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

A LOOK INTO THE FUTURE: SCENARIOS FOR DISTRIBUTED GENERATION IN EUROPE

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Abstract
Based on the analysis of the long-term historical and future technical, socio-economic and institutional dynamics of European electricity supply systems and markets, the SUSTELNET project developed scenarios for future electricity supply systems in EU Member States and Newly Associated States (NAS). These scenarios provide a background for the development of regulatory road maps, which can be used as a tool to map out a regulatory strategy, facilitating the transition of current regulation into a regulatory framework that is required for future sustainable electricity supply systems. This report describes four different scenarios for the future of electricity systems and DG in Europe in a qualitative manner. Moreover, the methodology used to develop these scenarios is described as well as the impact that disruptive events may have on these scenarios.

CONTENTS

PREFACE

Technological developments and EU targets for penetration of renewable energy sources (RES) and greenhouse gas (GHG) reduction are decentralising electricity infrastructure and services. Although liberalisation and internationalisation of the European electricity market has resulted in efforts to harmonise transmission pricing and regulation, no initiative exists to consider the opening up and regulation of distribution networks to ensure effective participation of RES and distributed generation (DG) in the internal market. The SUSTELNET research project provides the analytical background and organisational foundation for a regulatory process that satisfies this need.

Within the SUSTELNET research project, a consortium of 10 research organisations analysed the technical, socio-economic and institutional dynamics of the European electricity supply system and markets. This has increased the understanding of the structure of the current European electricity sector and its socio-economic and institutional environment. The underlying patterns thus identified have provided the boundary conditions and levers for policy development to reach long term RES and GHG targets (2020-2030 timeframe). Consequently analysis was made as to what regulatory actions are needed in the short-to-medium term to reach the existing medium-term goals for 2010 as well as likely scenarios for longer-term goals.

Regulatory Road Maps

The main objective of the SUSTELNET project was to develop regulatory road maps for the transition to an electricity market and network structure that creates a level playing field between centralised and decentralised generation and network development. Furthermore, the regulatory road maps will facilitate the integration of RES, within the framework of the liberalisation of the EU electricity market.

Participatory Process

To deliver a fully operational road map, a participatory regulatory process was initiated throughout this project. This process will bring together electricity regulators and policy makers, distribution and supply companies, as well as representatives from other relevant institutions with the final objective of enhancing implementation of DG.

Newly Associated States

The SUSTELNET project also anticipates the enlargement of the EU by providing support to the Newly Associated States (NAS) with the preparation of a regulatory framework and thus also with the implementation of EU Directives on energy liberalisation and renewable energy in four Accession Countries (The Czech Republic, Poland, Hungary and Slovakia).

Project Structure

The SUSTELNET project was divided into two phases. During the first phase, the analytical phase, three background studies were produced:

- Long- term dynamics of electricity supply systems in the European Union.
- Review of the current electricity policy and regulation in the European Union and in Member States.
- Review of technical options and constraints for the integration of distributed generation in electricity networks.

In the second phase, the participatory regulatory process phase two activities took place, during which there were extensive interactions with regulators, utilities, policy makers and other relevant actors:

- Development of a normative framework: criteria for, and benchmark of distribution network regulation.
- Development of policy and regulatory road maps.

This Report

This report was produced during the participatory regulatory process phase of the project to provide a background for development of policy and regulatory road maps.

EXECUTIVE SUMMARY

The SUSTELNET project has identified four different scenarios for the future of electricity supply systems and distributed generation (DG) in Europe, which have been described in a mainly qualitative manner. These scenarios are characterised by the degree of harmonisation of the electricity sectors within the EU and the level of incentives for DG (e.g. through support schemes). The diversity of current conditions in EU Member States (EU-15) and Newly Associated States (NAS) can be covered by the definition of four generic types of starting points. The paths from these starting points to the possible futures lead to two harmonised scenarios and two scenarios where considerable differences between the different generic types of countries still exist in 2020 and beyond. The four scenarios are:

A. DG opportunities in a fully harmonised EU market.
B. Difficult times for DG in a fully harmonised EU market.
C. DG opportunities in national markets.
D. Difficult times for DG in national markets.

In the SUSTELNET project, the use of a 'regulatory road map' is proposed as a tool to map out a regulatory strategy, facilitating the transition of current regulation into a regulatory framework that is required for future sustainable electricity supply systems. For the development of regulatory roadmaps, detailed country-specific scenarios have been constructed. They show the implications of the different scenarios on the development of the electricity sector in general, and on DG and electricity distribution systems in particular. The scenarios have been used as a background for the evaluation of regulation strategies and their possible effects in the future. They have proven to be a helpful instrument to identify robust regulation strategies that are able to handle the uncertainties of future developments, and also to identify decision points where regulation strategies might have to be adapted to the developments.

The course of developments may not only be influenced by policy decisions and regulatory strategies, but also by external events. Events with a disruptive nature have been identified and used to evaluate the consequences for the scenarios and regulatory strategies. Three possible international disruptive events have been identified affecting all EU MS and NAS. Moreover, some disruptive events on a national level have been identified for the analysis. The disruptive events that could have an impact at a European level are (1) a fuel cell technology breakthrough, (2) a collapse of the Kyoto process and (3) a gas price crisis. A fuel cell technology breakthrough may have a positive effect on DG development, whereas a collapse of the Kyoto process may have a negative effect. The effect towards DG development of the third disruptive event, a gas price crisis, may differ per country and per generation type (i.e. positive for RES but negative for gas-fired DG).

1 INTRODUCTION

In liberalised electricity markets, an innovative approach of economic regulation can facilitate the transition of electricity supply systems into an electricity and network structure that creates a level playing field between centralised and decentralised generation and therefore may also enhance the integration of electricity from renewable sources. The SUSTELNET project develops rationales, principles and criteria of a regulatory framework for future sustainable electricity supply systems. The transition of current regulation into this future regulatory framework requires a strategy that takes into account developments inside and outside the electricity supply system. In the SUSTELNET project the use of a 'regulatory road map' is proposed as a tool to map out such regulatory strategy.

This report describes scenarios that have been constructed as a background for the development of regulatory road maps. These scenarios describe the developments of distributed generation (DG) and electricity generated from renewable sources (RES) as well as overall perspectives of the electricity sector. The scenarios are based on the results of the analytical phase of the SUSTELNET project. In this analytical part, the long-term historical and future technical, socio-economic and institutional dynamics were analysed that shape the European electricity systems and markets. This exercise increased the understanding of the structure of the current European electricity sector and its socio-economic and institutional environment (Verbong and Van Vleuten, 2002). Furthermore, the current electricity policy and regulation was analysed in nine selected EU Member States and Newly Associated States (NAS) (Conner and Mitchell, 2002) and an overview was prepared of the technical options and boundaries for the integration of distributed generation in electricity networks (Nielsen, 2002).

This report starts with an overview of relevant policy targets against which possible developments of the electricity sector can be evaluated (Chapter 2). In this chapter policy targets for the EU Member States and Newly Associated States are listed as well as more country-specific policy targets. In Chapter 3, first, the methodology used to construct the scenarios is explained after which four scenarios for possible futures of electricity supply systems are presented. These 'generic' scenario descriptions have been used to develop more specific country scenarios, since the different circumstances of individual countries have a large impact on the possible developments and future of electricity supply systems and markets in these countries. The country-specific scenarios are part of the regulatory road maps[1]. Chapter 3 summarises specific results of these country scenarios.

Developments may follow the path of a certain scenario. However, a disruptive event may change this gradual development and subsequently the future state. Therefore, the impact of disruptive events on the scenario development and the regulatory strategy should also be investigated. In Chapter 4 disruptive events are identified that can take place in all EU MS and NAS, as well as some more country-specific disruptive events. Finally, Chapter 4 summarises the consequences of the disruptive events for country-specific scenarios.

[1] Regulatory road maps have been developed for Denmark, Italy, Germany, The Netherlands, United Kingdom, Czech Republic, Hungary, Poland, and Slovakia. These can be found on www.sustelnet.net

2 POLICY TARGETS FOR SUSTAINABLE ELECTRICITY SUPPLY

There is a multitude of policy targets within the EU that are relevant for the electricity sector. The project team has identified the following as being most relevant:

- Security of electricity supply (including system reliability).
- Securing the basic infrastructure of member states' economies.
- Economic efficiency and cost-effectiveness of electricity supply (this shall be facilitated by liberalised markets with fair competition).
- Harmonisation of electricity policy and creation of a European Internal Market (including integration of the NAS countries).
- Environmental targets, these include:
  - greenhouse gas emission reduction (Kyoto targets and EU burden sharing agreement),
  - expansion of renewable energy and cogeneration market shares (indicative RES-E targets quantified in Renewables Directive),
  - specific targets for the development of bio-fuels and hydrogen,
  - energy efficiency.
- Protection of other interests (creation and conservation of jobs, etc.)

In addition to this, the following more specific targets have been identified in the countries which were covered by the project:

- Reach and maintain a balanced mix of primary energy sources, reduce import dependence (Czech Republic, Slovak Republic).
- Reduce energy intensity and electricity intensity of the economy (Czech Republic).
- Harmonise energy market liberalisation with EU policies (Czech Republic, Slovak Republic).
- Monitor social effects of energy price changes and of employment in the energy sector (Czech Republic).
- CO_2 emission reduction of 20 - 23 million tonnes by cogeneration (Germany).

The targets can be used for the evaluation of the expected outcome of scenarios and regulation strategies in the different roadmaps.

3 SCENARIOS FOR DISTRIBUTED GENERATION

3.1 Scenario methodology

There is a variety of scenarios available for the electricity industry in Europe. Most of them focus on the quantitative description of futures (electricity demand, fuel mix, prices, emissions etc.). Although some quantitative description of the market is relevant for the SUSTELNET project as well, the scenarios within this project are mostly oriented to qualitative pictures of possible futures of the sector, which allow to understand how DG might fit into the system and what regulation strategies might be appropriate.

The question that the project team wants to answer with the help of the scenarios is:

> *"How does the electricity sector in general look like and what are the framework conditions for the development of DG and the regulation of distribution network operators in EU member states?"*

The range of possible future developments of complex systems like the electricity sector can be illustrated in a simplified way in the scenario funnel (Figure 3.1). It shows that the uncertainty of the future usually increases with the distance from the present. Usually there is not only one plausible future state of the system; in most cases several scenarios are possible. In addition to this, possible developments from the present to the future usually are not linear. They might be influenced by 'disruptive events' and they might contain 'decision points', where a choice exists between several future paths.

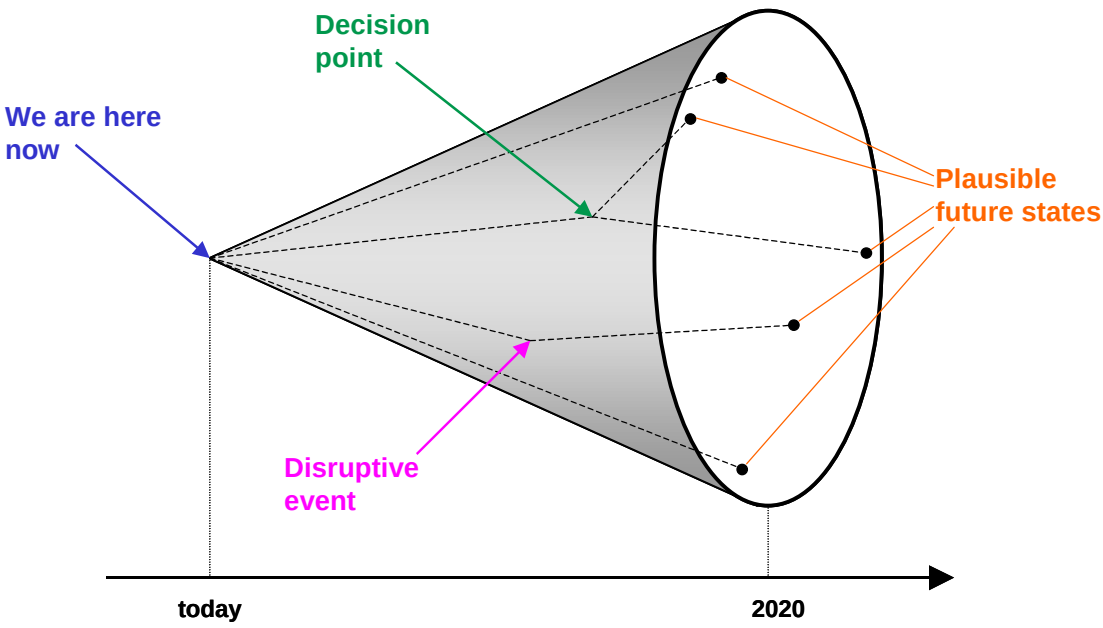

Figure 3.1 *The scenario funnel*

The system covered by the scenarios is described by a set of 'scenario descriptors'. The project team has identified more than 120 potential descriptors. To keep the scenarios operational, a limited number of these have been selected for the basic scenario layout; other can be used for 'fleshing out' details about the scenarios.

The scenario descriptors have been clustered in a matrix shown in Table 3.1.

Table 3.1 *Matrix for clustering scenario descriptors*

	Technical	Socio-economical/ political	Institutional/ organisational	Regulatory
Landscape				
Regime				
Overall				
Production/Dispatch				
Transmission/Distribution				
Demand				
Niche				

The vertical dimensions of this matrix are based on the "multi-level framework for socio-technical change", which has been developed for the analysis of long term, structural changes - or system innovations - in technology and society. The model tries to explain the development of technology from the interplay and interaction between developments at different 'levels'. (Geels, 1999; Verbong and Van Vleuten, 2002).

The framework distinguishes between three levels: the level of niches, regimes and landscape. Niches are protected spaces, created for enabling the development of promising innovations (or radical innovations), which could not survive the direct competition with the dominant technologies and practices. There are several promising technological options, that could substantially contribute to a more sustainable energy supply system, e.g. fuel cells or solar cells, but at this moment electricity generated by these technologies cannot compete at all with electricity from traditional power plants. Therefore, some kind of support is essential.

The stabilised or dominant technologies constitute the level of regimes or the 'rules of the game'. An essential characteristic of such regimes is that they provide the framework and guidelines for the actions and behaviour of the actors. Those actors have the option to change the dominant rules within a regime, but in practice this is rather difficult and regimes normally are quite stable. In this case the regime consists of the whole electricity supply system. It includes the power plants (production, dispatch), the networks (transmission and distribution) and the users (demand).

The third level is the (socio-technical) landscape, consisting of a set of deeper structural trends and changes, or - from an actor-perspective - from external factors or drivers. These drivers can have enormous impacts on existing regimes, but actors operating within such a regime do not have the ability to change events on the landscape level. E.g., the degree of harmonization in the EU is an important factor that cannot be influenced directly by the actors in the electricity sector. Political developments on the EU level therefore belong to the landscape level.

Within the descriptor matrix shown in Table 3.1 we also make a distinction between the technological aspects (power plants, networks, the management and control systems, ICT), the political and socio-economic aspects (policy, prices, consumer aspects) and the institutional framework, specifying the roles of the various actors and their relations (ownership structure, formal and informal rules). For analytical reasons we have isolated the regulatory framework from other institutional aspects because regulation is the key variable in the SUSTELNET project.

3.2 Generic starting points for European electricity system scenarios

The SUSTELNET project must reflect the diversity of the electricity systems and framework conditions for DG in EU member states and accession countries. Therefore, individual scenarios have been developed for the different countries, which are covered by the project. These are integrated parts of the roadmaps for each country.

In this report, some generalisations are being made from the individual scenarios for SUSTELNET focus countries. In order to do this, the project has identified a total of four 'generic' types, which describe the range of starting points in the different countries in a suitable way. The scenarios from countries which are typical for these starting points (or close to them) can be used to obtain general conclusions for the other European countries as well. These generic types of countries can in general also be applied to the NAS countries.

Table 3.2 *Generic starting points for the scenarios*

Type (typical example)	Explanation
Type 1 ('France')	Countries with some decentralised production, a large, dominant market player, regulation and liberalisation under development, public ownership of networks
Type 2 ('Italy')	Countries with some decentralised production, a large, dominant market player, moderate pace of regulation and liberalisation, mixed ownership of networks
Type 3 ('Netherlands')	Countries with much decentralised production, medium-concentrated markets, much liberalisation, regulation under development, public ownership of networks
Type 4 ('Finland')	Countries with much decentralised production, no dominant player, liberalised and well-regulated market, private ownership of networks

3.3 Four generic scenarios for the future of distributed electricity generation

The following sections provide an overview on the scenarios and the possible developments from the starting points into the scenarios. All scenarios are meant to cover a time frame until at least 2020. This year is used as a 'snapshot' point in the following descriptions. Because of the limited dynamics in changes of the distribution networks, the scenarios sometimes look even somewhat further into the future.

The scenarios are characterised by combinations of two main driving forces:

- the degree of policy harmonisation in the EU,
- the degree of incentives to RES and DG operators.

The following table characterises the four scenarios based on some of the scenario descriptors.

Table 3.3 Overview DG Scenarios

	High RES & DG incentives	Moderate RES & DG incentives
	Scenario A DG opportunities in a fully harmonised EU market	Scenario B Difficult times for DG in a fully harmonised EU market
Stronger EU policy harmonisation	• 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)	• 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 DG opportunities in national markets	Scenario D Difficult times for DG in national markets
Reduced EU policy harmonisation	• 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	• No harmonised regulation (national focus) • No improvements in grid access • National support schemes partially reduced • No compensations for regulatory deficits

Note that the scenarios only refer to the electricity sector. Common for all scenarios is the necessity to adapt the electricity sectors of the NAS countries to EU standards. However, this integration might look different in the scenarios as these assume different levels of overall harmonisation in the (extended) EU.

3.3.1 Scenario A: 'DG opportunities in a fully harmonised EU market'

- *Landscape:* The European electricity market is driven by strong EU-wide policy harmonisation and continuation of market liberalisation philosophy. This is supplemented by efficient operation of national departments of an EU energy regulator and general EU competition and Internal Market rules. An international CO_2 trading system has been established, which generates incentives for DG plants.
- *Regime:* Electricity industry has been unbundled at all levels. European TSOs have harmonised their operation. There is a single postage-stamp system tariff all over Europe. 75% of power generation is concentrated in six large European companies. 20% of the market volume is traded at power exchanges. The indicative targets from the renewable energy Directive have been transformed into national legislation and are facilitated by EU-wide support mechanisms based on tradable certificates. A similar support system exists for cogeneration. The share of renewable generation rises to 40% as an average. The share of DG also reaches 40% (excluding large hydro power plants and offshore wind farms).
- *Niche:* The strong demand for DG stimulates the development of new DG technologies, including ICT for optimised integration of DG into load management. DG lobby groups gain more influence on energy policies.
- *Developments from starting points:* As this is a harmonised European scenario, electricity markets in EU member states will converge to a nearly uniform system. For the generic types 1 - 3 this scenario means considerable progress in market liberalisation and develop-

ment of (harmonised) regulation. Types 1 and 2 will see a sharp increase of DG production, replacing older centralised power plants.

- *Scenario evaluation:* This is a quite favourable scenario for the development for DG. The setting of clear targets will lead to a continuous growth of the market shares of DG technologies. The general attitude towards regulation in the sense of facilitating fair market conditions is positive.

3.3.2 Scenario B: 'Difficult times for DG in a fully harmonised EU market'

- *Landscape:* Similar to Scenario A, the European electricity market experiences strong harmonisation and liberalisation, which is enforced by harmonised regulation co-ordinated at the EU level. Security of supply is a much stronger driver for energy policy than environmental issues. There is no CO_2 trading system.
- *Regime:* The general set-up of the market is similar to Scenario A: The electricity industry has been unbundled, TSO operation is harmonised and a single postage-stamp system tariff is applicable all over Europe. 75% of power generation is concentrated in six large European companies. 20% of the market volume is traded at power exchanges. Although there are EU-wide systems of tradable certificates for renewables and cogeneration, the member states have not set binding targets and support for these technologies is not increased. Demand for new capacity is covered by central plants based on nuclear and coal. The shares of renewable and DG do not grow much above the 2002 levels.
- *Niche:* The development of new DG technologies is slow because of small market volumes.
- *Developments from starting points:* Scenario B also is a strongly harmonised European scenario. The generic types 1 - 3 will make considerable progress in market liberalisation and development of (harmonised) regulation. The production from DG and also large renewables will not increase much from current levels, in some type 3 and 4 countries even a reduction of these market shares might occur.
- *Scenario evaluation:* This scenario would lead to a generally functioning electricity market including regulation. But regulation would be concentrated on balancing the interests of an oligopoly of large generators and utilities, and it would neglect the potentials and needs of DG.

3.3.3 Scenario C: 'DG opportunities in national markets'

- *Landscape:* The European electricity markets are not harmonised. Some countries continue with the market liberalisation philosophy, others stay with the current (minimum) market opening. Regulation is not harmonised and implementation of EU competition and Internal Market rules differs between member states. A high environmental awareness stimulates strong support for DG technologies, although member states choose individual support policies. An international CO_2 trading system has been established, which generates additional incentives for DG plants.
- *Regime:* Electricity industry unbundling, the operation of TSOs and system tariffs differ widely between member states. Some countries have established regulators, others lack regulation. The indicative targets from the renewable energy Directive have been transformed more or less directly into national legislation, but the design of support mechanisms for renewables and cogeneration is left to member states. New plants are built in part as centralised condensing plants, with a variety of fuels used. The shares of renewable and DG are rising to levels between 25% on average, only in some countries these shares are somewhat above 35%.
- *Niche:* The strong demand for DG stimulates the development of new DG technologies, including ICT for optimised integration of DG into load management.
- *Developments from starting points:* The four generic types develop into four sub-scenarios (C1 … C4). Type 1, 2 and 3 countries do not make much progress in the establishment of regulation, whereas Type 4 countries maintain their level of liberalisation and regulation.

The development of DG technologies depends from the starting points and is based on support instruments defined on a national basis.

- *Scenario evaluation:* This scenario would create quite favourable incentives for DG, although the framework conditions would differ strongly between member states. European countries would continue and intensify their current schemes for DG support. Not all countries regard regulation as being positive for establishing fair market conditions. Moreover, strong support schemes might be used to counterbalance continuous deficits in regulatory regimes. Some countries (Type 1 and 3) might think that regulation is not a relevant issue at all.

3.3.4 Scenario D: 'Difficult times for DG in national markets'

- *Landscape:* The European electricity markets are not harmonised. Some countries continue with the market liberalisation philosophy, others stay with the current (minimum) market opening. Regulation is not harmonised and implementation of EU competition and Internal Market rules differs between member states. Security of supply is a much stronger driver for energy policy than environmental issues. There is no CO_2 trading system.
- *Regime:* Electricity industry unbundling, the operation of TSOs and system tariffs differ widely between member states. Some countries have established regulators, others lack regulation. Member states have not set binding targets for renewables or cogeneration and support for these technologies is not increased. Demand for new capacity is covered by central plants based on nuclear and coal. The shares of renewable and DG do not grow much above the 2002 levels, in some countries they might even drop.
- *Niche:* The development of new DG technologies is slow because of small market volumes.
- *Developments from starting points:* The four generic types develop into four sub-scenarios (D1 … D4). Type 1, 2 and 3 countries do not make much progress in the establishment of regulation, whereas Type 4 countries maintain their level of liberalisation and regulation. DG technologies are generally not gaining more ground than they currently have.
- *Scenario evaluation:* Scenario D is leading to an adverse environment for DG. Although framework conditions would differ strongly between member states, existing positive incentives will even be reduced in most countries. Those member states with rather favourable conditions for DG (mostly Type 3 and 4) will experience a reduction of the DG market share. Effective regulation is only seen as being beneficial to the market in Type 4 countries (and partly in Type 2 countries).

3.4 Application of the scenarios in the SUSTELNET focus countries

This section summarises some major results from the application of the scenarios in the national roadmaps. Because an emphasis has been put in the roadmaps on describing Scenario A, the description of Scenarios B, C and D is given in table format.

3.4.1 Scenario A: 'DG opportunities in a fully harmonised EU market'

In *The Netherlands*, Scenario A will lead to a significant increase in offshore wind capacity after 2010 (reaching approx. 12,000 MW in 2020). Offshore wind is not covered by the definition of DG, but this development will certainly influence the operations of the overall electricity system. Industrial cogeneration could become the most important generation type already in 2010. The share of DG generation will grow from 17% in 2000 to 27% in 2020. Critical points for this scenario are a strong incentive program for DG and renewables, significant improvements of management procedures between the TSO and distribution system operators (including balancing of intermittent generation) and progress in offshore wind, biomass and fuel cell technologies.

In *Denmark*, the scenario will lead to a slight further increase of the DG share from current 37% to approx. 40%, half of which will be from renewables. This development is based on the EU-wide support mechanisms for renewables and cogeneration, which are a feature of this scenario. Transmission capacities to Germany, Norway and Sweden will be expanded and distribution networks will use advanced ICT technologies. DNOs will shift towards profit orientation.

In the *Czech Republic*, the electricity demand is expected to increase by more than 40% until 2020. The share of DG will slightly increase to 23%, which means a considerable growth in absolute terms. Distributed CHP generation will grow only slightly in absolute terms, but DG renewables (mainly wind and biomass) will grow considerably to a share of 6% in 2020. The slow development of cogeneration is due to the replacement of old CHP plants, which is due mainly until 2010 and which will adapt the generation capacities to the heat demand, which has decreased considerably.

For the *Slovak Republic*, the scenario assumes a decrease in domestic electricity generation until 2010, which falls below the demand, followed by a sharp increase to a level in 2020, which is 20% above the current generation. For DG, a continuous growth is expected, which could nearly double the DG share from current 23% up to 40% in 2020 (compared to domestic demand). A steady growth is expected for DG cogeneration. However, the expansion of renewables will be very limited after 2010.

In the case of *Germany***,** total power generation will be reduced slightly because of reductions in demand and nuclear power will be phased out shortly after 2020. Renewables will increase their production share to 20% in 2020, mainly due to wind (both onshore repowering and offshore development) and biomass. Around 35% of power production will be from cogeneration, mostly in the industry sector. The DG share will rise from 9% in 2002 to 43% in 2020.

In *Poland* the role of coal in power generation is expected to be still dominant for the next decades but diminishing. Electricity from renewables is expected to grow from the current 2.65% to 7.5% in 2010 up to 14% in 2020. The RES potential in Poland is mainly biomass and some hydropower. RES growth will come from biomass/biogas CHP, followed by wind and small hydro. The current share of CHP in electricity generation is expected to grow from the current 12.4% to 16% in 2010. By 2020 the share of DG may range from 13 to 19% of electricity consumption.

For *Italy*, the scenarios of the regulator expect a total share of cogeneration (not only DG) in 2010 between 15 and 19%, compared to 16% in 2001. This is based on an assumed growth in total generation between 20 and 30%, due to the current lack of domestic generation.

The Renewable Obligation system, which is already in place in the *United Kingdom*, will make it easy for market participants to work with the EU-wide certificate-based support systems for renewables and cogeneration. The share of DG will rise to 20% in 2020, after the government has indicated its strong commitment to achieve this target and the required support policies have been adjusted or put in place.

3.4.2 Scenario B: 'Difficult times for DG in a fully harmonised EU market'

Table 3.4 summarises the impact of Scenario B on the focus countries.

Table 3.3 *Impact of Scenario B (overview)*

The Netherlands	The growth in offshore wind will be limited to approx. 1.000 MW until 2020. Onshore wind will still grow, but the overall share of DG will not grow much beyond the current level of 17%.
Denmark	In general, electricity supply from renewables will grow, but slower than in Scenario A. The electricity supplied from DG will still increase in this scenario. However, the DG share relative to consumption in 2010 and 2020 will not differ substantially from the share of today.
Czech Republic	The impact of Scenario B is mainly a reduced development of renewable power generation. In 2020, the share of renewable DG will be slightly below 5%, which is still a significant increase compared to 2000. CHP development will not be affected strongly.
Slovak Republic	The DG development will be reduced compared to Scenario A, from the current share of 23% to a share of approx. 30% in 2020. Most of this increase will result from cogeneration.
Germany	Electricity demand will increase and coal-fired power plants will cover more than 60% of generation in 2020. Cogeneration and renewables will rise only slightly compared to the current levels.
Poland	The share of DG in the total energy consumption will remain at the current level or even decrease. Introduction of new technologies in DG will be slow as a result of high market concentration in generation and growing concentration at European level. Technical progress will take place mainly in these areas linked with central generation.
Italy	In Scenario B the level of support for DG and RES will be lower. The main effect would be a reduced pace of penetration and a general delay in market integration.
UK	In this scenario, the 10,4% target set for the Renewables Obligation will not be met, and this will also reduce the share of DG reached in 2020.

3.4.3 Scenario C: 'DG opportunities in national markets'

Table 3.5 summarises the impact of Scenario C on the focus countries.

Table 3.4 *Impact of Scenario C (overview)*

The Netherlands	Because of limitations to the export of renewable electricity, the development of offshore wind will be reduced compared to Scenario A, but higher than in Scenario B. The DG share will be similar to the development in Scenario A.
Denmark	The development for DG might not be affected, i.e. the development of onshore wind energy, fuel cell CHP, etc. will be similar as in Scenario A. The management of the distribution network will be changed. However, for the development of the transmission network, the import/export flows and system balancing this scenario has similar consequences as in Scenario B.
Czech Republic	This scenario will lead to the same development of DG as in Scenario A.
Slovak Republic	This scenario will lead to the same DG share as in Scenario A (40% in 2020).
Germany	The quantitative developments would be similar to Scenario A. The development of the electricity market would remain based mainly on voluntary agreements, and there would be only very weak regulation.
Poland	Lack of strong EU DG oriented policy will substantially reduce the interest in DG at national level.
Italy	In Scenario C there would be a lower pressure for reforms at EU level combined with a strong policy of support at national level. Because of a lacking effective competition and transparent regulation there could be a reduction of DG deployment especially if there are barriers for DG operators to exploit all market opportunities.
UK	This scenario will be very similar to Scenario A, because liberalisation in the UK is already in an advanced stage and therefore, the impact of lower EU harmonisation is limited.

3.4.4 Scenario D: 'Difficult times for DG in national markets'

Table 3.6 summarises the impact of Scenario D on the focus countries.

Table 3.5 *Impact of Scenario D (overview)*

The Netherlands	This is comparable with Scenario B (slow development of DG and RES electricity). Changes to the regulatory framework will be limited.
Denmark	Regarding the development of DG and RES this scenario is comparable with Scenario B. DG and RES will develop slower and the introduction of new technology will be more complicated, i.e. restricted to a niche market level.
Czech Republic	In this scenario, the DG share will decrease compared to the year 2000. This is due to the very limited development in DG renewables compared to all other scenarios.
Slovak Republic	Large centralised plants will play a stronger role. The DG share will stay at the current level, which still means a significant increase in absolute terms, because of increase in total electricity production.
Germany	The results will be similar to Scenario B, with only a very limited increase in power production from renewables and cogeneration. Power generation would rely heavily on coal. The intensity of utility regulation and the degree of unbundling would be low.
Poland	Large vertically oriented concerns dominate the market and where direct profits due to DG are not found little interest is shown in DG investments. That state is reflected by lack of strong DG oriented energy regulation policy.
Italy	Scenario D would have a combination of the negative effects of scenarios B and C.
UK	This scenario will be very similar to Scenario B.

4 THE IMPACT OF DISRUPTIVE EVENTS

Disruptive events can have a major impact on the development of electricity networks. Examples are the California power crisis in 2001, the September 11th attacks on the USA and, more recently, the blackouts in Europe (Italy, Denmark/Sweden, London) and USA/Canada. These events have created an acute awareness of the vulnerability of electricity systems and other infrastructural systems. Because of this reliability and security of supply have become (again) major issues.

There are several types of disruptive events. First of all, a distinction can be made between 'man-made' and 'natural' events. Examples of 'man-made' events are accidents, e.g. in a nuclear power plant or a terrorist attack on power plants or on the network infrastructure. Examples of 'natural events' are severe droughts, influencing the availability of hydropower, floodings or earthquakes, destroying the infrastructure. One can also make a distinction between events inside the electricity supply system (e.g. a crisis in supply like the California crisis) or outside the system (e.g. terrorist attacks, but also an economic or political crisis).

The essential character of disruptive events is that they disrupt the 'normal' course of development, or in other words they *can* change the direction or pattern of development decisively. The impact of disruptive events on a system depends on the timing (when does the event happen?). If such events happen in a situation of great stability, the impact usually will be limited. Stable systems normally are able to absorb or cope with external or internal disruptions. The impact of disruptive events on systems in a phase of transition - like the current electricity systems - can be much larger. Summarized: not only the specific nature of the event but also the state of the 'recipient' is relevant. Moreover, a combination of events (relatively close in time) or a chain of events can have a much larger impact than a single event.

4.1 Purpose of the analysis

A strategy for changing the regulatory framework for future electricity system may be developed on basis of only one scenario. Preferably, a scenario should be used that complies with existing and/or desirable policies. The other scenarios can then be used to analyse the robustness of the regulatory strategy for changes of developments and to identify alternative actions. Although, the electricity system and regulatory framework may develop in the expected and the desired direction, still disruptive events may change this gradual development and subsequently the future state. Therefore, the impact of disruptive events on the scenario development and the regulatory strategy should also be investigated.

Disruptive events are unpredictable by nature and by timing. For analysis purposes only a limit number of events will be used in the SUSTELNET project, since it will not be possible to investigate, and even to identify, all possible events. Furthermore, the moment events may occur will be restricted to the period of 2005 to 2015. Three international events are selected affecting all EU MS and NAS. Beside that, some disruptive events on national level are selected for the analysis.

4.2 Description of events considered

The selected three disruptive events that could have a European wide impact on the development of electricity supply systems in EU MS and NAS are: (1) a fuel cell technology breakthrough, (2) a collapse of the Kyoto process and (3) a gas price crises. A fuel cell technology breakthrough will probably have a positive effect on DG development, whereas a collapse of the

Kyoto process will most likely have a negative effect. The effect toward DG development of the third disruptive event, a gas price crisis, is more difficult to predict and may differ per country. In this section first the nature of these EU wide disruptive events will be described. Next some examples of national disruptive events are presented put forward by SUSTELNET partners. The impact of these disruptive events on the development of DG and RES will be discussed in the next section.

4.2.1 Fuel cell technology breakthrough

Already many years a breakthrough of fuel cell technology is expected. Such a breakthrough is mainly related to the unit specific costs that could make this technology competitive with conventional power generation. When car manufactures start to produce fuel cell motorcars on a large scale, substantial decrease of costs may be expected. Manufactures of (micro) CHP plants may profit from this development and supply competitive CHP units to the market. As fuel cell stacks uses hydrogen, a breakthrough also may originate from a breakthrough in the low-cost production of hydrogen, e.g. a cheap fuel processor converting natural gas into hydrogen.

4.2.2 Gas price crisis

A shortage of natural gas supply to the European market may result in high gas prices. Such a shortage may be caused by either a problems in gas production or in the gas network system. These problems may be of a geo-political, financial/legal or a technical nature. Although, a supply shortage may occur suddenly, the problem could be more structural, e.g. caused by lack of investments in the gas pipeline infrastructure transporting natural gas to Europe.

4.2.3 Collapse of the Kyoto process

If in the Kyoto process no agreement is reached on new greenhouse gas reduction targets, an important driver for DG and RES disappears. The European emission trading system could be abandoned to protect the European industry, which suffers from being unable to compete with countries outside the EU. An increase of RES (new indigenous energy source) and CHP (energy saving) in the electricity supply will still contribute to improvement of supply security. Depending on the political importance of this issue, the support for DG and RES might become less strong.

4.2.4 National disruptive events

Some examples of national events selected for different EU MS and NAS are:

- *A national power crises or a security of supply problem:* A structural shortage in power generation capacity relative to peak demand could very likely result in a power crises. Such a power crisis may materialise into supply interruptions (black outs) when supply shortage cannot be covered by imports, because other countries also suffer a power crisis or the import capacity is (temporally) insufficient. The shortage in generation capacity may result from a lack of investments. Also a flawed network regulation may result in insufficient maintenance and grid investment causing more frequent blackouts of larger scope than seen before. The evident vulnerability of the power system puts security of supply much higher up on the policy agenda.
- *Natural disasters:* Extreme floods or storms may damage power generators and electricity networks. In centralized systems the electricity supply of a whole country may be affected.
- *Low precipitation reducing hydropower capacity:* In countries with a high share of hydro in power supply a low precipitation for a longer period may reduce generating capacity substantially.

- *Accidents on gas supply pipelines*: A large share of natural gas in power generation could make the electricity supply vulnerable for gas supply interruptions. A large accident (explosion) on a gas pipeline can cause such an interruption. The gas supply interruption may be local, but if such an accident happens at a gas transit pipeline the impact of the gas supply interruption could affect several countries.

4.3 Impact evaluation in focus countries

This section provides an overview of the analyses in the different national regulatory road maps and shows the possible impact on the development of electricity supply systems of the disruptive described in the previous section.

4.3.1 Fuel cell technology breakthrough

A breakthrough in fuel cell technology could result in substantial lower investment costs and make fuel cell based power generation competitive to large gas-fired power plants, conventional CHP plants and electricity generated from renewable energy sources. Because unit specific costs (i.e. investment per kW) are not very scale dependent, also small fuel cell units may become competitive. In countries with mainly centralised power system a decentralisation of power generation may be observed, e.g. a (faster) introduction of CHP units. In countries with a substantial CHP share in power generation, fuel cell units will replace conventional CHP plants and a further increase of this type of power generation may be observed. In the domestic sector small consumers may start to generate electricity due to the introduction of micro-CHP units. However, the availability of natural gas (or hydrogen) might be a constraint to this development. Medium and small sized fuel cell based power generators will probably also compete to electricity generation from renewable sources, in particular wind turbines and PV, since fuel cells supply a more stable and reliable electricity. I.e. consumers may decide to buy a micro-CHP unit instead of a PV panel.

4.3.2 Gas price crisis

For the next decades a strong increase is expected of the natural gas share in Europe's power generation. Strong expansion of gas-fired power plants is the main driver in Europe's gas demand growth. A gas price crisis will therefore have a significant impact on Europe's power markets. Electricity prices will rise, in particular in peaking hours, since in most national markets electricity prices will be set by gas-fired units. Due to the high fuel prices the construction of gas-fired power plants will probably slow down and power producers start looking for alternatives. Because of the introduced CO_2 emission trading system and the fact that prices for CO_2 emissions probably are set by gas-fired power units, being the marginal option, also the prices of CO_2 emission permit will increase. This could result in a further increase of electricity prices. Diversification strategies may lead in some countries to cancellation of phase-out-policies of nuclear power or even to plans for constructing new nuclear power plants. Although conventional coal power generation will remain an unattractive option under a strict GHG-emission reduction policy, power generators may gain interest in clean coal technologies. New nuclear and clean coal power plants are both central options.

The impact of a gas price crisis on the development of CHP is unclear, since the profitability of CHP depends on the ratio between gas and electricity prices. If the gas price increase is stronger than the increase of electricity market prices, CHP becomes less attractive whereas profitability will increase in the opposite case. Situation may differ per country and also in time, due to price fluctuations. However, uncertainty on future gas and electricity prices will discourage CHP investments.

In principle options to generate electricity from RES could profit from higher electricity prices. However, most options still rely on support schemes. Revenues for RES will not change if support schemes are based on production costs and if support is given on top of the electricity market prices, the effect may be neutralised when tariffs are adjusted for market price increase.

4.3.3 Collapse of the Kyoto process

If in the Kyoto process no agreement is reached on new greenhouse gas reduction targets, an important driver for DG and RES disappears. Hence, the European emission trading system may be abandoned to protect the European industry, which suffers from being unable to compete with countries outside the EU. Subsequently, power generators may opt for new coal-fired plants, since coal is still a competitive fuel. In such circumstances it is very likely that national governments change their policies towards DG and reduce or cancel support systems for RES and CHP. However, depending on the political importance of the supply security issue, governments may also decide to maintain the support schemes, since RES (new indigenous energy source) and CHP (energy saving, demand side response) contribute to enhanced security of the electricity supply system.

4.3.4 National disruptive events

The impact of some national disruptive events (described in Section 4.2.4) on DG development can be analysed:

- *A national power crises or a security of supply problem:* In principle there are two effects: (1) very high electricity prices for some time and (2) (high risks for) supply interruptions. Because governments will be kept responsible for supply interruptions, they might prefer a conventional approach in solving the problem and issue a tender for new large power generation capacity. However, if supply is interrupted due to a supply shortage, consumers may become really interested in own power generation options. High prices will make self-generation profitable and these units may be realised much sooner than large generation plants. Governments may realize that in a liberalised market demand response is very essential and therefore start to promote demand side options. Since intermittent supply may not contribute to supply security, wind and solar could be excluded from such a policy.
- *Natural disasters:* Because a power supply disturbance in centralized systems could be much more extensive than in decentralized systems, a natural disaster that results in such a disturbance could stimulate DG development and the interest in actively managed distribution networks, i.e. distribution networks operated independent from the transmission network. If natural disasters like floods, hurricanes and heat waves are seen as a result of climate change this could also strengthen the motivation for enhanced environmental policies.
- *Low precipitation reducing hydropower capacity:* A low power supply from hydro power plants can be compensated by other generating capacity or imports. However, if this generating capacity is not available or interconnection capacity is insufficient, this could easily result in a power supply crisis, i.e. high electricity prices and outages. Response of consumers may be quite similar to the aforementioned national power crises. Generators and governments will probably look for diversification options such as gas-fired or nuclear power plants. If this natural phenomena is linked to climate change it could lead to enhancement of environmental policies, and therefore stimulate DG and RES development.
- *Accidents on gas supply pipelines*: An interruption of gas supply will affect gas power generation, including CHP. If power supply from these units is substantial the accident could be followed by a power supply crisis if no other power generating sources or import capacities are available. The effect for DG and RES of this disruption could be similar as those mentioned above. This disruptive event will probably also result in measures to improve the supply security of natural gas, i.e. improvements of the gas supply network.

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