



Enhancement of sustainable electricity supply through improvements of the regulatory framework of distribution networks for distributed generation

## Regulating Innovation & Innovating Regulation

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## **Project objectives**

The objectives of the DG-GRID project are to:

- To review the current EU MS economic regulatory framework for electricity networks and markets and identify short-term options that remove barriers for RES and CHP deployment.
- To analyse the interaction between economic regulatory framework, increasing volume share of RES and CHP and innovative network concepts in the long-term.
- To assess the effects of a large penetration of CHP and RES by analysing changes in revenue and expenditure flows for different market actors in a liberalised electricity market by developing a costs/benefit analysis of different regulatory designs and developing several business models for economic viable grid system operations by DSOs.
- To develop guidelines for network planning, regulation and the enhancement of integration of DG in the short term, but including the opportunity for new innovative changes in networks in the long-term

## **Project partners**

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- Institute for future energy systems (IZES), Germany
- RISØ National Laboratory, Denmark
- University of Manchester, United Kingdom
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## **List of abbreviations**

CAPEX:	capital expenditure
CHP:	combined heat and power generation
DG:	distributed generation
DNO:	distribution network operator
DSM:	demand-side management
DSO:	distribution system operator
ICT:	information and communication technology
IFI:	Innovation Funding Incentive, regulatory mechanism in the UK to promote network innovations
OPEX:	operational expenditure
PSO:	public service obligation
PV:	photovoltaic
R&D:	research and development
RAB:	regulatory asset base
RoR:	rate-of-return regulation
RPI:	retail prices index
RPZ:	Registered Power Zones, regulatory mechanism in the UK to promote more cost effective ways of connecting and operating distributed generation
TSO:	Transformation System Operator

## **Summary**

The present study analyses network innovation and integration of DG from a regulatory point of view. This is done in three steps:

1. **Innovating Regulation:** How can distributed generation be taken into account in (incentive) regulation mechanisms?
2. **Regulating Innovation:** How can regulation help network companies to spend on R&D and try out new approaches to network design and operation?
3. **Innovating Regulation and Transformation:** How can network regulation be oriented towards supporting long-term structural change in the network?

### **Innovating Regulation: Taking into account DG**

The relationship between DG and DSOs has in most cases been difficult. The main reason for that is the discrepancy of interests that arise under the standard regulatory frameworks. The incentives of network operators are mainly shaped by setting use-of-system tariffs. In Europe, this is increasingly done through an incentive regulation mechanism. For the development of DG, it is of great importance to try to minimise, or even dissolve those differences of interests by structuring incentive regulation accordingly.

It is important to accurately analyse the effects of a DG extension on the DSOs' interests within every step of the incentive regulation mechanism and to develop approaches

- to systematically take into account additional costs for DSOs,
- to at least neutralise the negative incentives resulting from a volume reduction in the case of auto-generation or independent area networks.

Against this background, we elaborate on two regulatory innovations that we consider particularly relevant:

- Benchmarking, including quality regulation,
- the implementation of article 14/7 of the 2003 EU electricity directive

#### *Benchmarking and DG*

A comparative efficiency analysis (or benchmarking) of DSOs aims at detecting inefficient DSOs. By reducing inefficient use-of-system tariffs it puts pressure on DSOs to reduce their costs. If it is not balanced by other mechanisms, it will further increase the incentives of DSO against DG.

We propose to include DG as one of the cost drivers in the benchmarking procedure, i.e. a higher share of DG would justify higher costs and thus network tariffs.

Two questions need to be answered:

- Through which indicators can higher costs due to DG be taken into account in an appropriate way, avoiding wrong conclusions regarding the DSOs' efficiency?
- What consequences will this have for the network tariffs, i.e. to what extent can a higher share of DG justify higher tariffs?

The main cost drivers to be considered in the benchmarking process should be identified through a quantitative analysis, yet as a hypothesis it can be assumed that the following correlations apply:

- The higher the number of DG plants in the network area the higher are the operating costs (OPEX)
- The higher the feed-in capacity in relation to the network capacity and the more stochastic the more likely are investments for network upgrades (CAPEX).

We can therefore assume the following cost drivers to be considered in the benchmarking:

- OPEX costs:  
Number of plants
- CAPEX costs:  
feed-in capacity in relation to peak load in the network

All benchmarking procedures have to be accompanied by quality measures because low costs are not a sufficient indicator for a good performance of the DSO. The relevant quality requirements are security, reliability and quality of products and services.

In our context it is important to additionally include an index on the 'distributed efficiency' of DG plants in a network. The 'distributed efficiency' would be all the higher the more distributed resources can replace centralised capacity.

A possible indicator would be the share of peak load on a network covered by DG plants in relation to total DG capacity. It should, however, be designed in a way that does not discriminate against intermittent generation.

This or similar indicators could be integrated into the incentive regulation by a Bonus-/Malus system setting remunerations or penalties that are to be integrated into the incentive regulation formula as a Q-factor.

#### *System optimisation: Implementing article 14/7 of the EU electricity directive*

Article 14/7 of the EU electricity directive requires DSOs to consider DG as an alternative to network expansion. Although it is very important for the further development of DG that its potential to replace network investments becomes realised, there is no concept yet as to how this provision can be implemented and backed up by appropriate regulatory mechanisms and incentives for unbundled network operators.

What is needed is an incentive system for network operators that leaves all system optimising decisions completely up to them, but gives them financial rewards for 'good' decisions and penalises 'bad' decisions.

This can be achieved through investment budgets for individual network operators. The budget would cover the complete regulatory period and it is up to network operators how they use it during the regulatory period. In order to implement such a scheme, the following two issues need to be examined:

- How is the budget for each network operator calculated?
- How to deal with the incentive to make use of the budget as little as possible in order to maximise profits?

A preset budget without ex-post correction (i.e. skimming the difference between allowed and spent budget) gives DSOs the incentive to spend as little of the budget as possible and to keep the difference as profit. Consequently they will try to defer investments as much as possible. Therefore the budget approach has to be accompanied by quality regulation which has the aim to keep up and even improve the security and reliability of supply in the network.

### **Regulating Innovation**

In the second step, the report analyses the role of network regulation in promoting network innovations and how network regulation can enable and incentivise network operators to develop and implement innovative network concepts.

As we have tried to show in the DG-GRID report “Review of Innovative Network Concepts”<sup>1</sup>, increasing the share of DG has triggered a need for innovations in a hitherto relatively stable industry. Both the structure of the network and the way it is operated may change. There are already a significant number of technical solutions under discussion and under development.

Rate-of-return regulation leads to a suboptimal level of R&D and innovation and incentive regulation can further exacerbate this effect. This is supported by an overview of current network regulation in the EU and a literature review. Network innovations have so far hardly been addressed by network regulators in Europe. Except for the UK, there are no innovation-specific regulatory instruments in the EU-15. Rather, in the majority of countries, the focus is on short-term cost reductions and network regulation tends to discourage rather than stimulate network innovations.

#### *Regulatory approaches to innovation*

In order to promote the innovations necessary for an efficient large-scale deployment of DG, network regulation should provide additional tailor-made instruments for DSOs to get involved in R&D and take the risk to try out new approaches to running their network. Especially as there is currently a lot of scope and need for network innovations to accommodate a rising share of DG, network regulation should pay explicit attention to innovation.

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<sup>1</sup> Goran Strbac, Nick Jenkins, Tim Green, Danny Pudjianto 2006: Review of Innovative Network Concepts, report of the DG-GRID project.

There are a number of approaches to regulating R&D and innovation in networks:

1. Separate R&D funding mechanism, e.g. in Italy and Denmark
2. Mandatory R&D spending obligations to perform R&D as a percentage of total sales placed on generation, transmission, and distribution companies, e.g. in Brazil
3. Including innovation costs in the regulatory asset base (RAB)
4. Separate treatment of innovation costs
5. Extending regulatory periods

Approaches 3-5 are analysed in some detail in this report.

#### *Including R&D costs in the RAB*

The third approach “Including R&D costs in the RAB” recognises innovation related costs as an investment. It is likely to have a positive effect on R&D expenditures. Yet the risk of innovation is not adequately reflected in the regulated company’s risk distribution and the company is mainly incentivised to spend on R&D rather than to develop useful innovations. The approach may be applied to some R&D expenditures that can clearly be identified, but needs to be complemented by other measures.

#### *Separate treatment of innovation costs*

Even though DSOs will in most cases not engage in basic research, but rather more advanced innovations closer to ‘the market’, the benefits of these, if any, can normally not be reaped in the short-term. These properties of R&D can justify a special treatment of innovation-related costs. There are several ways this can be done.

- Innovation RAB, that is separate from the normal asset base. The rate-of return applied to this RAB would be higher than the normal rate-of-return applied to the rest of the asset base.
- (Partial) cost-pass through to reduce the downside risk for companies
- Positive incentives, e.g. an increased revenue allowance

#### *Extending regulatory periods*

While it is plausible that the length of the regulatory period influences a company’s propensity to innovate, simply extending the regulatory period to provide innovation incentives does not seem to be a solution for a number of reasons. Companies may also have an incentive to delay the adoption of innovations, as such a delay would also postpone the price reduction imposed by the regulator. There is also a trade-off between innovation incentives and shifting innovation benefits to consumers. Moreover, extending the regulatory period would not just affect innovations developed by a company, but would be valid for the business as a whole.

What seems to be required, however, is a long-term framework, spanning several regulatory periods with clear and reliable objectives for DSOs. Developing such a framework could be complimentary to other innovation incentives in the regulatory mechanism, like the ones described in this section. Developing scenarios could be one way to draw up such a long-term framework. We will come back to this below.

#### *Integrated approaches to innovation*

A separate treatment of innovation can be justified and is likely to be more effective and efficient than the other two approaches (Including R&D costs in the RAB, Extending regulatory periods). However, a separate treatment establishes a special regime outside or complementary to the standard regulatory mechanism (e.g. RPI-X) in order to stimulate innovation. Innovation is a niche activity and there is a danger that it is not sufficiently connected to a DSO's main business. Especially with regard to DG related innovations, these should become more of a normal business activity once DG is no longer a niche activity.

We therefore present two regulatory approaches that have the potential to render network regulation more innovation-friendly, namely Output-Based Regulation and Yardstick Regulation.

The output-based approach we propose is not based on (intermediate) innovation-outputs but rather on general performance criteria that should be defined such that they foster the development of innovations. There could be performance criteria that are specifically geared towards incentivising the efficient integration of DG. A possible performance criterion could be the share of peak load on a network covered by DG plants in relation to total DG capacity. This links back to the discussion above to include DG-related performance criteria in the benchmarking process.

Yardstick regulation is the second regulatory mechanisms with the potential to be more innovation-friendly than standard incentive regulation. This is a regulatory approach where the price-cap a company faces is not based on its own costs (plus an assumption as to the cost reductions the company should be able to achieve) but on an industry-wide cost level, in most cases the average costs of all network operators.

Yardstick regulation may have positive effects on innovation. It is one of the main short-comings of 'traditional' incentive regulation with regard to innovation that it regularly reviews a company's cost to pass on to consumers any cost reductions that have been achieved during the previous regulatory period. As a result, a company can hardly benefit from successful innovations. Under yardstick regulation, there is no profit reduction as a consequence of reduced costs. On the contrary, if a company does not achieve cost reductions high enough to remain the average company it is assumed to be, it will earn below average profits. Yardstick regulation still gives an incentive for short-term cost reductions (potentially at the expense of innovation), but at the same time the company can also benefit from long-term cost reductions.

More research is needed to understand the innovation effects of output-based regulation and yardstick regulation and to come up with appropriate designs that can promote innovations (e.g. appropriate performance measures).

**Innovating Regulation: Towards system transformation**

In the third step, network regulation is analysed from a system transformation perspective. We argue that the developments ahead may go beyond incremental innovations in some parts of the network, developed and implemented by individual network operators, but may lead to an overall transformation of the network structure, involving a large number of actors and including both transmission and distribution networks.

The question arises what the consequences should be for network regulation. In the final section, we argue that the integration of DG and the network transformation this may require poses a new challenge to network regulation. This makes it necessary to rethink network regulation as a whole, rather than merely changing some parameters in the RPI-X mechanism. In order to promote a long-term transformation of the network, the regulatory process needs to be complemented by instruments that go beyond one regulatory period, enable the regulatory process to deal with future structural changes and future uncertainty and provide coordination mechanisms for the stakeholders involved (network and plant operators, technology developers etc.).

The following table gives an overview of different modes of network regulation. While mode 1 can be associated with the monopolistic era, most systems are currently in mode 2 “Sweating the assets”, where efficiency improvements are the main focus. Some systems are moving to mode 3 “Renewing the system”, i.e. securing investment is gaining importance. DG integration may take us to mode 4 “Transforming the system”.

*Table 1: Four modes of network regulation*

	<b>Building the system</b>	<b>Sweating the assets</b>	<b>Renewing the system</b>	<b>Transforming the system</b>
<b>Main objective</b>	Building the electricity system, security of supply	Cost-reduction (OPEX), short-term efficiency	Supply security, efficient investment within the existing system (like-with-like replacement)	Supporting certain system transformations, e.g. towards sustainability, higher shares of RES/DG etc.

Incentive regulation seeks to emulate the price mechanism of the market in that it gives network operators financial incentives to become more efficient or achieve other targets defined by the regulator. The question is if this governance mechanism is sufficient when a transformation of the electricity network is needed, necessitating close coordination of different actors changing different system components.

While the regulatory mechanisms to promote innovation presented above may give the individual DSO an incentive to invest in (cost-saving) innovations so that he can benefit from the achieved cost savings, it is difficult for the individual company to know in which direction the system may be going and how his innovation project links up with other innovation projects and the overall system transformation dynamics.

There are already a number of examples where different stakeholders are brought together to coordinate diverse network-related activities through facilitating exchange and providing platforms of debate, such as the EU Technology Platform “SmartGrids” and the UK Electricity Networks Strategy Group (ENSG).

While regulators are just about to come to grips with the third mode “Renewing the system”, more work will be needed to spell out network regulation in mode 4 “Transforming the system”. In this report we present two instruments that could help deal with the uncertainty of future system transformation:

- Developing long-term visions through scenarios and
- Experimentation with new regulatory instruments in “Regulatory Innovation Zones”.

## 1 Introduction

In the first part of the DG-GRID project, we have looked at regulatory barriers that currently hamper the integration of individual DG plants into the existing grid<sup>2</sup>. This report takes a more long-term system perspective. As the number of DG units connected to the grid increases, it will not be sufficient to address barriers to the integration of individual DG plants. Rather, the electricity network itself needs to change to accommodate a rising share of DG. WP2 is about medium- to long-term changes to the grid structure and how these need to be promoted and accompanied by regulatory innovations. Importantly, these regulatory innovations need to be developed in the short-term in order to achieve long-term changes, given the high path dependency of the electricity infrastructure.

As we have tried to show in the DG-GRID report “Review of Innovative Network Concepts”<sup>3</sup>, increasing the share of DG has triggered a need for innovations in a hitherto relatively stable industry. Both the structure of the network and the way it is operated may change. Especially if DG is to be integrated in an efficient way without affecting security of supply, the network needs to be adapted. There are already a significant number of technical solutions under discussion and under development<sup>4</sup>. Not all of them may be appropriate way forward for DG integration in the context of the existing European energy systems.

In this section, we will focus on the role of network regulation in promoting network innovations. When it comes to implementing network innovations, DSOs play a key role. Yet they also have a role to play in developing these innovations. Network regulation defines the framework within which network companies operate and the incentives of DSOs are mainly influenced by regulatory framework. It can be argued that most existing approaches to network regulation tend to hamper DG integration and network innovations. We will look at how network regulation can enable and incentivise network operators to integrate DG and implement innovative network concepts.

While innovations are important, the regulatory discussion should not be limited to promoting innovations: First of all, most networks still have scope for accommodating a higher share of DG even without network innovations. Waiting for technological breakthrough should consequently not serve as an excuse to delay the deployment of DG. Second, conventional regulatory frameworks tend to entail various disincentives against connecting and integrating DG per se, not just against innovation. Third, neutralising such broad incentives and giving DSO some positive incentives to connect DG should lead to a higher share of DG, which in turn might also promote innovative solutions.

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<sup>2</sup> Klaus Skytte, Stephanie Ropenus 2005: Regulatory Review and International Comparison of EU-15 Member States, report of the DG-GRID project.

<sup>3</sup> Goran Strbac, Nick Jenkins, Tim Green, Danny Pudjianto 2006: Review of Innovative Network Concepts, report of the DG-GRID project.

<sup>4</sup> Cf. (MottMacDONALD, BPI 2004) which analyses the scope for innovation in the distribution network in the UK.

So while innovation-specific mechanisms need to be developed, network regulation in general should take into account the DG and the changing role of DSOs. This requires innovations in the design of network regulation. Network regulation will need to give DSOs incentives for connecting DG, and, with an increasing share of DG, also for integrating DG into network operation.

In section 2 “Taking into account DG in network regulation” we will elaborate on two such innovations. We first ask how DG can be taken into account in both the comparative efficiency analysis (benchmarking) of DSOs and quality regulation. Second, we will look at article 14/7 of the EU electricity directive that requires DSO to consider DG as an alternative to network expansion.

Section 3 “Regulating Innovation” will then look at different regulatory mechanisms that are specifically geared towards promoting R&D and innovation.

Finally, in section 4 “Innovating Regulation” we argue that in order to promote a long-term transformation of the network, the regulatory process needs to be complemented by instruments that go beyond one regulatory period and enable the regulatory process to deal with future uncertainty.

## **2 Innovating Regulation: Taking into account DG**

### **2.1 Overview: The different stages of the regulatory process**

The relationship between DG and DSOs has in most cases been difficult. The main reason for that is the discrepancy of interests that arise under the given framework. The incentives of network operators are mainly shaped by setting use-of-system tariffs. In Europe, this is increasingly done through an incentive regulation mechanism. Consequently, for the development of DG, it is of great importance to try to minimise, or even dissolve those differences of interests by structuring incentive regulation accordingly.

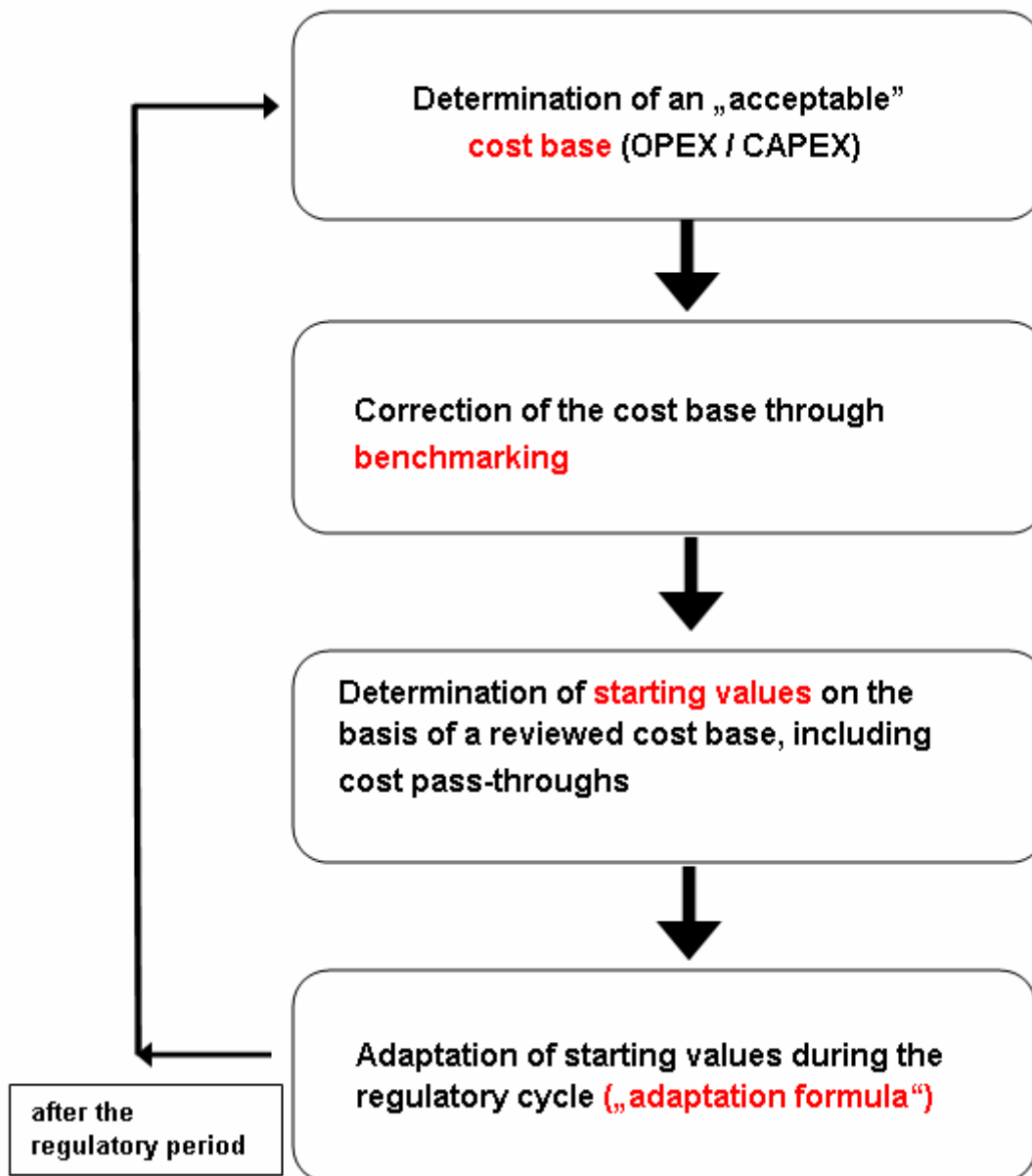
Assuming that a network operator with a higher share of DG connected to its system has to bear higher short or mid term costs, the question arises how these additional costs can be taken into account. They include beside contract and other transaction costs possible network extension costs.

Moreover, considerable negative incentives can result from reduced revenue for the DSOs because of auto-generation or the operation of small independent networks that reduce the load on the system. The objective should be to systematically reduce these negative incentives against DG and to add positive incentives to the incentive regulation process.

Setting use-of-system tariffs usually includes the following steps (see also Figure 1):

1. Determination of cost base, consisting of (foreseeable) operational costs (OPEX) and capital costs (CAPEX) for the duration of the regulatory period
2. Determination of possible reductions of the (controllable) cost base on the basis of a benchmarking procedure (either at the beginning of a regulatory period or during a regulatory period as part of step 4)
3. Determination of starting values of use-of system tariffs on the basis of the reviewed cost base, including cost pass-throughs
4. Automatic adaptation of initial values in a defined regulatory cycle based on an incentive regulation formula
5. After the regulatory period: start again with step one

Figure 1: Setting use-of-system tariffs



It is important to accurately analyse the effects of a DG extension on the DSOs' interests within each of these steps and to develop approaches

1. to systematically take into account additional costs for DSOs,
2. to at least neutralise the negative incentives resulting from a volume reduction in the case of auto-generation or independent area networks fed by cogeneration plants.

Moreover, a higher DG penetration in a network area is to be defined as a quality criterion to be considered in quality regulation and benchmarking.

In order to implement these objectives, existing regulatory mechanisms need to be adapted and new mechanisms have to be developed. In the following, we will elaborate on two such "regulatory innovations" that we consider especially relevant.

We first ask how DG can be taken into account in both the comparative efficiency analysis (benchmarking) of DSOs and quality regulation. Benchmarking has increasingly become an important element of regulatory mechanisms throughout Europe. Comparing the costs of companies (rather than merely setting a price cap based on the costs of an individual company) can lead to a significant disincentive against DG and it therefore needs to be considered how DG can be taken account. Quality regulation is also becoming an indispensable feature of incentive schemes to counter the DSOs' temptation to earn extra profits at the expense of quality. With a rising share of DG, it is increasingly becoming important to maximise the *quality* of DG integration (rather than simply connecting DG plants to the grid). It therefore seems interesting to widen the scope of quality regulation to include DG integration. The quality of DG integration and the extent to which DG can replace network capacity and central plants can also be termed "distributed efficiency".

Second, we will look at article 14/7 of the EU electricity directive that requires DSOs to consider DG as an alternative to network expansion. Although it is very important for the further development of DG that its potential to replace network investments becomes realised, there is no concept yet as to how this provision can be implemented and backed up by appropriate regulatory mechanisms and incentives for unbundled network operators. Implementing article 14/7 is also about increasing the "distributed efficiency" of DG plants.

## **2.2 Benchmarking and Quality Regulation**

A comparative efficiency analysis (or benchmarking) of DSOs aims at detecting inefficient DSOs and reducing their use-of-system tariffs. It puts pressure on DSOs to reduce their costs. If it is not balanced by other mechanisms, it will further increase the incentives of DSO against DG.

This is not the place to discuss the pros and cons of different benchmarking methodologies. Concerning the neutralisation of DSOs' incentives against DG the following options are to be considered:

**a) Excluding DG related costs**

Justified and confirmed operational costs associated with the implementation of DG could generally be excluded from the benchmarking procedure. As soon as they are included (without taking into account DG as a cost driver) DSOs have the incentive to avoid them wherever possible, even if other DSOs have similar costs. In this case reducing DG related costs would reduce the cost-cutting pressure in other areas where cost-cutting may be more difficult.

However, excluding the costs completely from the benchmarking has the disadvantage of taking away the incentive for an efficient connection of DG and is therefore not an option we would recommend.

**b) Including DG as a cost driver**

An alternative approach would be to include DG as one of the cost drivers in the benchmarking procedure, i.e. a higher share of DG would justify higher costs and thus network tariffs. Yet, at the same time the costs of connecting DG would also be benchmarked.

The German regulator Bundesnetzagentur (Federal Network Agency), in its report from June 2006 which set out the new incentive regulation mechanism to start in 2008 (Bundesnetzagentur 2006), has confirmed that DG has a cost-increasing effect on networks. Consequently DG plants connected to the network were identified as a cost driver to be considered in the benchmarking (Table 18, p. 238). It is still unclear, however, how this is supposed to be implemented in quantitative terms.

Two questions have to be distinguished:

1. Through which indicators can higher costs due to DG be taken into account in an appropriate way, avoiding wrong conclusions regarding the DSOs' efficiency?
2. What consequences will this have for the network tariffs, i.e. to what extent can a higher share of DG justify higher tariffs?

Moreover, the incentives stemming from such a mechanism for the DSO have to be analysed.

Regarding 1)

Starting point for defining appropriate indicators is an allocation of DG related costs. The following table gives an overview:

Table 2: Cost categories and related cost drivers

Cost category	Drivers
Contract costs / metering costs / other transaction costs	Number of third parties, number of plants
Implementing support mechanisms	Number of plants, technologies
Higher costs of running the network	Number of plants, feed-in characteristics
Potential network upgrade costs including control systems	Feed-in capacity in relation to network capacity

The main cost drivers to be considered in the benchmarking process should be identified through a quantitative analysis, yet as a hypothesis it can be assumed that the following two correlations apply:

- The higher the number of DG plants in the network area the higher are the operating costs (OPEX)
- The higher the feed-in capacity in relation to the network capacity and the more stochastic the more likely are investments for network upgrades (CAPEX).

We can therefore assume the following cost drivers to be considered in the benchmarking:

- OPEX costs:  
Number of plants
- CAPEX costs:  
feed-in capacity in relation to peak load in the network

Regarding 2)

For a quantitative consideration of the first parameter the regulatory agency could set anticipated allowed costs to be taken into account in the benchmark procedure: Excluding these costs when it comes to a comparison to DSOs without DG plants. Possibly a cost bundling regarding the kinds and sizes of plants might be a suitable way. It can be assumed that the additional OPEX costs of a PV plant are less than the additional cost of a large biomass cogeneration unit, for example. Building a lump sum of the estimated costs has the further advantage to give the DSOs an incentive for rationalisation.

As DG supply minimises network losses immediately it has the effect of a short-term remuneration for DG implementation as long as this effect is not charged up against the higher costs.

The second parameter can be considered by the regulatory agency in a simplified way: The total DG supply performance in the network territory in relation to the peak load entitles DSOs to higher use-of-system tariffs in a certain margin.

Virtual example: a supply performance of 70% of the peak load entitles to 3,5% higher use-of-system tariffs; a performance of 80% to 4%, etc. These graduations have to be founded on an empiric basis to get a feeling for the dimension. A lump sum approach also has the advantage of giving an incentive for rationalisation.

Assuming DG helps to reduce the network costs in a long term perspective DSOs with a bigger DG share will perform better in future benchmark procedures anyway.

### **c) Quality regulation**

All benchmarking procedures have to be accompanied by quality measures because low costs are not a sufficient indicator for a good performance of the DSO. The relevant quality requirements are security, reliability and quality of products and services.

At the moment quality indicators mainly cover reliability and service quality. The following indices are generally used:

- SAIFI (System Average Interruption Frequency Index):  
average number of interruptions per customer in a given period
- SAIDI (System Average Interruption Duration Index)  
average duration of interruptions per customer in a given period
- CAIDI (Customer Average Interruption Duration Index)  
average duration of interruptions per interrupted customer

In our context it is important to additionally include an index on the ‘distributed efficiency’ of DG plants in a network. The ‘distributed efficiency’ would be all the higher the more distributed resources can replace centralised capacity.

A possible indicator would be the share of peak load on a network covered by DG plants in relation to total DG capacity. It should, however, be designed in a way that does not discriminate against intermittent generation.

This or similar indicators could be integrated into the incentive regulation by a Bonus-/Malus system setting remunerations or penalties that are to be integrated into the incentive regulation formula as a Q-factor. However, it needs to be made sure that network operators do not benefit twice: both from reduced network costs that can result from DG integration and from the Q-factor in the regulatory formula.

Moreover, as a support for DG plants there have to be appropriate services by the DSO aiming at reducing information deficits and obstacles to market access as well as lowering investment and transaction costs for plant operators. These services are also to be rewarded in a quality regulation scheme, including sanctions for not achieving a minimum standard of service quality.

## 2.3 System optimisation (article 14/7 EU directive)

The 2003 European electricity directive contains a number of tasks that DSOs are to fulfil, including the joint optimisation of the development of the network and distributed resources. In Article 14/7 the directive stipulates:

*„When planning the development of the distribution network, energy efficiency/demand-side management measures and/or distributed generation that might supplant the need to upgrade or replace electricity capacity shall be considered by the distribution system operator“.*

Implementing this provision seems particularly challenging given the unbundling of network and generation. The question arises how unbundled network operators can be incentivised and enabled to implement it and how coordination between network and plant operator can be achieved.

### 2.3.1 Problems of system optimisation in an unbundled system

In order to illustrate the problems of system optimisation in an unbundled system, let us consider the following example:

The system load in the distribution network exceeds the maximum connection capacity to the higher voltage level. Upgrading the network capacity would be more expensive than supplying the electricity from existing distributed generators into the network. However, for DG to be an alternative option, its generation must be reliable and available when needed by the network operator. These requirements limit the plants' operation mode and make the generation more expensive than it would be without these restrictions. The DG plants must be remunerated accordingly.

Although using DG (or demand-side measures) as an alternative to upgrading the network may be more cost-effective from a system point of view, unbundling between DSO and DG leads to a number of problems that can undermine the DSO's ability for system optimisation.

- In most cases it will be unclear whether the network operator can include the remuneration to DG plants into the calculation of network tariffs.
- If the network operator decides to upgrade the network despite the cheaper DG option, it is unclear how such (in effect additional) costs will be treated and to what extent they can be included in the tariffs or whether there will be a cap based on the least-cost option, provided the regulator can gather reliable information on the costs of these alternative options.
- How is the risk assessed the network operator takes when relying on a third party to guarantee security of supply? Who bears the costs if the DG operator is not able to live up to its supply commitment and its plant is not available?

Given these problems, it is necessary to back up the mainly technical approach to system optimisation in Art.14/7 EC electricity directive with economic incentives.

### **2.3.2 How can the DSO be incentivised?**

A system-optimisation process as described above can have significant repercussions on system security and reliability of supply. If the regulator has the mandate to control its implementation in detail and penalise network operators that do not implement it appropriately, two problems will arise:

- The regulator has to develop a detailed understanding of the decisions made by the DSO, based on empirical data. That bears the risk of a micro-management of DSOs, with the regulator claiming to not only comprehend, but to even assess the economic parameters of each decision connected to system-optimisation. Such a micro-management is not only undesirable from an economic and policy point of view, it is also not achievable, given information asymmetries.
- If the regulator (or more generally the state) interferes in investment decisions of the network operators, some of the responsibility for security and reliability of supply will have to be taken over by the regulator. However, as the network is operated by private, profit-oriented companies, this responsibility and the related investment risk will have to completely remain with these companies.

Given these constraints, what is needed is an incentive system for network operators that leaves all system optimising decisions completely up to them, but gives them financial rewards for „good“ decisions and penalises „bad“ decisions.

Giving DSOs an incentive to take optimal decisions, can be achieved through investment budgets for individual network operators. In order to implement such a scheme, the following two issues need to be examined:

- a) How is the budget for each network operator calculated?
- b) How to deal with the incentive to make use of the budget as little as possible in order to maximise profits?

Regarding a)

Ideally the necessary investment budget will be set as an overall budget. It can be based on model network analyses and empirical data. Thereby the cost drivers of capital expenditures/CAPEX (e.g. length of circuit, number of circuit points, peak load, etc.) have to be analysed. During the first budget setting different depreciation cycles have to be considered. The budget covers the complete regulatory period and it is up to network operators how they use it during the regulatory period.

Regarding b)

A preset budget without ex-post correction (i.e. skimming the difference between allowed and spent budget) gives DSOs the incentive to spend as little of the budget as possible and to keep the difference as profit. Consequently they will try to defer investments as much as possible. Therefore the budget approach has to be accompanied by quality regulation which has the aim to keep up and even improve the security and reliability of supply in the network. For this reason the quality indicators mentioned above

(and possibly additional indicators) are to be evaluated on a regular basis. There need to be strict penalties for underperformance.

If the budget that is not spent by the DSO will be skimmed by the regulator, the incentive for network operators to spend the budget in an optimal way would be lost completely. Even worse, they would aim to spend the budget completely because any remaining balance would be taken off their tariffs in the next period. Regarding our aim to give network operators a sufficient incentive for system-optimisation, this approach is probably not an option.

### **2.3.3 How can (some of the) system benefits be appropriated by the DGO?**

Network operators with a preset investment budget should have an adequate financial incentive to undertake a system-optimisation according to Art. 14/7. They will take into account the risk and the costs stemming from the integration of third parties. The costs include the remunerations for third-parties for their system-related services. These remunerations should be based on a transparent market mechanism and should lead to an equilibrium between additional costs incurred by plant operators and the network related benefits.

### **3 Regulating Innovation**

As we have elaborated in the previous section, new mechanisms need to be developed through which network regulation can provide incentives for DSOs to connect DG plants (for example through benchmarking and quality regulation that includes DG or through a mechanism that incentivises and enables DSO to consider DG as an alternative to network expansion). Such a general DG-oriented regulatory framework may foster network innovations, simply because there is more DG activity that makes DSOs think about how these plants can best be integrated.

Nevertheless, in order to promote the innovations necessary for an efficient large-scale deployment of DG, network regulation should provide additional tailor-made instruments for DSOs to get involved in R&D and take the risk to try out new approaches to running their network. Especially as there is currently a lot of scope and need for network innovations to accommodate a rising share of DG, network regulation should pay explicit attention to innovation. This should be seen as complementary to public spending for R&D projects, many of which include DSOs, as for example on the European level.

Analysing mechanism to promote network innovations through regulation should be seen in a broader context. While there is some evidence that electricity market liberalisation has stimulated innovation (Markard et al. 2004), there is an increasing discussion as to the ability of liberalised electricity markets for long-term development beyond short-term efficiency improvements. This is not limited to the network, but also includes the generation side. While the issue of investment adequacy in competitive generation markets and regulated networks has increasingly become a focus of analysis and political debate (Burns, Riechmann 2004; Hirschhausen et al. 2004; Neuhoff, de Vries 2004; Roques et al. 2005).

Obviously, on the generation side, R&D is conducted under competitive conditions with potential market failures with respect to R&D that are very different from the regulated environment in which network companies operate. There are studies that analyse the effects of liberalisation on innovation in the electricity industry in general (Markard et al. 2004). What is needed, however, is a disaggregated analysis that examines the specific conditions of regulated monopolies.

The question may be asked why DSOs should get involved in developing innovations themselves. While they are indeed unlikely to take part in more basic research activities, it is crucial for DSOs to get involved in applied research activities to establish a link between research and DSOs' needs and to further develop and test innovations under real network conditions. This requires DSOs to participate in research projects and set up demonstration projects on their networks. Furthermore, it can be argued that companies need to have at least some R&D capabilities in-house to be able to appropriate the results of external R&D.

Innovative activities with respect to DG integration are not limited to DSOs. As the case of Denmark shows, TSOs can also play an important role in this area. In some cases, DSOs may be too small to carry out (efficient) R&D on their own, in which case joint innovation activities or a stronger role of the TSO may be needed.

### **3.1 Network regulation and innovation: The status quo**

#### **3.1.1 A European overview**

In work package 1 of the DG-GRID project, we have conducted a survey of the status quo of DG in the EU-15 member states. This survey has covered regulatory instruments to promote network regulations. Project partners were asked to answer the following question for their respective countries:

*“Are there schemes or provisions in the regulations, that either explicitly or implicitly, stimulates DSOs to innovate, i.e. apply new methods and technologies in the network? If so, describe this schemes or provisions.”*

The general picture that emerges from this survey is network innovations have so far hardly been addressed by network regulators in Europe. Except for the UK, there are no innovation-specific regulatory instruments in the EU-15. Rather, in the majority of countries, the focus is on short-term cost reductions and network regulation tends to discourage rather than stimulate network innovations.

This confirms the results of the Sustelnet project, which concluded that the effect of price-cap regulation

*“in the UK and the Netherlands appears to have been to lock the DSOs into focusing on trying to do the same thing in each of the price control review periods, but with greater efficiency and reduced costs (...) and to reduce the potential for innovation in the way that the system can operate” (Connor, Mitchell 2002).*

The explicit treatment of innovation in the UK network regulation that was introduced in 2005 as a result of the short-comings of incentive regulation with regard to innovation will be described below.

For Spain, to give another example, it is reported that there are currently no regulatory mechanisms to encourage DSOs to innovate. Rather, regulation has the opposite effect. Revenue caps are leading to cost reductions and quality of service degradation. DSOs complain that the revenues they can achieve are not sufficient to maintain a minimum standard of supply continuity. There seems to be a general agreement in Spain that a fundamental revision of the regulatory framework is needed.

In Austria, the regulator E-Control has published a detailed study on DG in Austria (E-Control 2005). It acknowledges that DG will play an increasing role and that this will require changes in the way the network is run. A number of potential innovative future network concepts are outlined in some detail. What is missing, however, is an analysis

as to how network regulation can promote the development and implementation of such concepts.

In the Netherlands the regulator took the position that innovation is a normal business activity and should be part of OPEX. The economic incentive regulation includes a quality performance indicator that rewards (or penalizes) DSOs if quality improves (or deteriorates). The economic benefit of cost reductions and quality improvements should stimulate DSOs to innovate. DSOs are allowed to collaborate in innovation projects. Since 2005 some joint innovation projects have been carried out as a result of HERMES, a platform for DSOs and research institutes to discuss and establish joined R&D project for electricity networks. Before 2005 the government subsidized the PREGO program, mainly to guarantee the continuity of the electricity network R&D in the Netherlands.

Outside Europe, there are some countries that have paid attention to the development of DG within their design of electricity markets or network regulation, like for example in New South Wales in Australia. Yet we have not found any innovation-specific regulatory instruments outside the EU.

While in the electricity sector, the network has been relatively stable, the telecommunication sector has seen a highly dynamic development of its network infrastructure and innovations abound. One of the main rationales of liberalisation was to foster technical change and network innovations. While there are differences between telecoms and electricity, it is interesting to note that telecom regulation is much more concerned with innovation. The EU telecommunications directive (2002/21/EC) explicitly states that:

*„The national regulatory authorities shall promote competition in the provision of electronic communications networks by (...) promoting innovation.“*

A first step to gear electricity network regulation more towards innovation could be to include a similar provision into the EU electricity directive and define the promotion of innovations as one of the tasks of network operators (Sambeck, Scheepers 2004).

### **3.1.2 R&D funding through Public Service Obligations in Denmark, France and Italy**

In the following we will present in a bit more detail the approaches in Denmark, France and Italy on the one hand, where R&D is based on public service obligations and the UK on the other hand, where R&D incentives have been incorporated within the incentive regulation mechanism.

#### *3.1.2.1 Denmark<sup>5</sup>*

Denmark has a pioneering role in Europe when it comes to redesigning the network to accommodate an increasing share of DG. Within the regulation of network tariffs, it does not have any regulatory instruments that are specifically geared towards promoting

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<sup>5</sup> Sources: [www.ens.dk](http://www.ens.dk), [www.energinet.dk](http://www.energinet.dk), [www.elforsk.dk](http://www.elforsk.dk), [www.energiforskning.dk](http://www.energiforskning.dk)

innovation. However, there is a separate funding mechanism for R&D based on a public service obligation<sup>6</sup>.

The Danish DSO and research institutions can obtain funding for R&D projects dealing with the integration of DG (environmentally friendly production) to the grid. This is financed by a levy called 'public service obligation' on the consumers.

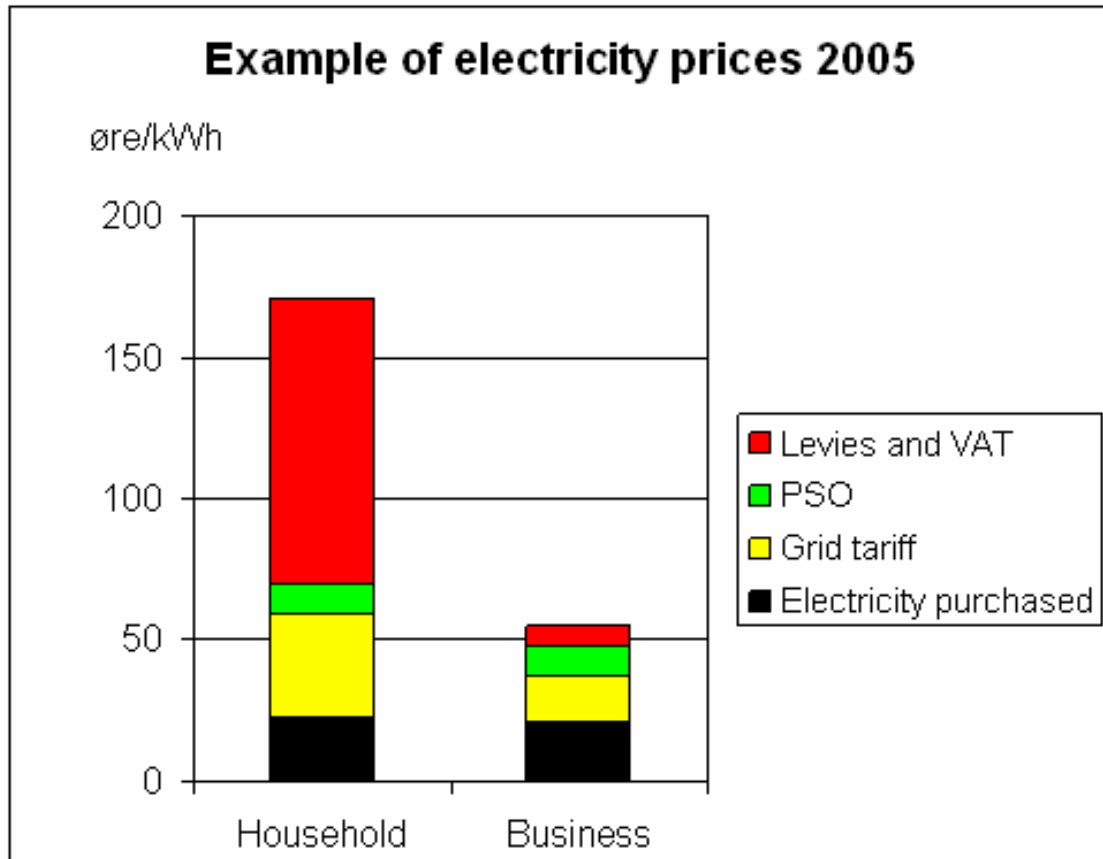
The Danish Electricity Supply Act defines in greater detail which kinds of PSO activities are involved, and states how the collected PSO costs can be accounted for by grid companies (use of system charges). All subsidies are passed on to the consumers as an equal Public Service Obligation (PSO) tariff on their total consumptions. At the start of 2005 the PSO tariff was approx. 11 øre/kWh (1.5 cent Euro/kWh). All prices, tariffs and terms have to be reported to the Danish Energy Regulatory Authority for checking and approval.

For a private household the PSO-levy is roughly 7% of the total electricity price (see Figure 2).

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<sup>6</sup> Public Service Obligations (PSOs) are compulsory services the state applies to companies designed to satisfy public interests (Directive 2003/54/EC).

Figure 2: Composition of the electricity price for a household with a consumption of 4,000 kWh/year and a business with a consumption of 1,000 MWh/year.



Source: [www.ens.dk](http://www.ens.dk)

The PSO funds are used by the transmission system operator (TSO, Energinet.dk) and DSOs for a number of PSOs. Examples include:

- supply security
- collection and re-allocation of levies e.g. support schemes for environmentally-friendly electricity
- along with research and development on environmentally-friendly production technology (R&D)

In Denmark, around 3/4 of all PSO costs go to the subsidy for environmentally-friendly electricity production [[www.ens.dk](http://www.ens.dk)].

A share of the PSO is used to finance two R&D programmes respectively coordinated by Energinet.dk and Elfor.

1. Energinet.dk, the company responsible for the operation of the Danish transmission electricity system since January 2005 provides funding for energy R&D

projects concerning environmentally friendly production of power.<sup>7</sup> The R&D budget, areas, and programmes for R&D are adjusted yearly (legal notice 1463 of 19. December 2005). In 2005 the amount of 130 million DKK (17.5 million Euro) was available for project funding. This corresponds to approximately 0.4 øre/kWh consumption.

2. The grid companies are obliged to make plans for and carry out R&D in order to promote more efficient use of electricity. Elfor, an association of electricity distribution companies, coordinates the funding for energy R&D projects concerning efficient use of electricity. In 2005, the amount of 25 million DKK (3.4 million Euro) was available for project funding.

The former PSO-R&D programme in 2005 focused on wind energy, biomass, PV, wave power, CHP and natural gas, fuel cells, and load and system management. Besides technical R&D projects also more analytical projects are supported, e.g. intelligent grid regulation.

The latter PSO-R&D programme, coordinated by Elfor, in 2005 had focused on different energy saving options and load management.

Since the two PSO-R&D programmes have different focus areas it is hard to say how much of the funding spent on integration of DG in the net is going to mere innovation. This share does not only depend on the specific focus areas - which are adjusted every year- but also on the project proposals submitted to the programmes.

In addition to the two PSO-R&D programmes addressing predominantly private DSO, the state hold Danish TSO, Energinet.dk, is obliged to carry out R&D activities that are considered necessary to allow for the electricity transmission and distribution system to become sustainable, environmental friendly and energy effective. The TSO is hence carrying out R&D activities concerning innovative network development.

### 3.1.2.2 France<sup>8</sup>

In France, as far as distribution is concerned, the objective to improve the functioning of electricity networks has been laid down in a contract between the French government and Electricité de France, namely the “contrat de service public entre l’Etat et EDF”, signed in November 2005.

In this contract, EDF commits itself to fulfil a series of obligations including a safe use of systems and the guarantee of a certain level of quality. EDF Réseau Distribution,

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<sup>7</sup> Before 2005 the system operators ELTRA and ELKRAFT SYSTEM were responsible.

<sup>8</sup> The information on France has been provided by the regulatory commission (Commission de Régulation de l’Energie) and EDF R&D. The funding of R&D in the distribution network is addressed in the public service contract signed between the State and EDF (“Contrat de Service public entre l’Etat et EDF”) on October 21, 2005, for the years 2005 to 2007). This contract has been established according to the first article of the law 2004-803 adopted on August 9, 2004, relating to the public service of electricity and gas and to electricity and gas companies.

EDF's subsidiary operating 95% of distribution in France, committed to study the improvement of network management systems, keeping itself informed of new materials available as well as technical progresses in general, and to study the impact of distributed generation on the functioning of networks and the quality of electricity. However, the results of this research, while communicated to the government, are kept confidential. This means that no dissemination procedure is included in the public service contract.

The research and development activities applied to distribution systems are carried out by EDF R&D in the framework of programmes set up by EDF distribution subsidiaries. EDF R&D operates as a consultant. Each research operation on distribution is evaluated individually and yearly. These programmes are funded in the framework of a financial protocol signed between EDF Production and EDF Distribution.

The amounts dedicated to R&D are submitted by EDF to the regulator for approval in the procedure of the elaboration of the tariffs for the use of public distribution networks. As a consequence, in distribution, R&D is funded by the tariffs paid by the final consumers through the use of system charges. In 2005, EDF spent 25 million euros in R&D dedicated to distribution.

### *3.1.2.3 Italy<sup>9</sup>*

In Italy, the researches on electricity systems were traditionally carried out by CESI in the framework of the Public Interest Energy Research Project named "Ricerca di Sistema" (Italian Ministry for Productive Activities Decree of 28 February 2003). Nowadays, these activities have been transferred to CESI RICERCA SpA, a new research centre created in January 2006, jointly owned by ENEA 51% and CESI 49%. Its mission is to take over funded research activities of national and international interest in the electricity and energy sector, with strong emphasis on experimental applications, thus ensuring the consistent continuation of all current research activities and the development of new strategic projects in the future.

Focus of the mission is to ensure the technology transfer in order to improve the operation of the Italian electrical system from the environmental, safety, security and economic point of view. In this context, great attention is given to the promotion of innovation in distribution network management and operation and to distributed generation. The company also ensures the proper diffusion of scientific results to provide a good indication of the potential of emerging technologies in the electrical energy field.

In Italy, all research and development activities which have an impact on the electricity system are directly paid for by the Italian consumers. The funds for the Public Interest

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<sup>9</sup> The information on Italy has been provided by the Italian regulatory Commission (AEEG) and CESI. The official documents are: Decree n. 79 of 16 March 1999 of the Ministry of Productive Activities (which establishes the funding of the Public Interest Energy Research Project "Ricerca di Sistema") and Decree of 28 February 2003 of the Italian Ministry for Productive Activities, which designates CESI as responsible for the Public Interest Energy Research Project named "Ricerca di Sistema".

Energy Research Project "Ricerca di Sistema" are provided by customers' tariffs in accordance with the Italian Ministry for Productive Activities Decree n. 79 of 16 March 1999. Italian consumers pay for a levy on the final tariff which is yearly updated by the regulatory commission, the AEEG. In 2006, this levy amounted to 0.03 cEUR/kWh.

### **3.1.3 Regulatory Innovation Incentives: Registered Power Zones and Innovation Funding Incentive in the UK**

The UK is the only EU country that has explicitly set up mechanisms within its network regulation scheme to promote innovations in the network. According to the electricity regulator Ofgem, promoting network innovations is necessary for two reasons (ofgem 2004b):

First, there is a need for an increasing rate of asset replacement in the network, providing a window of opportunity to introduce innovative network solutions. Secondly, the penetration of generation into distribution systems is expected to continue to increase. According to Ofgem this is likely to present significant new technical challenges to the DSOs and consequently a requirement for additional capital expenditure.

The average R&D Intensity for the DSOs has been significantly below the UK average (0,1% compared to 2,5% according to Ofgem). Ofgem therefore argued that mechanisms geared towards promoting innovation by network operators were needed.

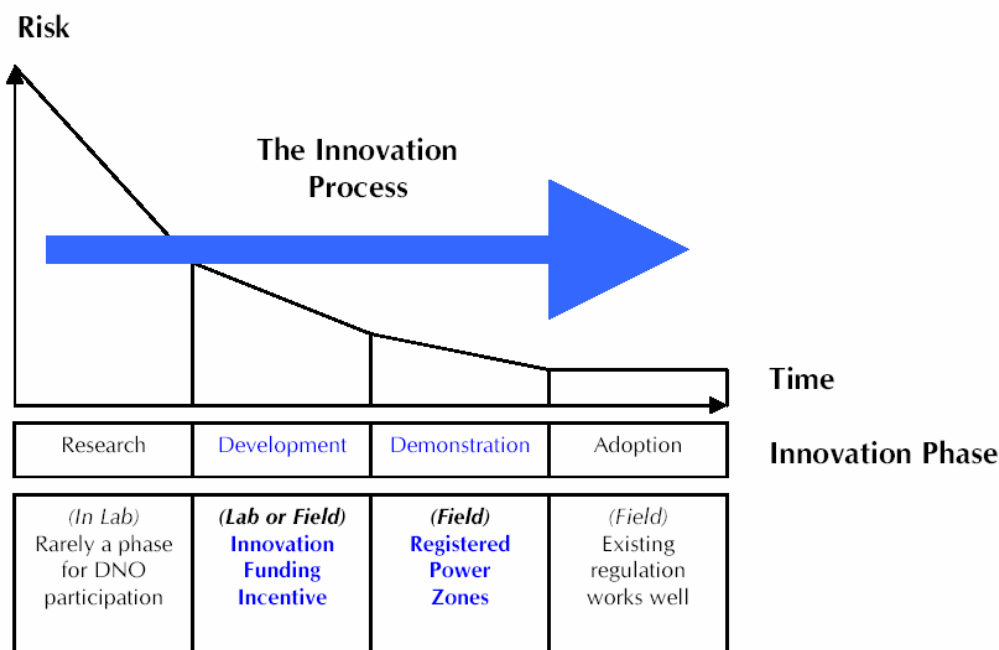
Against this background, OFGEM has set up two mechanisms – Innovation Funding Incentive (IFI) and Registered Power Zones (RPZ) – within the 2005 Distribution Price Control Review (ofgem 2004a; ofgem 2004b; ofgem 2004c)<sup>10</sup>.

The IFI and RPZs are designed to be complementary, addressing different stages of the innovation process. The following figure shows the different stages of the innovation process and where the two mechanisms are to be located in this process.

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<sup>10</sup> cf. Separate treatment of innovation costs

Figure 3: The Innovation Process and the role of IFI and RPZ



Source: (ofgem 2003: 5)

IFI projects are supposed to be development projects. These can cover all technical aspects of distribution networks, including network design, operation and maintenance. The RPZ scheme addresses demonstration projects employing new, more cost effective ways of connecting and operating generation.

The details of the two mechanisms are as follows:

The Innovation Funding Incentive gives network operators an allowance to spend 0.5% of their regulated revenue on innovation projects in the development stage on a use-it-or-lose-it basis. Within this limit, there is an average 80% cost pass-through over 5 years with the following profile:

Table 3: Pass-through of the IFI

Year	2005/6	2006/7	2007/8	2008/9	2009/10
Pass-through rate	90 %	85 %	80 %	75 %	70 %

Source: (ofgem 2004a: 49)

The projects are typically carried out by third-parties, although DSOs can spend up to 15% on in-house R&D.

The second mechanism, Registered Power Zones is based on the hybrid incentive mechanism for DG connection, which gives DSOs a £/kW incentive for new DG con-

nection. If the connection is carried out in a RPZ, employing new solutions, the £/kW incentive is increased. While ‘normal’ DG connections are rewarded with a 1.5 £/kW incentive rate for a 15-year period, this incentive is increased to 4.5 £/kW for five years. The additional revenue that can be derived from the £3/kW uplift that a DSO can claim for RPZ projects is capped at £0.5 million per year.

By the end of 2006, three RPZs have been set up by the following DSOs:

- Central Networks: connection of wind generation using dynamic line rating technology
- Scottish & Southern Energy: connection of renewable generation on Orkney using active network management
- EDF Energy: connection of generation using novel voltage control technology

### **3.2 The effect of different regulatory mechanisms on innovation**

In this section, we give a brief overview of the peculiarities of R&D and innovation in regulated natural monopolies. We look at rate-of-return and incentive regulation as the main approaches to network regulation and discuss the main mechanisms through which they affect DSOs’ innovation activities.

Although it is fair to say that the effect of regulation on innovation has received little attention in the literature, there are a number of studies – both empirical and model-based – that have analysed regulation from an innovation perspective. Especially in the 70s and 80s there were some studies in the US (Bailey 1974; Mayo, Flynn 1988; Müller, Vogelsang 1979; Schoppe, Wass von Czege 1984; Sweeney 1981). For an overview see Jamasb, Pollitt (2005). They examined the rate-of-return regulation (RoR) that was predominant at the time. In recent years, ‘Incentive Regulation’ has become the form of regulation which is considered to be most sophisticated in the electricity industry. Yet its effects on innovation have received little attention so far. Moreover, the focus of most studies on innovation under regulation has been on vertically integrated monopolies rather than unbundled networks in liberalised markets. Although it is often not made explicit, the analysis tends to focus on innovations on the generation side of these companies.

Although the empirical basis is therefore different from the current situation in most EU countries and although we are particularly interested in network innovations, these studies can provide some insights into the general effects and mechanisms. Back in 1979, Müller and Vogelsang (pp. 91-92) concluded that there were only ambivalent and often contradictory results as to the effect of regulation on innovation. Both empirically and theoretically, this still seems to be the case, yet the overall impression that emerges is that rate-of-return regulation leads to a suboptimal level of R&D and innovation and incentive regulation can further exacerbate this effect.

When analysing the effect of regulation on innovation, it is important how regulation affects both the ability and the incentive of network operators to spend on the develop-

ment of innovations. In the following we first summarise the mechanisms through which rate-of-return regulation affects R&D and innovation.

### **3.2.1 Rate-of-return regulation (RoR)**

The effect of rate-of-return regulation (RoR) can briefly be described as follows: It gives companies the ability to conduct R&D, but gives them only limited incentives to do so. On the one hand, companies have no incentive to improve their efficiency. They lack both the stick of competitive pressure and the carrot of supra-competitive profits. A regulated monopoly cannot lose market share because it is not innovative and cost reductions which a company can achieve through innovation will not lead to a higher rate of return. Any innovation gain that would lead to a higher rate of return, will be passed on to customers.

As the potential benefits of R&D mainly accrue in the medium- to long-term and will therefore be discounted more than short-term reductions in R&D spending, this generally reduces the attractiveness of R&D. Under RoR, there is no patent protection for long-term benefits, which may further reduce the net present value of R&D.

RoR tends to give companies an incentive against capital-saving innovations and will therefore make active management less attractive as compared to new cables.

On the other hand, under RoR, there is no cost-cutting pressure for companies. Consequently, it should not be a problem for them to spend on R&D. Companies also do not get penalised for failed R&D investment. In as far as R&D increases the capital base, this may be a reason for companies under RoR to spend on R&D. Free-riding of other companies, that are not as innovative, but may benefit from the results of companies with higher innovation efforts, is less of a problem for regulated monopolies as compared to a competitive market.

### **3.2.2 Incentive regulation**

We now turn to the innovation effects of incentive regulation, which is becoming the dominant regulatory regime with a convergence of European regulatory mechanisms towards this form of regulation. Due to a lack of detailed empirical studies of the effect of incentive regulation on innovation, our discussion is mainly based on theoretical considerations. These, however, are in line with the results of our European survey (see 3.1.1).

The core of incentive regulation is to provide companies with an incentive to improve efficiency by temporarily (i.e. within one regulatory period of three to five years) decoupling prices from costs. At the beginning of an incentive regulation scheme, there is likely to be scope for reducing x-inefficiencies<sup>11</sup> and companies can become more efficient using existing technologies through managerial and organisational improvements.

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<sup>11</sup> X-efficiency is the effectiveness with which a given set of inputs are used to produce outputs. If a firm is producing the maximum output it can given the resources it employs, such as men and machinery, and the best technology available, it is said to be x-efficient.

Sooner or later, however, companies will reach a point where further efficiency improvements can only be achieved through technical change, requiring investment.

Although incentive regulation in principle provides a framework for efficiency improvements including efficiency improvements through technical change, it can at the same time undermine the development of innovations. Incentive regulation is mainly short-term oriented and gives incentives for cost-reductions in the next regulatory period. Innovation, on the other hand, is more of a mid- and long-term issue with short-term costs and long-term rewards and relatively high risk. Innovation is mainly about network development beyond the next regulatory period.

Incentive regulation, like RoR, still leaves companies not much time for appropriating the benefits of innovations. On top of that, it gives them an additional incentive to reduce costs in the short-term in order to increase profits. This will also apply to R&D costs. As there is a cost associated with taking risk, companies may generally become more risk-averse, and will therefore be reluctant to develop and try out new options. There may also be a free-riding problem, as companies will wait for their peers to spend on R&D and for the diffusion of results. This may be exacerbated by benchmarking companies against each other.

As a result, the static efficiency improvements that can be prompted by incentive regulation may run counter to dynamic efficiency improvements through technical change that can be achieved in the medium- to long-term, but require short-term expenditures. This effect may be all the more severe when it comes to structural rather than merely cost-saving innovations. Especially when it comes to integrating DG, innovation is not merely about cost reductions, but also about doing new things that were not within a DSO's remit before and which involve risks at a level not experienced before.

### **3.3 Regulatory approaches to innovation**

Having looked at the way conventional regulatory approaches affect innovation, we now turn to mechanisms that may be used to make network regulation more innovation-friendly. When discussing instruments to promote innovation activities, one should bear in mind that there can also be too much innovation efforts and that R&D can be inefficient from a welfare point of view. For example the 'Regulatory Asset Base (RAB)' approach to promoting innovations (see 3.3.1 further down) can lead to gold-plating R&D projects.

Specific instruments targeted at promoting innovation should also be designed in a way that they represent one element of a consistent overall framework. They should not be put in place as an add-on to repair the negative side-effects of a regulatory mechanism that discourages innovation. Incentives to innovate should be integrated into the general regulatory framework to the extent possible.

While these general arguments should be taken into account, it is also important to note that – as we have tried to show above – distribution networks face the challenge of in-

creasing DG connection and in the years to come there is a lot of potential and need for innovations in these networks. Consequently, it can be argued that in this specific context, regulation should err on the side of innovation.

Regulators should not select individual R&D projects and get involved in detailed innovation-management<sup>12</sup>, but should rather promote an innovation-friendly regulatory environment. Yet it is questionable whether regulation can be totally neutral to the *direction* of innovation. In the UK, for example, the RPZ and IFI schemes were specifically designed “to deploy new technologies, and encourage their wider application, where this enables distributed generation to be integrated more effectively and efficiently, to help meet the government’s targets for renewables and CHP”. While leaving it to companies which innovations they consider worthwhile, they should pursue the general objective to improve the integration of distributed generation.

There are a number of approaches to regulating R&D and innovation in networks:

1. Separate R&D funding mechanism, e.g. Italy, Denmark, see 3.1.2
2. Mandatory R&D spending obligations to perform R&D as a percentage of total sales placed on generation, transmission, and distribution companies, e.g. in Brazil
3. Including innovation costs in the regulatory asset base
4. Separate treatment of innovation costs
5. Extending regulatory periods
6. Integrated approaches to innovation

While these mechanisms are more or less based on financial obligations and incentives placed on innovation inputs or outputs, there may be additional ‘soft measures’, e.g. requiring DSOs to make their R&D activities transparent, e.g. through regular reporting, or facilitating exchange and providing platforms of debate such as the UK “Electricity Network Strategy Group” (see section 4).

While approaches 1 to 4 mainly tackle the input side of R&D (by making R&D expenditure mandatory, ensuring cost-recovery and/or rewarding R&D expenditures), the last two approaches focus on R&D outputs. As opposed to input-oriented measures, they seek to avoid the problem that companies may have an incentive to spend on R&D without an incentive to produce useful innovations that make their network more efficient or enable a higher share of DG.

In the following we will analyse approaches 3 to 6 in more detail, as these need to be directly linked to the regulation of network tariffs.

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<sup>12</sup> See also section 2.3.2 on the danger of micro-management of network companies.

### 3.3.1 Including R&D costs in the Regulatory Asset Base (RAB)

If a network company is to get involved in R&D and develop innovative solutions, the costs incurred should be recognised when the regulator determines the companies cost base. Leprich et al. (2005) have argued that the regulator should give a clear signal that it expects network operators to participate in development and demonstration projects and that the respective costs will be accepted. The costs of demonstration projects testing new ways to integrate DG into networks should be included in the OPEX costs.

A more far-reaching approach would be to include R&D costs not just as OPEX, but to capitalise R&D costs in the regulatory asset base (RAB). As Holt (2005: 3) has pointed out, *“the economic rationale for capitalising the value of R&D is that it is likely to generate benefits beyond the year in which these expenditures are made. In this respect such expenditure is like investment in any physical, tangible asset and could be capitalised into the RAB”*.

Based on an analysis of empirical data, Mayo and Flynn (1988) confirm that capitalising R&D expenditures into the rate base significantly increases the amount of money spent on R&D by the regulated company. This supports the theoretical argument that the RAB approach takes away the downside risk from companies and insures that regardless of whether R&D expenditures lead to innovations and cost reductions sufficient to justify the costs of R&D, they will in any case generate the allowed rate of return.

At the same time, however, the upside risk for the regulated company, i.e. its chances to make extra profits, is very limited, as the benefits of a successful innovation will quickly be passed on to customers. As a result, the risk distribution of R&D, that tends to be broader than that of ‘normal’ activities, is in no way reflected in the companies risk distribution. What will pay off for the company is the increased asset base resulting from increased R&D, whereas it will hardly be affected by innovation gains or losses for longer than one regulatory period in the best case. In other words, companies have a strong interest in R&D but only limited interest in the productive outcome of innovations<sup>13</sup>. Increasing R&D expenditure, however, is not an end in itself, and does not necessarily translate into innovations.

Consumers, on the other hand, are highly exposed to the innovation risk, as they both have to pay the standard rate-of-return even for failed R&D and will get the main share of successful R&D leading to cost reductions.

Increasing the allowed rate of return can further increase the incentive of regulated companies to spend on R&D. However, consumers would bear an even higher risk, while the companies’ main interest would still be to spend on R&D and only to a lesser extent to develop successful innovations. What is more, the higher rate of return would not just apply to R&D but to other capital expenditures, too, leading to further distortions.

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<sup>13</sup> Benchmarking between companies will reduce their incentives to increase the asset base and increase their incentives to turn R&D activities into successful (i.e. cost-cutting) innovations.

With this approach, there is a danger that capitalising R&D expenditures can lead to an inefficient over-investment in R&D or ‘gold-plating’ of R&D projects, similar to the more general problem that rate-of-return regulation can lead to excessive capital expenditure (Averch-Johnson effect). This effect will be less relevant under incentive regulation.

A further problem of capitalising R&D expenditures can be that it gives companies an incentive to declare as many costs as possible as R&D costs. As DSOs will in most cases not get involved in basic research, but will test how an innovation can be implemented in its network in demonstration projects etc., most innovation costs will not be incurred in a specialised R&D centre, but will be more linked to ‘normal business’. Introducing an innovation to test and enhance it can require staff training and other ‘restructuring costs’. There are examples that such costs have been capitalised in other sectors (Holt 2005: 4). Yet in practice it will be difficult to assign costs to the R&D budget that is to be capitalised.

As a conclusion, we can say that including R&D into the regulated asset base is likely to have a positive effect on R&D expenditures. Yet the risk of innovation is not adequately reflected in the regulated company’s risk distribution and the company is mainly incentivised to spend on R&D rather than to develop useful innovations. The approach may be applied to some R&D expenditures that can clearly be identified, but needs to be complemented by other measures.

### **3.3.2 Separate treatment of innovation costs**

In the previous approach “Including R&D costs in the RAB”, regulation recognises innovation related costs as an investment. Yet it does not recognise that it differs from normal investments and treats R&D expenditures in the same way as any other capital costs. However, research by its very nature carries a higher risk than normal business – both upside and downside.

Even though DSOs will in most cases not engage in basic research, but rather more advanced innovations closer to ‘the market’, the benefits of these, if any, can normally not be reaped in the short-term. These properties of R&D can justify a special treatment of innovation-related costs. There are several ways this can be done.

Based on the capitalisation approach described above, it has been proposed to capitalise R&D expenditures into an ‘innovation RAB’ that is separate from the normal asset base (Holt 2005). The rate-of return applied to this RAB would be higher than the normal rate-of-return applied to the rest of the asset base.

This approach only partly addresses the problems of the RAB approach described above. As we have argued, under the RAB approach the regulated company is not exposed to the risk and its main incentive is on R&D spending rather than on innovation. In the ‘innovation RAB approach’, companies do get an additional incentive to spend on R&D, yet the extent to which they benefit from this is still not linked to the actual innovation outcome. They would still have only little incentive to spend on useful R&D and

the downside risk would completely be passed on to customers. A separate treatment of R&D costs should not aim at taking the risk away from network companies completely, but should balance the risk in a way that they can gain enough from successful R&D to justify the higher risk of innovation activities.

As the benefits a company can gain from innovations are truncated by the regulatory cycle, an alternative approach would be to extend the regulatory period for savings resulting from innovations. This approach will be discussed in the next section (3.3.3).

If innovation gains remain truncated from the companies point of view and are passed on to its customers after the next regulatory review, the risk must also be truncated. This is the approach that has been chosen in the UK with the Innovation Funding Incentive (IFI) approach. Instead of capitalising R&D costs, Ofgem has chosen to reduce the downside risk for companies through a partial cost pass-through (an average of 80% over five years under the IFI mechanism). This is basically done through a z-factor applied to the revenue- (or price-) cap formula:

- Revenue/Price (t) = Revenue/Price (t-1) \* (1+RPI-x) + z

Cost pass-throughs are often used for costs which a company has no control over. In this case, it is used to shield DSOs from the uncertainty of R&D. The limited downside risk that remains with the companies is to give them an incentive for efficient R&D spending.

As opposed to the RAB approach, under this approach R&D does not automatically generate a rate of return, but companies can only benefit from actual benefits an innovation has produced. Benefits will still be passed on to customers after five years, but these also take part of the risk and pay for 80% of the costs.

While the IFI mechanism protects DSOs against innovation risk, the 'Registered Power Zone scheme' (RPZ) gives them an additional positive incentive for the innovative connection of DG plants in demonstration projects. If DSOs connect plants in an RPZ they will get a further £3/kW revenue entitlement for a period of 5 years after the year of connection.

Any separate treatment of R&D related costs with cost pass-throughs or additional incentive increases the risk that DSOs seek to shift costs that are not related to innovation into this special regime. This risk can be mitigated by capping the amount that can be spent in the special regime. For example, the additional revenue entitlement under the RPZ scheme in the UK is capped at £0.5m per annum per company.

### **3.3.3 Extending regulatory periods**

While in competitive markets, innovations can provide companies with the necessary competitive advantage, in a natural monopoly due to the lack of competition this is not relevant for them. Incentive regulation with benchmarking tries to emulate competition. Yet given the rather short-term targets they impose, companies get incentives for short-term cost-reductions. R&D investments, that generate short-term costs but mainly pay off in the future may even worsen their benchmarking position in the short-term. If a

company is to spend on R&D, the economic rent resulting from R&D should be large enough and not taken away from the innovator for a sufficiently long period of time so that they undertake this risky activity. The more a company can reap the benefits of innovations they have developed, the stronger their incentive 1) to spend on R&D and 2) to spend on R&D that promises to produce benefits for them.

During regulatory periods, i.e. in between regulatory reviews, regulated companies can benefit from efficiency gains, i.e. companies can appropriate the benefits of investments in innovation. In the next regulatory period of an incentive scheme, efficiency gains are shifted to consumers. Under rate-of-return regulation, the regulatory lag has the same effect.

In most cases, it seems unlikely that a DSO can appropriate the benefits of an innovation within one regulatory period which is geared towards incentivising standard efficiency increases. R&D is riskier and may have relatively high up-front costs, while benefits accrue only some time in the future. As a result, they will be significantly discounted, leading to a smaller net present value on the basis of which an R&D project will be assessed. Once the innovation has been successfully introduced, its benefits may well be visible for some time to come. Yet such long-term effects that go beyond one regulatory period will be to the advantage of customers rather than DSOs, at least as long as network tariffs are regularly reset based on the DSOs cost base (see also section 3.3.4.2 on Yardstick Regulation).

It can be argued, that the regulatory lag or regulatory period has a similar effect on the incentive to innovate as patents, in that it protects the gains made through innovations (Schoppe, Wass von Czege 1984: 147). While patents protect the innovation for a certain amount of time from being imitated by competitors, the regulatory period protects the benefits of innovations from being passed on to consumers. Based on this line of argument, Fuckso et al (2004: 38) have proposed for network regulation in Hungary to extend the regulatory period from four to five years.

In a model-based study, Bailey (1974: 295) has shown for rate-of-return regulation that extending the regulatory lag does have a positive effect on R&D activities: *“if regulatory lag is short, the firm will adopt a lower level of innovative activity. If the lag is longer, then the firm innovates more but society does not obtain as quickly the benefit in the form of lower prices”*.

While it is plausible that the length of the regulatory period influences a company's propensity to innovate, simply extending the regulatory period to provide innovation incentives does not seem to be a solution for a number of reasons. First of all, the innovation incentive is not unambiguous. In another model-based study, Sweeney (1981) has come to the conclusion, that while the regulatory lag does play an important role for the incentive to innovate, companies may also have an incentive to delay the adoption of innovations, as such a delay would also postpone the price reduction imposed by the regulator.

As it has already been indicated by the quote from Bailey, there is also a trade-off between innovation incentives and shifting innovation benefits to consumers. In fact, there

is a more general trade-off between efficiency incentives for the company and allocative efficiency that needs to be taken into account when discussing an extension of the regulatory period. In other words, an extension cannot solely be judged from an innovation perspective. The longer the regulatory period, the more a company can benefit from improved efficiency, yet the more prices deviate from costs. Also, a new regulatory period gives regulators the opportunity to fine-tune and adapt regulatory mechanisms based on the experiences made. As a consequence, the regulatory period should not be too long, and the question arises if given this constraint it can be long enough to stimulate innovations. Regulatory periods normally are between three and five years and Fucsko et al. (2004: 38), when putting forward their proposal to extend the regulatory period to promote innovations, concede that a one-year extension does not do much to promote innovation. Yet a longer extension does not seem to be feasible, given other regulatory objectives and constraints.

There is an important difference between patents and regulatory periods. While patents protect one specific innovation, extending the regulatory period would not just affect innovations developed by a company, but would be valid for the business as a whole.

In order to differentiate between innovation effects and the rest of the business, Holt (2005) has proposed to “*allow companies to retain the benefits of efficiency savings derived as a result of undertaking R&D for longer than the current five-year period for ‘conventional’ efficiency savings*”. It is however, doubtful, if this approach is feasible in practice. It would require a detailed analysis by the regulator as to which efficiency savings can be traced back to a company’s R&D efforts. The fact that some in-house R&D can lead to efficiency savings by enabling a company to appropriate external R&D results would make this even more complicated.

To sum up, as opposed to the regulatory lag under rate-of-return regulation, the regulatory period under incentive regulation is fixed ex-ante to give companies efficiency incentives. However, extending the regulatory period to stimulate R&D and innovation cannot provide strong enough incentives, especially given the constraints of the overall regulatory process. Yet the question remains how the short-term nature of regulatory periods can be better reconciled with the longer-term nature of innovation. How can the regulatory mechanism ensure that network operators both address short-term inefficiencies and pursue longer-term innovation activities?

What seems to be required is a long-term framework, spanning several regulatory periods with clear and reliable objectives for DSOs. When it comes to innovation, DSOs have repeatedly asked for such long-term objectives.<sup>14</sup> Through its RPI-X mechanisms incentive regulation does provide a long-term framework in that companies can expect

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<sup>14</sup> e.g. Martin Bongaerts from the Dutch network operator Continuon netbeheer in his presentation on regulation and innovation at the DG-GRID workshop, March 8 2006 in Berlin: “There has to be long-term vision where to go”. Similarly, Dave Openshaw from the UK network operator EdF Energy, when commenting on the UK innovation instruments RPZ and IFI at the Distribution Europe conference in Barcelona, May 17-19, said that “the problem is that we need certainty beyond 2010”, i.e. beyond the current regulatory period. See also Helm (2004: 36).

that efficiency improvements will be required from them in the regulatory periods to come. Yet except for this general efficiency objective there are no medium- to long-term objectives that can guide innovation activities.

Developing such a framework could be complementary to other innovation incentives in the regulatory mechanism, like the ones described in this section. Developing scenarios could be one way to draw up such a long-term framework. We will come back to this below in section 4 “Innovating Regulation”.

### **3.3.4 Integrated approaches to innovation**

A separate treatment of innovation can be justified and is likely to be more effective and efficient than the other two approaches (Including R&D costs in the RAB, Extending regulatory periods). However, a separate treatment establishes a special regime outside or complementary to the standard regulatory mechanism (e.g. RPI-X) in order to stimulate innovation. Innovation is a niche activity and there is a danger that it is not sufficiently connected to a DSO’s main business<sup>15</sup>. Especially with regard to DG related innovations, these should become more of a normal business activity once DG is no longer a niche activity (cf. Frontier Economics 2003).

There is also a danger that establishing such regulatory niches may make the overall regulatory framework inconsistent. While this is not an argument against well-designed mechanisms that may be necessary to tackle specific problems or to set off certain developments, it is crucial to carefully consider how incentives to innovate can appropriately be integrated into the general regulatory framework.

In the following, we will present two regulatory approaches that have the potential to render network regulation more innovation-friendly, namely Output-Based Regulation and Yardstick Regulation.

#### *3.3.4.1 Output-based Regulation*

One way to promote innovations through the regulatory framework could be to move from mechanisms based on R&D inputs to mechanisms that define output-related performance criteria within the general regulatory framework and link the revenue allowance to them, thereby stimulating DSOs to innovate so that they can meet these performance criteria in the most cost-effective way. Introducing performance criteria to stimulate innovations could be part of a general move from input- to output regulation.

Performance criteria could also be one element of a long-term framework spanning several regulatory periods, as DSOs would know they will need to improve their performance along the lines of these output criteria beyond the next regulatory period, provided the regulator can credibly commit to more or less stick to the performance criteria beyond one regulatory period.

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<sup>15</sup> Just before the RPZ and IFI schemes started in the UK in April 2005, an employee of a UK network operator said these mechanisms were too small to get enough management attention.

While it has been proposed to make use of innovation-related output criteria such as patents (Holt 2005: 4), the approach we propose goes one step further and is not based on (intermediate) innovation-outputs but rather on general performance criteria that should be defined such that they foster the development of innovations.

For example, Abildgaard et al. (2003) have proposed in order *“to prompt active networks and innovation, the revenue should become more dependent on network performance/output (volume, maximum load, distance, number of outages, frequency fluctuations etc.). (...) This change in orientation will give stronger incentives to cut costs, and it will give DSOs freedom to seek cost efficient solutions independently of the algorithm for the revenue cap.”*

However, while this gives companies stronger incentives to aim at cost reductions and at the same time maintain certain quality standards, it may still not give sufficient innovation incentives. Short-term cost reductions may still be more attractive than investments in innovations.

Moreover, from a DG perspective, this approach may even be counter-productive, as the innovative integration of DG may be cheaper than traditional approaches, but no DG at all may be even cheaper to meet performance criteria. Performance criteria should therefore not replace, but complement cost-based regulation. They should also be designed in a way to allow for innovation incentives.

There could be performance criteria that are specifically geared towards incentivising the efficient integration of DG. For example, Mitchell and Connor (2002) have proposed that *“the portion of DNO revenues related to performance measures could be increased and focussed on incentivising DG , via losses, as opposed, and in addition, to the current quality of service output measures.”*

Another possible performance criterion could be the share of peak load on a network covered by DG plants in relation to total DG capacity. This links back to the discussion above to include DG-related performance criteria in the benchmarking process (see 2.2).

#### 3.3.4.2 Yardstick Regulation

Yardstick regulation is a regulatory approach that is increasingly being applied in practice.<sup>16</sup> Yardstick regulation is a form of regulation where the price or revenue-cap a company faces is not based on its own costs (plus an assumption as to the cost reductions the company should be able to achieve) but on an industry-wide cost level that represents either the average costs of all network operators or the costs of the most efficient company.

While it was one of the core ideas of price and revenue cap-regulation to decouple prices from costs, this is only done for one regulatory period. At the beginning of each

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<sup>16</sup> E.g. in the Netherlands. The German regulator also plans to move towards yardstick regulation after the second regulatory period.

regulatory period, the cap is adjusted to a company's new cost level that has been achieved at the end of the previous period.

As opposed to this approach, yardstick regulation does not base the cap on the actual costs of a company, but assumes that the company has an average cost level, and the cap is set accordingly (see e.g. Burns et al. 2004). The price path a company has to achieve (in order to earn average profits) is entirely exogenous to the company's own performance, provided there is a sufficiently large number of companies so that individual companies do not influence the yardstick. The objective of yardstick regulation is to promote indirect competition between the regulated companies to reduce the problem of information asymmetries between the regulator and the regulated companies and the regulated companies' gaming incentives.

Yardstick regulation, while not providing tailor-made innovation incentives, may also have positive effects on innovation<sup>17</sup>. As we have described above, one of the main short-comings of 'traditional' incentive regulation with regard to innovation is that it regularly reviews a company's cost to pass on to consumers any cost reductions that have been achieved during the previous regulatory period. As a result, a company can hardly benefit from successful innovations. Under yardstick regulation, there is no revenue or tariff reduction as a consequence of reduced costs. On the contrary, if a company does not achieve cost reductions high enough to remain the average company it is assumed to be, it will earn below average profits. Yardstick regulation still gives an incentive for short-term cost reductions (potentially at the expense of innovation), but at the same time the company can also benefit from long-term cost reductions. Importantly, the efficiency analysis which the yardstick is based on should take into account the costs of DG as outlined in section 2.2. Otherwise, yardstick regulation is likely do give strong disincentives against DG.

### **3.4 Conclusion**

Current regulatory practice based on incentive regulation discourages innovations in the network that are needed to integrate a rising share of DG. Network regulation should therefore be geared more towards promoting innovations.

A separate treatment of innovation can be justified and is likely to be more effective and efficient than simply including R&D costs in the RAB or extending regulatory periods. Especially to introduce more innovative activities by DSOs it can be useful to establish separate innovation mechanisms.

However, a separate treatment establishes a special regime outside or complementary to the standard regulatory mechanism (e.g. RPI-X) in order to stimulate innovation. Innovation is a niche activity and there is a danger that it is not sufficiently connected to a

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<sup>17</sup> Note that simply introducing yardstick regulation does not remove the DSOs incentives against additional costs of DG. Yet the potential trade-off between short-term costs and long-term benefits of DG may be seen in a different light by the DSO.

DSO's main business. Especially with regard to DG related innovations, these should become more of a normal business activity once DG is no longer a niche activity.

We cannot give a clear-cut answer as to which regulatory option is best. This will depend on the regulatory context, the status of DG and the scope for innovation in a given system. Different approaches will be appropriate in different phases.

Output-based regulation and yardstick regulation have been proposed as integrated approaches to regulation. More research is needed, however, to understand the innovation effects of these two approaches and to come up with appropriate designs that can promote innovations (e.g. appropriate performance measures to foster network innovations).

## **4 Innovating Regulation: Towards system transformation**

### **4.1 From innovation to system transformation**

In the previous sections we have analysed regulatory mechanisms to provide DSOs with incentives to integrate DG and to actively promote network innovations. These mechanisms more or less fit into the standard procedure of incentive regulation based on regulatory periods and are in line with more general developments towards output- and yardstick regulation.

In the DG-GRID report “Review of Innovative Network Concepts”<sup>18</sup> Strbac et al. have reviewed the key characteristics and limitations of the existing network operation and design philosophies and examined possible future developments of electricity transmission and distribution network technology in the context of alternative electricity generation scenarios in the medium and long term. A number of alternative visions of the future were described and discussed. It has become clear that large scale penetration of distributed generation will impose significant challenges in network operation and development in the medium to long term. A radical shift may be required from traditional central control philosophy (which is presently used to control typically hundreds of generators) to a new more distributed control paradigm (applicable for operation of large number of generators and controllable loads).

In other words, the developments ahead may go beyond incremental innovations in some parts of the network, developed and implemented by individual network operators, but may lead to an overall transformation of the network structure, involving a large number of actors and including both transmission and distribution networks.

The question arises what the consequences should be for network regulation. In this final section, we argue that the integration of DG and the network transformation this may require poses a new challenge to network regulation. This makes it necessary to rethink network regulation as a whole, rather than merely changing some parameters in the RPI-X mechanism. In order to promote a long-term transformation of the network, the regulatory process needs to be complemented by instruments that go beyond one regulatory period, enable the regulatory process to deal with future structural changes and uncertainty about the future and provide coordination mechanisms for the diverse stakeholders involved (network and plant operators, technology developers etc.).

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<sup>18</sup> Goran Strbac, Nick Jenkins, Tim Green, Danny Pudjianto 2006: Review of Innovative Network Concepts, report D4 of the DG-GRID project.

## 4.2 Modes of network regulation: From building to transforming the system

Just as the regulatory agenda, institutions and instruments have evolved in the past to live up to new challenges, the challenge of network transformation may lead to yet another mode of network regulation. We agree with Helm (2005: 1) who argued that

*“the reason why regulation has not withered into a narrow technical discipline, and become predictable, is because of a fundamental misconception about its rationale. Regulation is not a timeless technical activity, in which there are right and wrong answers. (...) On the contrary, regulation is, in an important sense, time-dependent. Different periods throw up different objectives and challenges, and what suits one period is not necessarily best for another.”*

The following table gives an overview of different modes of network regulation. While mode 1 can be associated with the monopolistic era, most systems are currently in mode 2 “Sweating the assets”, where efficiency improvements are the main focus. Some systems are moving to mode 3 “Renewing the system”, i.e. securing investment is gaining importance. DG integration may take us to mode 4 “Transforming the system”. In both mode 3 and 4, network regulation is concerned with replacing existing assets, yet while mode 3 is mainly concerned with like-with-like replacement, mode 4 aims at transforming the existing system.

Table 4: Four modes of network regulation

	<b>Building the system</b>	<b>Sweating the assets</b>	<b>Renewing the system</b>	<b>Transforming the system</b>
<b>Main objective</b>	Building the electricity system, security of supply	Cost-reduction (OPEX), short-term efficiency	Supply security, efficient investment within the existing system (like-with-like replacement)	Supporting certain system transformations, e.g. towards sustainability, higher shares of RES/DG etc. Investment need as a window-of-opportunity for structural change
<b>Dominant regulatory approach</b>	Rate-of-Return Regulation	Incentive regulation, relatively simple formula without adjustment mechanisms e.g. for DG	Incentive regulation, separate treatment of investment?	Incentive regulation, complemented by more long-term coordination mechanisms
<b>Main shortcomings</b>	Lack of efficiency, not much innovation, over-investment	Static efficiency improvements at the expense of investment and innovation	Focus on investment adequacy may hide opportunities for system change	Unknown
<b>Coordination (between network and generation)</b>	Coordination through vertically integrated monopolies	Coordination necessary between existing network and new DG plants	Coordination problem aggravated: Coordination necessary between network and generation development	Transformation aggravates the coordination problem further: Changes in different components need to be aligned Shared Vision of the future energy system necessary to coordinate system transformation
<b>Relationship between regulation and politics</b>	Often not clearly separated	Increasing efficiency as technical problem, hold-up problem ->independent regulator	Investment need exacerbate hold-up problem ->independent regulator	Uncertainty of system transformation may exacerbate hold-up problem Transformation in which direction? Political nature of regulation becomes more prominent
<b>Role of innovation</b>	Innovations play only a minor role in the regulatory debate	Innovations to increase efficiency	Replacement is seen as an opportunity to introduce innovations in individual parts of the system, but innovations are not seen as elements of system transformation	Innovation is not just about making cost savings, but about system transformation. Various complementary innovations make up system transformation

In modes 2 and 3 network regulation is seen primarily as the application of a defined formula to ensure that network tariffs provide for system efficiency, security and universality of services. However, the idea of an intentional transition towards more inno-

vation oriented and DG-friendly systems that gains importance in mode 4 requires network regulation of a higher level of reflexivity.

Up until now, regulatory mechanisms have mainly been designed to generate productive and allocative efficiency in the coming regulatory period. While long-term effects gain importance in mode 3 “Renewing the system”, the focus is still on investments more or less within the existing system structure.

In order to enable a higher share of DG in future electricity networks, not only the rules of network regulation – applied in one regulation period after another – should be reflected upon with regard to the way they incentivise actors to integrate DG into the network. In addition, the regulatory process as a whole should be reviewed to enable a targeted transition towards future electricity systems that reap the maximum benefit of DG integration.

“Transforming the system” requires orienting the regulatory procedures towards their long-term structural effects. The longer the time-period under consideration, the more external factors gain relevance: new technical options and longer term trends in supply and demand need to be considered – although burdened with a lot of uncertainty – if the best possible outcome of regulation shall be achieved.

As Helm has pointed out (see quote above), network regulation is often seen as a merely technical discipline, delegated to independent regulatory authorities. The independence of regulators is seen as an important prerequisite to overcome time inconsistency problems and achieve efficiency. Yet as soon as network regulation deals with structural changes in the electricity system, the political character of network regulation becomes more prominent.

### **4.3 Coordination beyond market mechanisms**

Incentive regulation seeks to emulate the price mechanism of the market in that it gives network operators financial incentives to become more efficient or achieve other targets defined by the regulator. The question is if this governance mechanism is sufficient when a transformation of the electricity network is needed, necessitating close coordination of different actors changing different system components.

This refers to a wider debate as to whether competitive markets can take care of long-term system planning. Even in mode 3, merely relying on market mechanisms may not be sufficient to guarantee enough investment. Price signals may fail to give sufficient incentives to potential investors which make investment decisions on the basis of the profitability of individual projects rather than system requirements. On the generation side, it is being debated whether and under which conditions competitive markets are able to provide sufficient capacity when old plants need to be replaced (Brunekreeft 2005; Neuhoff, de Vries 2004; Roques et al. 2005) and what kind of complementary mechanisms are needed. For example, Keller and Wild (2004) argue that market-mechanisms will not be sufficient to bring about the necessary investment and propose coordinated investment decisions, e.g. through a “club” of the parties involved.

When it comes to transforming, coordination requirements become even more important. While the regulatory mechanisms to promote innovation presented above may give the individual DSO an incentive to invest in (cost-saving) innovations so that he can benefit from the achieved cost savings, it is difficult for the individual company to know in which direction the system may be going and how his innovation project links up with other innovation projects and the overall system transformation dynamics.

When it comes to transforming the system rather than renewing it, there is also more scope for conflicting interests between actors. Summerton and Bradshaw (1991: 33) have summarised the regulatory challenges stemming from system transformation as follows:

*“When new power producers partly or wholly outside utility operations enter traditional grid systems (...), far-ranging issues of interorganizational coordination and control are actualized, potentially giving rise to extensive conflict. Utility and non-utility power producers often have strong conflicting organizational interests in relation to long-term goals and views of their respective roles in the grid system. (...) The process of dispersing a traditional grid system is therefore predictably a process of negotiation and renegotiation among involved groups. For regulators, this underscores the importance of adopting active, problem-solving roles in mediating between varying organizations.”*

It is important to note that coordination is not only about coordinating different commercial actors within the sector, but coordination is also required between companies and the regulator. Companies need to know that there is long-term regulatory commitment to support innovation and transformation.

There are already a number of examples where different stakeholders are brought together to coordinate diverse network-related activities through facilitating exchange and providing platforms of debate, such as the EU Technology Platform “SmartGrids” and the UK Electricity Networks Strategy Group (ENSG). For example, the aim of the ENSG is to identify, and co-ordinate work to address the technical, commercial, regulatory and other issues that affect the transition of electricity transmission and distribution networks to a low-carbon future<sup>19</sup>.

While regulators are just about to come to grips with the third mode “Renewing the system”, more work will be needed to spell out network regulation in mode 4 “Transforming the system”. In the following we present two instruments that could help deal with the uncertainty of future system transformation:

- Developing long-term visions through scenarios and
- experimentation with new regulatory instruments in “Regulatory Innovation Zones”.

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<sup>19</sup> <http://www.ensg.gov.uk/>

### 4.3.1 Regulatory scenarios

As Coutard (2003: 164) has pointed out quite rightly,

*“grids inextricably mix technical, economic, organizational and political issues, so economic regulation regarding the ownership, planning, development, operation, access to, and use of grids must take into account wide-ranging effects.”*

The wide-ranging effects are all the more relevant when the network is undergoing structural change. In order to decide on the best possible procedures and formula for the coming regulatory periods and to make sure that short-term regulatory developments are compatible with long-term visions, decision makers throughout the sector need to have a common understanding of possible long term developments. Such considerations about future developments – in order to make them negotiable – need to take on the form of more or less explicit hypotheses about future developments based on the (limited) knowledge available. Clusters of such hypotheses could be called scenarios.

Scenarios need to address developments both on the supply side (like new generation technologies entering the markets) and on the demand side (like demographic and industrial trends and DSM) and need to take network issues into account. The scenarios – if they earn some kind of legitimacy – could possibly co-ordinate the decisions of a multitude of actors and hence allow for a governance towards future electricity systems, which complies with the overall political objectives such as increasing independence from fossil resources, increasing security and sustainability of supply etc..

Medium and long-term trends in generation technology, demand and network options etc. need to be integrated into descriptive scenarios, in order to provide a background for concrete regulatory decisions. Besides technological trends and emerging opportunities, they need to pay attention to changing political framework conditions such as long-standing trends of liberalisation and foreseeable market developments. They would embark on a perspective of ‘system innovation’ and look at possible ‘transitions of socio-technical regimes’, taking into account that the performance of technical innovations will largely depend on their future embedding into social practices. From the perspective of the regulator following the suggested paradigm of long-term, object related network regulation, such scenarios would allow to scrutinise alternative options such as different regulation algorithms or shorter or longer regulation periods with regard to their possible effects and the robustness of measures to probable developments on the markets, in the technologies and in other policy fields. Especially the main cross-cutting impacts of decisions in the neighbouring fields of technology policy (e.g. subsidy schemes), economic policy, and environmental legislation need to be considered and contrasted in such scenarios, if the regulatory measures chosen are supposed to achieve more than just unintended effects.

The actual processes in which long-term and dynamic scenarios could be developed needs to be designed in accordance to the national circumstances such as current mandates for network planning, actor constellations and national policy styles. Yet the basic requirement to implement such a process and orient network regulation on negotiated

long-term scenarios could be established as a mandatory policy instrument in the context of EU energy policy.

There are a number of examples for scenario-processes that could be used in the context of network regulation, for example

- the regulatory road maps developed in the EU project Sustelnet<sup>20</sup>,
- the scenarios in the German project “Integrated Microsystems of Supply”<sup>21</sup>.

In the following we present an example of what scenarios of decentralisation could look like, showing various potential forms of decentralisation and illustrating how technical and institutional elements combine in different ways. These could also be used as an input for the more encompassing regulatory scenarios described above.

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<sup>20</sup> See <http://www.electricitymarkets.info/sustelnet/>

<sup>21</sup> See <http://www.mikrosysteme.org/>

Table 5: Possible scenarios of decentralisation

	1) DG Niches (Status Quo)	2) Market integration	3) System decentralisation	4) System fragmentation	5) The electricity web
<b>A) General description</b>	DG operated in niches, not integrated in markets and networks	DG increasingly integrated in centralised markets, some coordination between DG and DSO	Decentralisation of system control, DG fully integrated	Fragmentation in stand-alone grids	Control distributed to intelligent nodes
<b>B) What does decentralisation mean?</b>	Increasing share of small-scale plants connected to medium- and lower-voltage grid	Increasing share of small-scale plants connected to medium- and lower-voltage grid	Decentralisation of control Decentralised matching of supply and demand	Decentralisation of system balancing	
<b>C) Status</b>	Present system	Being implemented in some EU countries	Pilot projects	Feasible in principle. How realistic as a large-scale application for Europe by when?	Speculative model
<b>D) Examples</b>	Most EU countries	Vaillant Virtual Fuel Cell Power Plant, SaarEnergie Virtuel Balancing Plant, market integration in UK and Denmark	Project 21 Denmark, Virtual Power Plant Unna/Germany	Islands, new systems e.g. in developing countries	
<b>E) feasible share of DG</b>	approx. 25% of gen.?	approx. 50%, but at high costs and security risks	More than 50%	Up to 100% of gen.?	up to 100% of gen.?
<b>Technical developments</b>					
<b>F) Network model</b>	Traditional top-down network	Traditional top-down network, increasing bi-directional flows, some areal networks	Decentralisation of control hierarchy, Active management, system-based microgrids, islanding. Medium-voltage cells, virtual power plant, bi-directional power flows Network provides connectivity between supply and demand customers	Microgrids, fragmented control	'neural networks'
<b>G) Which decentralised resources (DER) in use?</b>	Mainly DG	Mainly DG, demand-side (large customers)	DG and demand side	DG, demand-side fully integrated, storage	Demand side fully integrated, storage
<b>H) What kind of investment is needed?</b>	Transformers, cables	Transformers, cables, information and communication technologies (but not from DSO)	ICT on all levels	local ICT	
<b>I)</b>		Decentralised	Decentralised		

<b>Necessary innovation (DG, demand-side, network)</b>		energy management systems to integrate DG, yet not run by DSOs DG connected to virtual power plants to mimic centralised plants	energy management systems, DG able to provide ancillary services		
<b>Actors</b>					
<b>J) Who controls the system (balancing)?</b>	TSO	TSO	TSO and DSO	Local grid operators and DSOs	Self-organisation, control completely decentralised
<b>K) What is the role/business model of distribution system operators?</b>	Passive DSO, no influence on DG operation, kWh maximisation	Passive DSO, limited influence on DG operation kWh maximisation	DG connection no longer an additional activity for DSOs, but a core function DSO provides connectivity between generation and load Influence on DG operation DSOs take over responsibilities from TSO	DSO as coordinator of separate systems	Only network operator, no system responsibility
<b>L) Are there new actors? What do they do?</b>	Companies specialised in DG connection, e.g. Econnect	Consolidators combine DG and integrate them into markets, e.g. Smartest Energy, SaarEnergie Areal network operators	Demand-side, local grid-operators Virtual Utilities	Microgrid-operators	
<b>Institutional developments</b>					
<b>M) How do markets need to be adapted?</b>	DG not integrated into markets	Markets allow for DG to perform system benefits.	Markets organised on lower network levels	Separate microgrid-markets, exchange between them as back-up	Integrated, but completely decentralised market
<b>N) Support mechanisms for DG</b>	Based on priority dispatch	Some market integration	DG remunerated for network-related benefits		
<b>O) Regulatory approach</b>	Traditional cost-based incentive regulation, focus on economic efficiency, DG not taken into account	Some DG costs treated as separated costs, some incentives for DSO to connect DG, some innovation niches	Active network regulation pro DG, DG costs not treated separately, innovation integrated in regulatory model, rules for re-integration (after islanding) required	Rules for operation of independent grids required.	

### 4.3.2 Regulatory innovation zones

Another approach which we would like to sketch briefly because it can be useful to deal with regulatory uncertainty, is to develop and test new regulatory instruments in what we call “regulatory innovation zones”. While the RPZ and IFI mechanisms in the UK (see 3.1.3) have been designed to set up niches for technical innovations, regulatory innovation zones would provide niches where the regulator can work with individual DSOs to develop and test new regulatory instruments to promote DG integration in the context of changing network architectures and control philosophies. As was pointed out by EU Technology Platform SmartGrids (European Commission 2006: 23)

*“there is a strong need for pilot projects, not only in the technical sense but also at the markets and organisational level. For example, regulatory regimes should be revised, based on new knowledge about how regulation should work to provide incentives for innovation”.*

In Germany, the German partners of the DG-GRID project have just started a new project called OPTAN where a regulatory innovation zone is to be set up together with a municipal utility. In Austria, research organisations and grid operators are currently planning such an innovation zone within the project ‘DG Demonetz’ ([www.edz.at](http://www.edz.at)).

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