'entry charge' Mitchell (2002). The entry charge is a charge for feeding into the network, and it can have a positive, zero or negative value. It must not be cost-reflective because its main purpose is to give right locational signals to DG investors.[14] An entry charge can be a tool for avoiding that prohibitively large connection charges are charged up front, but charged (entirely or partly) during the lifetime of the DG plant.

From this it is clear that there is a whole range of options for connection charges between shallow and deep connection charges. It should be kept in mind that the difference between deep and shallow connection costs would be socialized and paid through the use-of-system charges by the customers.

Following the rationale of a level playing field the SUSTELNET project proposes as guideline for setting up DG connection charges:

Choose shallow connection charges and individual entry charges, which give correct locational signals. The revenue balance of the entry charges has to be considered when calculating the use-of system charges. The difference between shallow and deep connection charges should be a part of the use-of-system charges.

Use of System charges

Use of System (UoS) charges represent the main revenue stream to DSOs, and their incentives are strongly related to the way they are calculated. While the level of the UoS charges is one of the central points of the liberalisation discussion, it does not however discriminate against DG no matter how high it is. Therefore the SUSTELNET project does not discuss the resulting level from the different UoS calculation schemes but instead the schemes themselves and especially the incentives that are incorporated.

[14] It should be noted however that the decision for a specific location is rather complex and that an entry charge is just one factor that could influence the decision. Beside this other forms of price signals (e.g. nodal/zonal pricing) might be an alternative to an entry charge.

In general the UoS charges will enable the recovery of the following costs: [15]

- Operation and maintenance costs of the network, including taxes (operational expenditures; OPEX).
- The annual (calculatory) depreciation from the asset base which includes mainly the investment costs of the network and the transformers (capital expenditures; CAPEX).
- The allowed rate of return on the (regulatory) asset base (RAB).

If there are entry charges as described above they have to be subtracted from the total costs in order to calculate the UoS charges[16].

Different types of regulatory approaches exist that range from light-handed to heavy-handed regulation systems. Alongside the liberalisation of the electricity sector, the regulation of networks developed from traditional, heavy-handed, rate of return (ROR) regulation to, more light-handed, incentive regulation systems. The ROR regulation allows the DSO to cover its operation and capital expenditures as well as a return on capital, without encouraging firms to reduce costs and become more efficient. Incentive regulation aims at providing DSOs with incentives for efficiency improvements while also passing them down to consumers. Incentives are given through the benchmarking of certain costs. Jamasb and Pollit provide a review of different countries, including some EU Member States that have implemented incentive regulation systems.

In order to provide a sustainable regulation, the regulatory framework should consider the values of DG. In other words, DSOs should be provided with incentives to use DG as an option for the efficient operation of the network. As Connor and Mitchell (2002) show, current distribution regulation systems in a number of EU MS currently do not properly consider DG. Examples of these problems include:

- Incentive regulation systems implemented prove to be anti-innovative. For example, when both operational and capital expenditures are benchmarked, DSOs are encouraged to minimise these costs. As a result, DSOs are not given incentives to undertake innovative actions which could prove to be more expensive in the short-term but more profitable in the longer-term.
- When capital expenditures are provided with a fixed rate of return, DSOs will not be encouraged to connect DG, as this type of generation can avoid network investments and therefore reduce DSOs income.
- Connection costs are also of high significance to DG. While deep connection costs can prove prohibiting to DG projects, shallow connection costs can be a burden to DSOs because they don't cover costs generated inside the net. As a result DSOs are disincentivised towards possible connection of DG and are likely to look for ways of avoiding its connection and of avoiding investment in the support of a network favourable to DG.

Following the rationale of a level playing field, the SUSTELNET project formulated guidelines for setting up use-of system charges:

1. *Ensure the recovery of all (planned and unplanned) costs associated with the connection of (economic efficient) DG plants that are not paid for by the DG plant operators.*
2. *Neutralise the sales maximisation incentive through the application of a UoS charge adjustment formula that has different revenue drivers.*

[15] For a more detailed description of common regulation schemes see e.g. Phillips 1988; Politecnico di Milano et al. 2000.

[16] Sometimes UoS charges are then referred to as 'exit charges'.

3. *Include the grid reinforcement costs induced by DG plants and possibly the connection costs in the regulatory asset base (RAB) of the DSO.*[17]
4. *Implement a dependency between the allowed rate of return and both the performance standards with regard to customer satisfaction, system reliability and DG connections, and the long-run network optimisation including local/regional DG plants and line losses.*

Having the resulting incentives of the different regulatory schemes and the above guidelines in mind, the schemes can be sorted in ascending order according to their bias against DG (first has the strongest bias, last the weakest or none):
1. ROR regulation with a long 'regulatory lag', price-cap and revenue-cap regulation with *index-oriented* adjustment clauses or 'pure' benchmarking.
2. ROR regulation, price-cap and revenue-cap regulation with *cost-oriented* adjustment clauses or benchmarking with cost adjustments.
3. Revenue-per-customer cap or multiple driver cap regulation with cost-oriented adjustment clauses and *correction factors*[18] as leading regulation scheme, benchmarking with cost adjustments as a complementary approach to increase the pressure for efficiency.

5.2 Status of unbundling

The incentive structure of DSOs is influenced by the degree of unbundling:
- If the distribution function is not completely unbundled with the generation function-prefererably by ownership - the DSOs might see DG plants as competitors that threaten to reduce the output of their own plants.[19]
- If the distribution function is not completely unbundled with the supply function, the DSOs will fear to loose supply margins because of DG plants as auto producers selling excess energy to the grid or presumably as neighbourhood-suppliers.[20]

Table 5.2 *Level of unbundling and impact on DG*

	Unbundling by ownership	Weaker forms of unbundling[a]
Distribution/generation	Neutral against DG.	Biased against DG from third parties because of possibility to under-utilise own plants.
Distribution/supply	Neutral against DG except against auto producers who (partly) do not use the network.	Biased against DG because of loosing the supply margin especially in case of neighbourhood-suppliers.

[a] Weaker forms of unbundling are unbundling of accounts, administrative and legal unbundling. The EU Electricity Directive (2003/54/EC) requires minimal legal unbundling.

The guidelines for DSO regulation have to take the status of unbundling into account in order to neutralise the biases that might result from weak forms of unbundling.

[17] Even though the costs for the connection line are paid by the DG plant operators, it would make sense to include them into the RAB of the DSO for two reasons: a) the depreciation rates will ensure the upgrade of the connection line in the future and b) this practice would give the DSOs an incentive to connect DG plants to their grid. The inclusion of the connection costs into the RAB however depends on who is the owner of the connection line. If it is included into the RAB the DSO has to be the owner of it.

[18] The main correction factor would be the consideration of the balance between forecasted and actual sales (i.e. distributed kWh).

[19] If the DSOs need certain DG plants to manage their networks in an optimised way the possibility of DG ownership should not be excluded generally. On the other hand the bundling of the generation and distribution function tends to bias the DSOs towards the utilisation of their own plants and thus distorts the market. We think that the market should be able to provide enough offers for every situation where the DSO needs DG plants.

[20] This will also hold true in an unbundled situation with respect to the grid charges, but then at least the DSOs do not care about loosing the supply margin. So unbundling will not solve this problem, but weaken it.

5.3 Future of DSOs

DSOs have to also radically evolve if it is expected for a more sustainable system to develop. DSOs in the current electricity supply industry are passive organisations whose sole objective is the provision of distribution network services, mainly transport of electricity. The operation of the system and provision of ancillary services is generally done by the Transmission System Operators. However, if the expected increase in DG wants to be successfully accommodated in the electricity system, electricity networks should reconfigure into active networks, where DSOs evolve from this passive organisation into more active actors. In other words, DSOs should become active and innovative entrepreneurs that would facilitate and profit from the connection of DG into the system. By doing so and because DSOs would receive (for some part) the benefits DG creates, they would on the one hand be provided with incentives to connect DG and, on the other hand, provide the correct signals to generators and consumers in order to efficiently behave towards the network.

6 BENCHMARKING OF ELECTRICITY MARKET REGULATION

By using the guidelines and criteria developed in the SUSTELNET project Boccard (2004) performed a benchmarking exercise in Work Package 4.3. The methodology is based on three steps:

1. Identification of actual regulatory practices (using reviews of the existing regulatory framework in the participating EU Member States from Work Package 2).
2. Value a series of standardized questions relative to these practices against a single 'adequate' regulatory framework (result of Work Package 4.2).
3. Synthesize of the results.

The evaluation method used in this benchmarking exercise was based on three normative valuation grids, one for each stage of market presence of DG: low, intermediate and high. Following the DG characterisation of Table 2.1 the level of DG in the participating Member States have been identified (see Figure 6.1). For each DG level and for each qualitative or quantitative question the possible answers were evaluated being repulsive (-1), neutral (0) or supportive (+1) to DG in the light of the level playing field objective. I.e. policies are benchmarked against the guidelines and criteria that came out of Leprich and Bauknecht (2004) and not against each other.

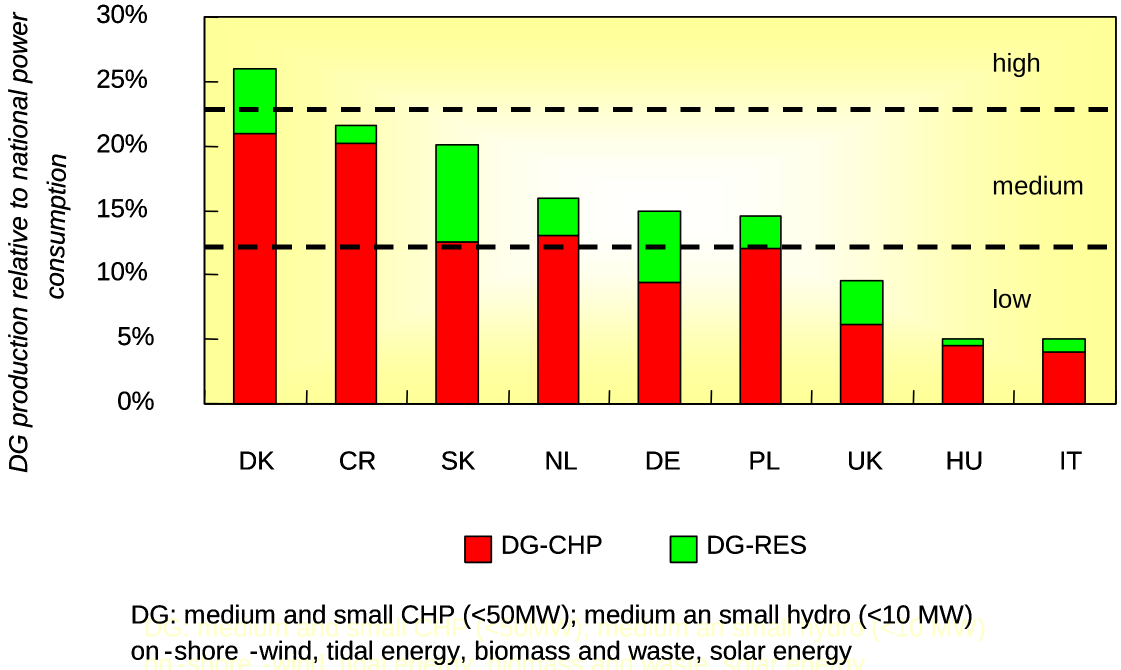


Figure 6.1 *Indicative DG shares in power supply in participating EU Member States*

The regulatory issues have been divided in those related to network regulation and those related to market access for DG. To derive a rough idea of the strengths and weakness of a Member States' regulation toward DG the actual regulatory practices were gathered into 4 groups, one for market access and three for network regulation:

1. the regulatory framework for DG,
2. the DG-DSO financial relationship,
3. the regulatory framework of DSOs.

Hence the synthesis for a Member State shall consist of four numbers each summing the valuation for all items inside one class. Overall scores are frequently negative since the benchmark corresponds to the ideal situation where a level playing field is in place, which is planned at the horizon of 2010-2020. Table 6.1 shows the results in three separated classes.

Table 6.1 *Results of the benchmarking exercise*

	Denmark	Czech Republic	Germany	The Netherlands	Poland	Slovakia	Hungary	Italy	United Kingdom
Market Presence	High	Med.	Med.	Med.	Med.	Med.	Low	Low	Low
Market Access	-2	-1	-1	3	1	1	0	1	1
Network Regulation									
• Regulatory framework for DG	-1	4	3	3	-1	-1	4	-1	0
• DG-DSO financial relationship	-1	2	-3	-1	-1	-3	2	0	-3
• Regulatory framework for DSOs	-2	-3	-5	-1	-3	-1	-1	-5	-1

Conclusions cannot be drawn from the results of the benchmarking exercise because the study is partial and incomplete by nature. It only can help to identify in which topics Member States differentiate in a given class of DG penetration.

Paradoxically, the country with the highest level of DG penetration, Denmark, receives on average the lowest marks for its regulatory regime. To a large extend this is due to the fact that the criteria used for high levels of DG penetration are more stringent than for lower levels. It indicates the need to adjust the Danish regulatory regime to a situation where DG is a major market player, and where DG should be included in the market on terms that induce efficiency[21]. Conversely, countries with low levels of presence for DG fare rather well. As a general result, new Member States outperform older Member States since the implementation of electricity legislation has closely followed the relevant European directives. The differences in scores are strongly affected by the number of questions addressing the different issues. For instance different levels of unbundling create large differences in the category ‘Regulatory framework for DSOs’.

[21] It should be noted that the high DG penetration in Denmark is the result of a strong supportive policy from the past.

7 REGULATORY STRATEGIES

Just as building electricity networks is a long-term activity, changing existing distribution networks into innovative networks will also take many years. Furthermore, to create stable conditions in economic network regulation, new rules are only introduced at the start of a new regulatory period (i.e. each 3 to 5 years). Changing the regulatory framework may take more than one step and therefore also the transition period for regulation may take many years. A long-term regulatory strategy is needed for the transition of the current regulatory framework into a new regulatory framework that creates the level playing field in electricity supply, considers the deployment of DG and creates incentives for DSOs to innovate. A clear regulatory strategy could help to reduce regulatory uncertainty.

In Work Package 5 of the SUSTELNET project the concept of regulatory road map has been developed as to provide regulators with an instrument to map out regulatory strategies. Subsequently, regulatory roadmaps were developed for the nine EU Member States participating in the SUSTELNET project in close cooperation with stakeholders in these countries.

7.1 Regulatory roadmaps

To operationalise the regulatory strategy, regulatory roadmaps can be used[22]. A regulatory road map is a guide to the development of electricity regulation. A road map stipulates the regulatory actions that are necessary to reach a desired future state of market organisation. A road map contains a series of regulatory actions and developments. Furthermore, the road map indicates the timing of regulatory steps. The timing of these steps depends on key developments in the electricity sector and the penetration of DG in the electricity market. The level of detail in the description of the regulatory actions is higher for the short-term actions than for the long-term actions. Considering that regulation never takes place in isolation, a road map should address all stakeholders.

In Work Package 5 a framework has been set up for developing regulatory roadmaps (Van Sambeek and Scheepers, 2003). The regulatory issues that need to be tackled in the regulatory roadmaps can be divided in issues related to network regulation and issues related to market access for DG/RES. For network regulation five consecutive stages have been identified and three stage for market access. The criteria and guidelines of each stage are listed in Tables 7.1 and 7.2. Criteria are provided for each stage of regulatory development to help to determine what the current status of regulation is and to help define which regulatory steps need to be undertaken in order to establish a level playing field.

The scheme for defining the starting point and regulatory steps for the roadmaps can be established through a combination of the stages of network regulation and the stages of market access. Figure 7.1 provides an overview. The stages for market access may depend on the share of DG/RES in the total electricity supply. I.e. a 'protected niche market' may be appropriate if there is only a limit amount of DG/RES, whereas the 'level playing field' stage should be reached in case of moderate to high level of DG/RES supply. The arrows indicate the possible routes for improvement of the regulatory framework. Network regulation can be improved separately from market access, but if market access of DG improves this will probably also require changes in network regulation. If DG/RES will remain on a low or moderate level this will not

[22] The principle of regulatory road maps can be derived from technology road maps. Technology road maps describe possible routes of technology development and show the probable date of market introduction. Often technology road maps also indicate the intermediate steps and timing of technology development. For example: Electricity Technology Roadmap, EPRI, 1999 (http://www.epri.com/corporate/discover_epri/roadmap/index.html).

require innovative networks (grey area in Figure 7.1). Therefore, the development of network regulation could be limited to ‘refinement of cost driven incentive regulation’ for a low and ‘innovative regulation’ for a moderate DG/RES supply level.

The process of developing regulatory roadmaps can be divided into five steps:

1. *Define starting point*
   The starting point can be described with use of descriptors that were used in the scenario development (see Section 3.3). In order to be able to develop a regulatory road map more details on the status of electricity regulation are needed. Therefore, the regulatory starting point should also be established. This is done by using stages of network regulation and market access in the regulatory roadmap scheme (see Figure 7.1).
2. *Scenarios and background story line*
   The next step is to define the possible future for the electricity supply system. Scenario A (DG opportunities in a fully harmonised EU market) is the preferred scenario for developing the regulatory roadmaps (see also Section 3.3). Subsequently, specific policy targets and ambitions should be defined. The most important target for the development of the roadmaps is the level of DG and RES. A background story line should be constructed, i.e. a description of the path along which developments could take place. From the background story line critical points and path dependencies in achieving medium and long-term targets should be identified.

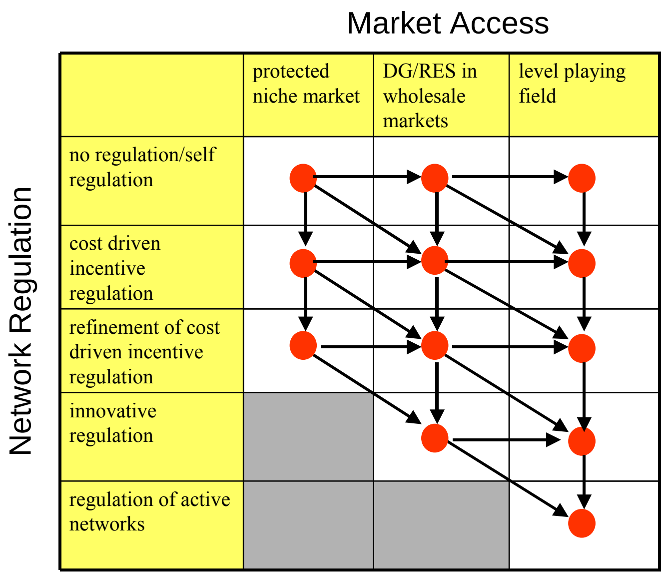


Figure 7.1 *Regulatory roadmaps scheme*

3. *Identify final status of the regulatory framework*
   With the scenario and the background storyline the future is described. Now the final status of the regulatory framework in the roadmap scheme should be identified, using the regulatory road map scheme by establishing the stage of market access on the basis of the level of DG (low, medium, high) and establishing the stage of network regulation.
4. *Back cast regulatory steps and check robustness*
   The route along which the regulatory framework could be improved should be established and the consecutive steps should be timed. Next, guidelines for each regulation step should be described. Subsequently, future developments different from Scenario A should be considered. Regulatory actions in the roadmaps should be checked for their robustness against these different developments or for disruptive events.

Table 7.1 *Stages of network access and regulation*

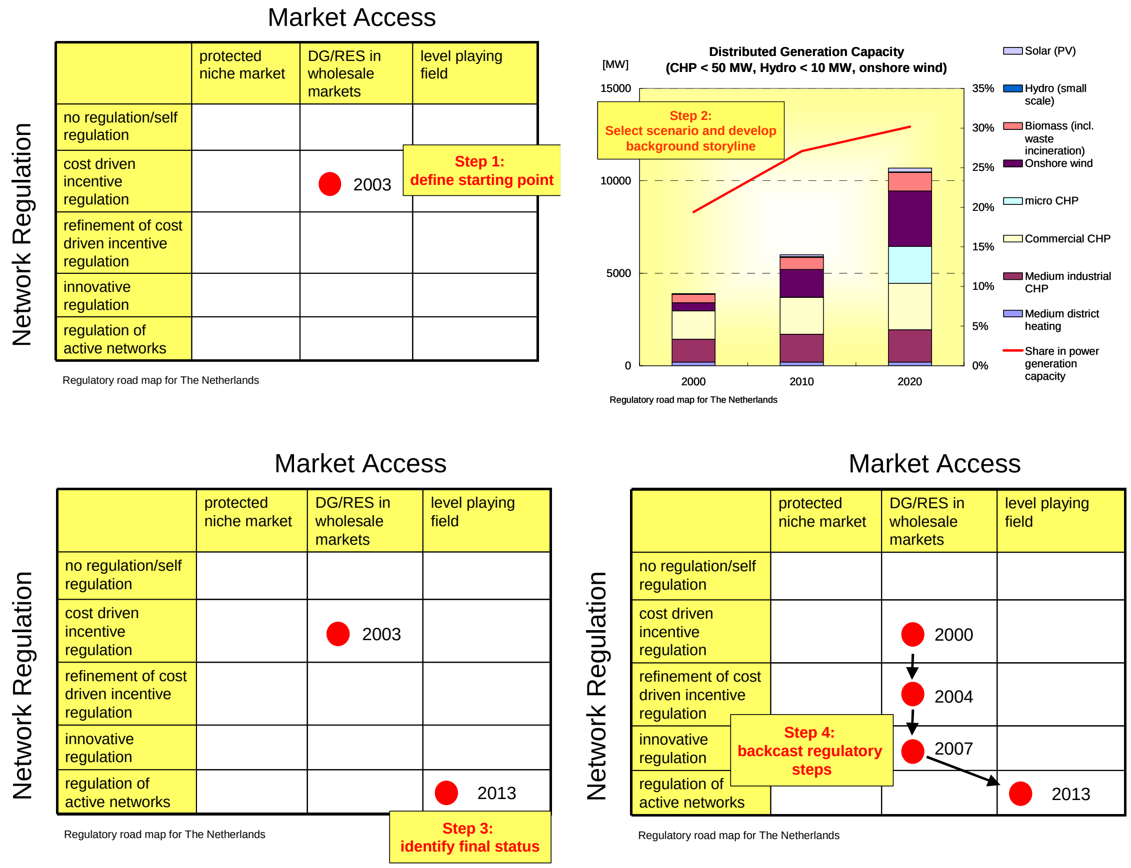
Network Access	Description	Criteria		Guidelines [a]
		DG values	Regulatory issues	
No regulation/self regulation.	Passive, nTPA, no real unbundling required.	-	(negotiated) connection charges (Access possible?)	Negotiated TPA
Cost-driven incentive regulation.	Passive, cost-driven, efficiency improvements, accounting/legal unbundling.	-	(standardised) connection charges (Access mandatory)	Shallow connection charges. E.g. Large scale power generation charged with UoS charges of the transmission network.
Refinement of cost-driven incentive regulation.	Passive, cost-driven, short-term benefits and costs of all DG incorporated, multiple-drivers (quality, etc), DG integrated part of the regulation model, legal unbundling.	Short-term; measurable/non-measurable; socialised.	<u>Short-term</u> *Socialised*: network losses, avoided investments, (extra) DSOs OPEX.	Shallow connection charges. E.g. dummy compensation for DG connected to low/medium voltage for network losses; DSOs contract system services with DG.
Innovative regulation.	Innovative network predominantly passive, multiple drivers, long-term/short-term, benefits/costs of DG, some individual allocation, incentives for innovation, legal unbundling.	Some short-term / long-term; measurable/non-measurable; socialised/individual.	<u>Short-term</u> *Individual*: metering, connection costs. *Socialised*: network losses, (extra) DSO's OPEX. <u>Long-term</u> *Individual*: avoided investments. *Socialised*: improved security of supply by DG, DSO's innovation incentive.	Shallow connection charges plus entry/exit charges. E.g. surcharge UoS charge in order to cover for innovation experiments costs.
Regulation of active networks.	Holistic approach, active, innovation, DG integrated part of regulatory model, legal (ownership?) unbundling.	Short-term/Long-term; measurable/ non-measurable; socialised/individual.	<u>Short-term</u> *Individual*: network losses, metering, connection costs, system services (reactive power, voltage support, etc). *Socialised*: (extra) DSO's OPEX. <u>Long-term</u> *Individual*: avoided investments. *Socialised*: improved security of supply by DG, DSO's innovation incentive.	Actively managed networks Shallow connection charges plus entry/exit charges. E.g. higher allowable rate off return for innovation investments (consequence of higher risk).

[a] This section includes both, guidelines that are universally agreed and therefore should be considered when building the roadmap, and examples of guidelines. The latter, which are preceded by an e.g., are included only for clarification purposes and therefore it is up to the users to apply it or not in the development of the country roadmaps. Although the examples can repeat themselves in the different regulatory stages, they are only included once in the table.

Table 7.2 *Stages of market access*

Market Access	Description	Rationale	Criteria		Guidelines
			Type of market access issues	Market access issues	
Protected niche market.	DG outside the markets; good market mechanisms in place?	Low (Moderate) penetration level of DG. Protection of incipient DG.	Energy	DG supplies: Energy	– Priority dispatch, obligatory purchase regimes. – Regulated feed in tariff possibly also compensating for system benefits.
DG/RES in wholesale market. (settlement in wholesale and ancillary service markets)	Assuming markets for energy and ancillary services in place, DG anticipates in the demand side of this market. Demand side is regulatory/mandatory. DG has no or indirect effect on prices.	(Low) moderate penetration level of DG.	Supply of energy and demand of services.	DG supplies: Energy DG demands: Reactive power, balancing power, back up power, voltage support.	– Separate commodity price. – Market support mechanisms to stimulate technologies and account for externalities. – DG in competition with large scale generation.
Level playing field. (active participation in energy and ancillary services markets)	DG participates in demand and supply side of markets. DG has direct effect on prices through markets.	High penetration level of DG.	Supply and demand of energy and services.	DG supplies: Energy, balancing power, reserve power, voltage support, reactive power. DG demands: Balancing power, back-up power, voltage support, reactive power.	– Separate commodity price. – Market support mechanisms account only for externalities. – DG in competition with large scale generation.

5. *Describe actions and responsibilities*
In the final step the responsibilities of different stakeholders are described as well as their actions in the road map (what and when), divided into three groups: market access, network regulation and governance.



Actor	2004	2007	2013
Ministry of Economic Affairs	• if necessary, has to changes the Electricity Law		
Regulator	• Yardstick system • Quality measures • Benchmark of: - Network losses - Network investments - Reactive power	• Entry/exit charges • Performance base incentives • Innnovation incentives	• Improvement of incentives based on the active networks
DNOs	Step 5: Describe actions and responsibilities	• Increase innovation and technolgy testing to develop active networks • Evevolv into active business oriented firms • Actively manage the network, providing location signals to generation • Improve coordination with TSO	• Allocation of benefits and costs to DG
DG operators		• Actively participate in energy and ancillary markets	

Regulatory road map for The Netherlands

Figure 7.2 *Schematic illustration of the development of the regulatory roadmap for the Netherlands in five steps*

7.2 Development of nine national regulatory roadmaps

Today there are large differences between EU MS regarding electricity regulation, electricity market competition, share of DG in the electricity supply, electricity network structure, incentives for RES and DG, etcetera. Large differences between countries can also be identified if the potential for RES and CHP development is considered. Therefore, the starting point as well as the future outcome of a DG opportunities scenario will be different for each specific country. Within Work Package 5 of the SUSTELNET project regulatory roadmaps have been constructed for nine EU Member States, including four new Member States. Table 7.2 provides an overview of the nine regulatory roadmaps, indicating the starting point and the final state. The Text Box gives an illustration of the development of the regulatory road map for The Netherlands.

Table 7.3 *Overview of starting point and final stage of the nine national regulatory roadmaps (note that the road map may contain one or more intermediate stages)*

Country	Starting point		Final stage		
	Network regulation	Market Access	Year	Network regulation	Market Access
Czech Republic	Cost driven incentive regulation.	DG/RES in wholesale market.	after 2010	Innovative regulation.	Level playing field.
Denmark	Cost driven incentive regulation.	Protected niche market.	2012-2020	Regulation of active networks.	Level playing field.
Italy	No regulation/self regulation.	DG/RES in wholesale market.	2013-2020	Innovative regulation.	Level playing field.
Germany	No regulation/self regulation.	Protected niche market.	not defined	Regulation of active networks.	Level playing field.
Hungary	Cost driven incentive regulation.	Protected niche market.	2014-2020	Innovative regulation.	DG/RES in wholesale market.*
Poland	Protected niche market.	Cost driven incentive regulation.	2016-2020	Regulation of active networks.	Level playing field
Slovakia	Cost driven incentive regulation.	DG/RES in wholesale market.	2010-2020	Innovative regulation.	Level playing field.
The Netherlands	Cost driven incentive regulation.	DG/RES in wholesale market.	after 2013	Regulation of active networks.	Level playing field.
United Kingdom	Refinement of cost driven incentive regulation.	Protected niche market.	2006	Innovative regulation.	DG/RES in wholesale market.

* Possible: level playing field

8 RECOMMENDED ACTIONS FOR EUROPEAN POLICY

The key findings of the SUSTELNET project were compared with the current EU legislation, i.e. the Electricity, the Renewables and the CHP Directive. Additional EU policy, regulation and initiatives have been identified that can help Member States in developing future economic efficient and sustainable electricity supply systems (Van Sambeek and Scheepers, 2004).

Non-discriminatory network access is a key precondition to a level playing field between centralised and distributed generation. To ensure non-discriminatory access to the network for distributed generation connection charges should be based on shallow connection costs. The current EU Directives contain no provisions on the prescription of shallow or deep connection charges in national electricity regulation. However, it is stated in various directives that non-discriminatory access to the network shall be given to all generators.

Open access to wholesale electricity markets for distributed generation is already granted by the Electricity, RES and CHP Directives. The scope of market access should be broadened to include ancillary services. These services can be provided through market-based methods from both centralised and distributed plants, but are currently mostly sourced from centralised generation by TSOs and passed on to the DSOs, while distributed generators cannot offer ancillary services to the DSOs. In particular services related to balancing and power quality such as, reliability, reactive power and voltage support should be considered in this respect. It is recommended that the markets for ancillary services are opened up to distributed generators and that DSOs are given more flexibility in sourcing these services to meet their service obligations to their connected customers.

The benefits and cost of distributed generation to the electricity system are directly related to the geographical point of connection. It is therefore considered fair that these costs and benefits are somehow reflected in the use of system charges and electricity pricing to the distributed generator. More specifically, locational signals that take into account long-run system costs and benefits should be incorporated in an entry charge on top of the shallow connection charge. This entry charge may be positive in the case of cost to the system, or negative in the case that DG entails benefits to the system. Furthermore, systems of nodal spot pricing should be implemented to provide correct local valuation of the energy delivered to the network.

To facilitate the integration of DG in electricity networks DSOs have to endorse ‘active network management’. This active network management entails investment in innovations to improve network management, in particular in the field of ICT. The current regulatory frameworks often do not allow for DSOs to recover the cost of investments in innovation. It is therefore recommended that the Electricity Directive is amended to grant authority to national regulators to create a regulatory framework that provides an effective and efficient environment for investment in innovations. In view of the required innovations in network management EU policies should also seek to stimulate the exchange of knowledge in the field of DSO incentivisation and innovation in distribution networks.

9 ASSESSMENT OF RESULTS AND CONCLUSIONS

The SUSTELNET project analysed the main drivers and obstacles that play a role in the current transition towards sustainable electricity supply systems in Europe. Whereas sustainability policies (i.e. GHG emission reduction, renewable energy supply, energy saving) are driving electricity supply systems towards decentralisation and renewable energy supply, economic regulation implemented in EU Member States as part of the liberalisation process comprise still many flaws discouraging the deployment of distributed generation. The current regulatory framework does hardly recognize the economic values distributed generation can provide for the electricity system and still favours large-scale generation. In order to achieve the sustainability goals governments in many countries use support schemes for RES and CHP to overcome the barriers of inadequate economic network regulation.

The project developed guidelines and criteria for a regulatory framework that will improve the allocation of benefits (and costs) of distributed generation between DSOs and DG operators, will create a better level playing field between large scale power generation and DG and will provide DSOs with the means to optimise the network in the long term.

The regulatory incentives should stimulate distribution system operators to consider distributed generation to optimise network. Operational optimisation will only be possible if a new type of network management is adopted - so called ‘active networks’. Network innovation is a necessity for the transition towards sustainable electricity supply systems with a high level of decentralised and renewable energy supply as was illustrated by the Danish example. The new regulatory framework should therefore also provide provisions for network innovation. DSOs should be allowed to experiment with new network technologies without direct consequences for their profits. Furthermore, distribution system operators should be motivated also to become ‘active’, i.e. become innovative entrepreneurs.

Since the transition towards sustainable electricity supply systems and ‘active networks’ will take many years, the regulatory framework should be gradually adapted to the new situation. The project developed an instrument for regulators to develop a regulatory strategy for the medium and longer term. The method - regulatory roadmaps - has been applied for nine EU Member States involved in the project.

The development of guidelines and criteria for the future regulatory framework as well as the development of regulatory roadmaps has been discussed with stakeholders (regulators, utilities, policymakers, etc.). In general stakeholders appreciated the results of the SUSTELNET project and showed interest in possible future developments. However, regulators seem to hesitate to adopt the guidelines and criteria or the road map method. For some countries this can be explained by the still limited experience with economic regulation of electricity networks (new EU Members States, Germany). For some others it seems that regulators and distribution system operators are already locked into the new system were DSOs minimize their regulatory exposure and regulators refrain from giving DSOs incentives to change (e.g. the Netherlands).

Promising is, however, that in the UK the possible impacts of renewable energy development on the electricity network have been analysed and that the UK regulator has created instruments for DSOs for innovating the distribution networks. Furthermore, in Denmark initiatives exist to start experiments with active network management.

REFERENCES

Boccard, N. (2004): *A Benchmarking of 9 European Member States policies towards Distributed Generation*, University of Girona, January 2004, http://www.sustelnet.net/documents.html.

Connor, P and C. Mitchell (2002): *A Review of Four European Regulatory Systems and Their Impact on the Deployment of Distributed Generation*, University of Warwick, October 2002, http://www.sustelnet.net/documents.html.

EU (1996): Directive 96/92/EC.

EU (2001): Directive 2001/77/EC.

EU (2002): *Towards a European Strategy for the Security of Energy Supply*, (COM (2002) 321 final, June 2002.

EU (2003a): Directive 2003/54/EC.

EU (2003b): *European Energy and Transport - Trends to 2030*, January 2003, http://europa.eu.int.

EU (2003c): COM(2003) 735 final.

EU (2004): Directive 2004/8/EC.

EU (2004b): *The Share of Renewable Energy in the EU*, COM (2004) 366 final, May 2004.

Jamasb, T. and M. Pollitt: *Benchmarking and Regulation of Electricity Transmission and Distribution Utilities: Lessons from International Experience*, Working paper, University of Cambridge, http://www.econ.cam.ac.uk/dae/repec/cam/pdf/wp0101.pdf.

Leprich, U. and D. Bauknecht (2004): *Development of criteria, guidelines and rationales for distribution network functionality and regulation*, IZES/Öko institut, March 2004.

Mendez, V.H., et al.: *Impact of Distributed Generation on Distribution Losses*, Univerisdad Pontificia Comillas, http://www.iit.upco.es/docs/02VMQ01.pdf.

Mitchell, C. (2002): *Response to Ofgem's update on structure of Electricity Charges*, University of Warwick, October 2002, http://users.wbs.warwick.ac.uk/cmur/publications/response_ofgem_dec6.pdf.

Nielsen, J.E. (2002): *Review of Technical Options and Constraints for Integration of Distributed Generation in Electricity Networks*, Eltra, October 2002.

Nielsen, J.E. (2002): *Review of the Role of ICT in Network Management and Market Operations*, Eltra, October 2002.

Phillips, Charles F. (1988): *The Regulation of Public Utilities: Theory and Practice, Second Edition*, Arlington VA: Public Utilities Reports, Inc., June 1988.

Politecnico di Milano /Wuppertal Institut / Energieverwertungsagentur Wien (2000): *DSM pilot actions, DSM bidding and removal of DSM disincentives from price regulation. A joint project in Italy, Germany and Austria co-funded by the European Commission (DGXVII, SAVE programme). Volume 3: Price regulation and removal of DSM disincentives in monopoly segments of restructured electricity markets*, Mailand/Wuppertal/Wien 2000.

Ten Donkelaar M., R. Čížek, M. Malý, A. Tomeková, J. Fucskó, T. Skoczkowski (2003): *Review of technical options and constraints for integration of distributed generation in electricity networks - Country overviews of the Czech Republic, Slovakia, Hungary and Polan,,* ECN-C--03-076, July 2003,.

Timpe, C. and M.J.J. Scheepers (2003): *A look into the future: scenarios for distributed generation in Europe*, Öko institut/ECN, ECN-C--01-012, November 2003 (can be downloaded from http://www.sustelnet.net).

Verbong, G., E.van der Vleuten and M.J.J. Scheepers (2002): *Long-Term Electricity Supply Systems Dynamics - a histroic analysis*, ECN/Eindhoven University of Technology, ECN-C--02-084, October 2002.

Van Sambeek, E.J.W., M.J.J. Scheepers and A. Wals (2003): *An Outline for Developing Regulatory Roadmaps*, ECN-C--03-101, 2003.

Van Sambeek, E.J.W. and M.J.J. Scheepers (2004): *Regulation on Distributed Generation - A European Policy Paper on the Integration of Distributed Generation in the Internal Electricity Market,* ECN-C--04-070 (2004).

Wals, A.F., R. Cižek, M. Malý, M.A. Tomeková, J. Fucskó and T. Skoczkowski (2003): *A Brief Review of Four New Accession States Regulatory Systems and Their Impact on the Deployment of Distributed Generation*, ECN-I--03-008, May 2003.