Transforming the Grid

Electricity system governance and network integration of distributed generation

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Declaration

I hereby declare that this thesis has not been, and will not be, submitted, either in the same or different form, to this or any other University for a degree.

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Summary

The thesis analyses how the standard model of liberalised electricity markets that was developed to increase the efficiency of electricity supply can deal with new objectives. While the liberalisation literature argues that additional objectives can be incorporated in the market framework through price signals, a large body of literature based on evolutionary economics argues that innovation and systemic transformation require governance mechanisms that complement the price mechanism of the market to overcome the lock-in of the existing system and coordinate innovation processes.

The thesis focuses on the integration of distributed generation (DG) into electricity networks. In the standard model the governance of networks is mainly based on incentive regulation by independent regulators. Thus, the main question is how DG can be integrated into this regime and whether and how it needs to evolve. The research question is broken down according to both different governance issues (connection, integration, innovation, transformation) and different governance levels on which they can be addressed.

This is analysed from two angles: Firstly, there is a mainly theoretical discussion of network regulation. Various approaches to amending the standard model are discussed. Secondly, this is complemented by country case studies of the UK and Denmark.

The conceptual analysis shows how incentive regulation can accommodate the efficient integration of DG as an additional objective. There is also scope for this model to incorporate governance mechanisms that are geared towards infrastructure transformation. The UK case study shows the practical implementation of this approach and corresponding difficulties.

As for Denmark – a DG and network transformation pioneer – the standard model plays a marginal role and economic issues are mainly dealt with outside regulation. The same is true for mechanisms beyond economic incentives.

The thesis shows the potential of the standard model to pursue new objectives as well as the need to broaden the scope beyond governance based on economic incentives.

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Dierk Bauknecht

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

CAPEX	Capital expenditures
CEGB	Central Electricity Generating Board
CHP	Combined-heat-and power plant
DEA	Danish Energy Agency
DERA	Danish Regulation Agency
DG	Distributed generation
DGCG	Distributed Generation Co-ordinating Group
DPCR	Distribution Price Control Review
DSO	Distribution System Operator
DTI	Department of Trade and Industry
EdF	Électricité de France
EGWG	Embedded Generation Working Group
ENSG	Electricity Network Strategy Group
ERGEG	European Energy Regulators
IEA	International Energy Agency
IFI	Innovation Funding Incentive
kV	Kilovolt
kWh	Kilowatthours
MW	Megawatt
NETA	New Electricity Trading Arrangements
OECD	Organisation for Economic Co-operation and Development
OFGEM	Office of Gas and Electricity Markets
OPEX	Operating expenditure

PV	Photovoltaic
RD&D	Research, Development and Demonstration
R&D	Research and Development
RAB	Regulatory Asset Base
RoR	Rate of return
RPZ	Registered Power Zone
SET-Plan	Strategic Energy Technology Plan
TSO	Transmission System Operator

Part I:
Introduction, Background and Research Question

1 Introduction

1.1 Background

This thesis deals with two major political forces that have shaped policy-making in general and the electricity sector in particular throughout recent decades: Market liberalisation on the one hand and sustainability as well as climate change in particular on the other hand.

For many decades, the electricity supply industry was run by vertically integrated and often state-owned monopolies. Starting in the 1990s, the sector was turned upside-down in the European Union and many countries throughout the world through privatisation, vertical unbundling and the introduction of competition in generation and supply. The main objective of liberalisation was to increase the economic efficiency of the sector and reduce electricity prices (Sioshansi, Pfaffenberger 2006; Sioshansi 2008a). During the introduction of competition, there was in most cases no particular concern about sustainability issues (Helm 2007: 1-8). For example, a search in the above mentioned references (Sioshansi, Pfaffenberger 2006; Sioshansi 2008a) that contain an overview on the worldwide liberalisation process provides a total of 9 hits for ‘sustainability’ and a total 193 hits for ‘efficiency’. On a very general level the question of this thesis addresses whether and how liberalisation and sustainability can be reconciled.

Within the broad debate on electricity market liberalisation and sustainability, this thesis focuses on one specific development that can contribute to making the electricity sector more sustainable: electricity generation in small-scale plants, often called distributed generation (DG), powered by renewable energy sources or producing both power and heat.

For many decades, the electricity supply industry has been dominated not only by large vertically integrated monopolies, but also by centralised power generation in large-scale plants. With generation and networks being closely intertwined, the network infrastructure has developed accordingly: Most power plants are connected to the high-voltage transmission grid, while the distribution network mainly serves as a distributor of power. In recent years this paradigm has been increasingly challenged by distributed generation (Jenkins et al. 2000: 1-3).

Distributed generation impacts significantly on the electricity network (Jenkins et al. 2000) and is one of the reasons why the electricity network has come to be seen as a cornerstone of transformation of the electricity system towards more sustainability. Innovations in the grid are often discussed under the label ‘Smart Grids’ (IEA 2011).

As opposed to generation and supply, electricity networks are still regulated as natural monopolies. With the introduction of incentive regulation, the efficiency objective of liberalisation has also been applied to the networks. Network regulation is the dominant governance mechanism for electricity networks and it therefore heavily affects the network integration of DG (Cossent et al. 2008).

1.2 Research question

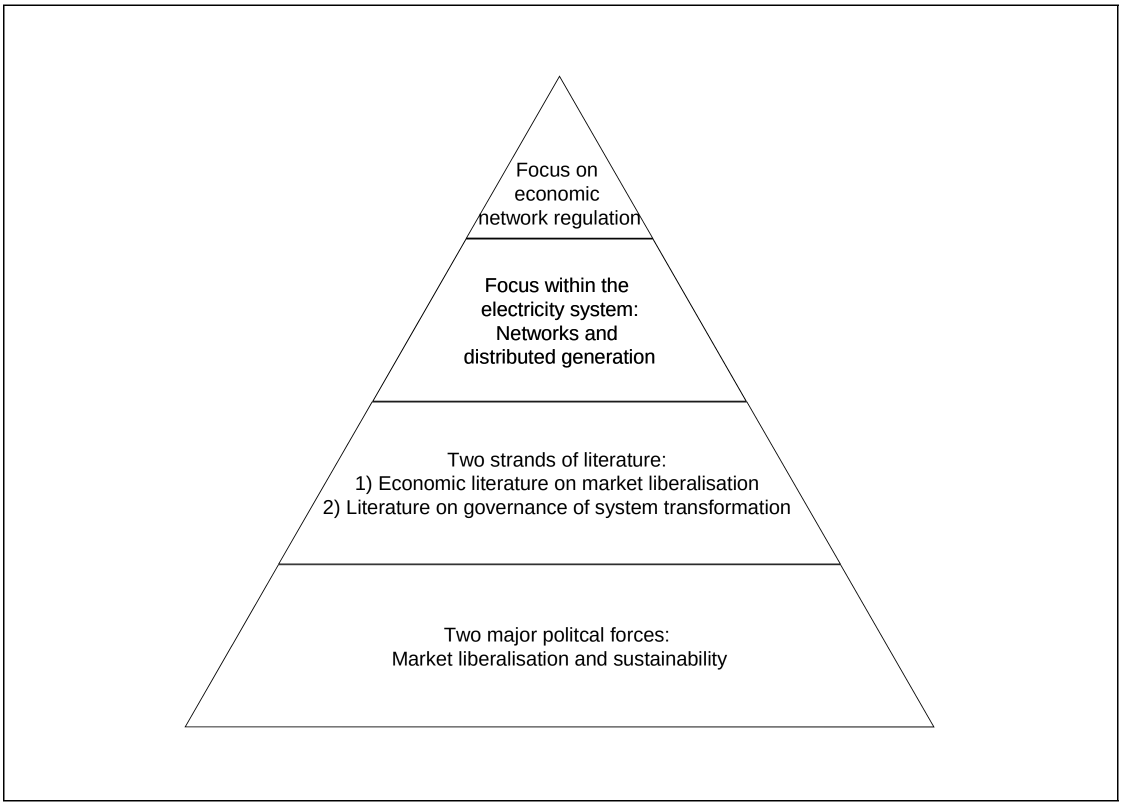
The starting point of this thesis is the question of whether and how market liberalisation that was designed to increase efficiency, and where market prices are the main governance mechanism, can accommodate new objectives resulting from sustainability and climate change.

While the liberalisation literature argues that additional objectives can be incorporated in the market framework through price signals, a large body of literature based on evolutionary economics argues that sustainability requires systemic transformations rather than individual innovations. In turn, this requires governance mechanisms that complement the price mechanism of the market to overcome the lock-in of the existing system and coordinate innovation processes.

This general question is broken down for the case of distributed generation and electricity networks. More specifically, it is analysed whether and how the standard model of network regulation that is part of the standard model of electricity market liberalisation can be developed and adapted to accommodate DG and network developments necessary to integrate a higher share of DG. An important part of the research is thus based on regulatory economics and explores ways of incorporating additional incentives alongside economic efficiency for network operators. At the same time, the thesis explores the limits of the standard model of economic network regulation.

The following figure shows how the general question on liberalisation and sustainability is narrowed down in the following chapters 2 and 3 to address the specific research question of this thesis.

Figure 1: Narrowing down the focus of research



1.3 Overview of thesis structure

The thesis consists of three parts: a literature review, a conceptual part that analyses ways to integrate DG and network innovation into the standard model of network regulation from a conceptual perspective, and an empirical part with two country case studies.

Following this introduction, the first part presents in two steps the relevant literature upon which the research question is based. Chapter 2 introduces and contrasts two perspectives on electricity systems. Firstly, the economic literature on electricity market liberalisation and secondly the system transformation literature. The "tension" between these two accounts, especially when it comes to making the electricity system more sustainable, represents a central starting point for the further research. Within this general debate, chapter 3 then concentrates on the focus of this study: distributed generation that can make the electricity system more sustainable, its interaction with the electricity network as well as network regulation as the standard way of dealing with networks in the liberalised electricity market model. Based on chapters 2 and 3, chapter 4 presents the research question and methodology for the further research.

Based on the methodology derived in the first part, the second part examines the interaction between DG and the electricity network in three steps: Chapter 5 analyses DG connections to the networks and how network operators can be incentivised to connect and integrate DG. Chapter 6 analyses how network regulation affects RD&D and innovations in the network and discusses various approaches to promote network innovations. Chapter 7 examines mechanisms for dealing with a more comprehensive system transformation that may become necessary because of DG, and analyses how the overall standard model of network regulation may be adapted.

The third part consists of two country case studies (on the UK and Denmark), examining how the standard model of network regulation is applied and adapted in the light of distributed generation and network innovation. Chapters 8 and 9 present the case studies of the UK and Denmark respectively, and chapter 10 contains a comparative evaluation of the two cases.

Finally, chapter 11 presents conclusions and recommendations.

2 Liberalisation and transformation of electricity systems

The electricity sector has seen major restructuring since the early 1990s through the privatisation and liberalisation of electricity markets, which has been introduced in the European Union and many other countries worldwide (for an overview see Sioshansi, Pfaffenberger 2006). The main objective of liberalisation has been to introduce competition in the electricity sector in order to increase the efficiency of electricity supply. While liberalisation has been unfolding, climate change has been moving up the political agenda. The electricity sector has always been an important object of environmental policy (Joskow 2006b: 3), yet climate change together with a more general sustainability discourse has intensified this debate (Scrase et al. 2009; Smith 2009) and many argue that a structural transformation of the entire electricity system is required to provide low-carbon electricity (Praetorius et al. 2009) . Another reason why the efficiency objective has lost its dominance is concerns about security of supply (Jamasb, Pollitt 2008c).

On a very general level, the question of this thesis is how liberalisation and climate policy objectives can be reconciled; or in other words whether and how market liberalisation that was designed to increase efficiency can accommodate new objectives resulting from climate change. The following section presents some basics of electricity market liberalisation. Proponents of liberalisation argue that additional objectives like carbon reduction can be accommodated within this framework if markets are designed correctly and prices are allowed to signal all relevant costs. Energy policy thus mainly becomes a matter of market design.

As distinct from this line of thought, the second section presents the literature on system transformation that has emerged from evolutionary economics and science and technology studies. It emphasises that systems like the electricity sector can be locked into ‘suboptimal’ structures. As a consequence, price-signals will not be sufficient to achieve the required carbon reduction. Additional governance mechanisms are therefore needed.

The final section of this chapter summarises and compares the two approaches, deriving in the process a number of general research questions.

2.1 Electricity market liberalisation

The following section sketches out the standard model of electricity market liberalisation, its main objectives and how it proposes to deal with new objectives such as the ones resulting from climate change.

2.1.1 The standard model of electricity market liberalisation

Liberalisation introduces a new governance arrangement for the electricity sector, replacing hierarchical governance through state-ownership, monopolies and top-down planning with competitive markets where decisions by private actors are first and foremost guided by market prices.

The previous monopolies have often led to inefficient electricity supply, with high costs and prices that did not reflect costs. Liberalisation and competition are to increase the efficiency of power supply and *"to provide better incentives for controlling construction and operating costs of new and existing generating capacity, to encourage innovation in power supply technologies, and to shift the risks of technology choice, construction cost and operating 'mistakes' to suppliers and away from consumers"* (Joskow 2006b: 3). Additionally, competition and the threat of new entry are to reduce companies' profit margin.

Electricity market liberalisation is rooted in neo-classical economics. It rejects the previous notion that electricity markets are different and is based on the assumption that electricity can be treated just like any other commodity and the electricity market can largely be run like any other market, except that market design needs to provide for real-time balancing of demand and supply. The outcome of the competitive market process is considered to lead to an optimal allocation of resources (IEA 2005: 71-97).

As a consequence, policy interventions should be limited to the correction of market failures and should make use of market-based instruments and price signals. One example of a market failure is the natural monopoly in the electricity network. The standard model therefore proposes to regulate the network, using profit incentives to increase the efficiency of the networks (see section 3.2). A second source of market failure is externalities in which the market price does not include all the costs incurred by society. The liberalisation paradigm relies on correcting these market failures through internalising all costs into prices (Joskow 2006b: 22).

It is now more widely agreed than at the beginning of the liberalisation process that liberalisation and regulation are not substitutes, and that liberalisation generally involves re-regulation rather than deregulation. It is acknowledged that 'regulation-for-competition' is an important prerequisite for markets to function properly (Jordana, Levi-Faur 2004: 5-8; Pollitt 2008). However, proponents of the standard model are still wary that regulation goes beyond the promotion of competition and recommend to *"to avoid excessive government and regulatory involvement"* (Littlechild 2006b: xviii). According to the IEA (2005: 14-15), while competition requires strong government involvement and commitment, this is often best expressed by not intervening. The role of the government thus becomes reduced to making the market work.

In terms of market design, electricity liberalisation around the world has been guided by what has been called the "standard model" (Littlechild 2001) and different variants of this model have been implemented. According to Joskow (2006b) and Littlechild (2006b), the standard model consists of the following elements:

1) *Privatisation* of energy companies that were state-owned

2) *Unbundling or vertical separation:* Liberalisation of the industry is based on the innovative notion that the sector can be unbundled and the different parts of the electricity supply chain can be organised separately. For electricity generation and supply, it is currently widely agreed that competitive markets can best achieve efficient outcomes. For electricity networks, however, a consensus has emerged that they cannot be run as a competitive market, at least not for the time being (as opposed to many telecommunication networks).

3) *Horizontal restructuring* to create an adequate number of competing generators.

4) Designation of an *independent system operator* to maintain network stability and facilitate competition.

5) Voluntary energy and ancillary services *markets and trading arrangements*, including contract markets and real-time balancing of the system.

6) Regulation of *access to the transmission network* and incentives for an efficient location and interconnection of new generation facilities.

7) *Retail competition* and the unbundling of retail tariffs from network charges and rules to enable access to the distribution networks in order to promote competition at the retail level.

8) Specification of *arrangements for supplying customers* until retail competition is in place.

9) Creation of *independent regulatory agencies:* In the standard model of liberalised electricity markets economic regulation through sector-specific regulatory authorities has become the main governance approach for electricity networks. Other parts of the market may be regulated by this agency.

10) Provision of *transition mechanisms* that anticipate and respond to problems and support the transition rather than hinder it.

Examples of countries and regions that come closest to the standard model and have significantly influenced its development typically include the UK, Scandinavia, Australia as well as the Pennsylvania-New Jersey-Maryland interconnection (PJM) in the north east of the US (IEA 2005).

Although there is a standard model of electricity market liberalisation, it is important to keep in mind that this model is not fixed but undergoing change. As the IEA (2005: 11) has pointed out, "*electricity market liberalisation is not an event. It is a long process (…) that has not yet been completed anywhere in the world – nor will it be in the foreseeable future.*" There is an ongoing process of developing and improving the governance structure of liberalised markets (Sioshansi, Pfaffenberger 2006; Sioshansi 2008a). There is a standard model, but there are also a number of open questions, new questions, setbacks and "*reform of the reforms*" (Sioshansi 2008b: 1). The practical experiences from implementing liberalisation in different countries have fed back into the further development of the standard model.

The assumption was that the electricity sector can be run like other markets (Helm 2007: 1), but to make it work in practice requires a lot of detailed development work specific to the electricity sector (Sioshansi, Pfaffenberger 2006; Sioshansi 2008a). There are also many variations emerging in the actual implementation of the standard model (Correljé, de Vries 2008). Pollitt fittingly calls electricity market liberalisation "*the longest running and most interesting set of multi-country micro-economic experiments*" (Pollitt 2008: vii).

2.1.2 Objectives beyond short-term efficiency in the standard model

Given that electricity market liberalisation was driven by the desire to make the sector more efficient, the question arises as to whether and how new objectives resulting from the need to make the sector more sustainable can be accommodated within this model.

When discussing the liberalisation model in the electricity sector we need to bear in mind the coordination needs of this sector (Stoft 2002: 17-29; de Vries 2004). Electricity supply requires a close coordination between different components. In every single moment electricity generation must exactly match electricity demand (which requires appropriate operational mechanisms) and there needs to be enough capacity available to meet peak demand (which requires timely and sufficient investment). This is one of the main reasons why electricity markets around the world were for many decades operated by vertically integrated and often publicly owned monopolies. There is also a tight technical coupling between generation and networks. Unbundling vertically integrated companies that used to run these system elements within one company requires alternative governance mechanisms.

Based on the economic thinking that is behind the liberalisation model, proponents of market liberalisation argue that competitive markets can achieve sustainable and low-carbon electricity supply (Joskow 2006b: 22). In order to achieve this, they need to be designed to allow any costs of high-carbon electricity production that have hitherto been external to the market process to feed through into the price signals market participants receive. Other governance mechanisms are generally not required.

According to the liberalisation literature, policy interventions should be designed to be compatible with competitive markets (Joskow 2006b: 22-23). The European Emission Trading Scheme that creates a market for CO_2 emissions is a case in point. Further political intervention, like direct support for renewable technologies, is not required according to this view and would indeed be counterproductive, as it tends to distort the price signal (Pollitt 2008: xxxii; e.g. the German discussion on emissions trading and support for renewables: Wissenschaftlicher Beirat BMWA 2004). From a liberalisation perspective, the rising climate change agenda is regarded as *"a potential vehicle for the return of old-style intervention in electricity generation and in retail competition"* and thus a potential threat to competition. (Pollitt 2008: xxxii).

The liberalisation literature generally argues that new objectives like environmental ones can be integrated into the market framework (Joskow 2006b: 4). However, there is no clear evidence yet for the proper functioning of competitive electricity markets even with regard to the initial objectives that go beyond short-term efficiency, namely efficient investment and innovation, as will be argued in the following sections.

At the beginning of liberalisation, the main issue was how liberalised markets can best be designed and regulated in order to promote competition and increase the efficiency of existing assets. Sweating the 'inherited' assets has worked well, and most competitive markets have led to cost as well as price reductions (Newbery, Pollitt 1997; Jamasb, Pollitt 2008a: xxviii; Markiewicz et al. 2004).

However, beyond the reduction of operational costs, there is an increasing debate on the ability of competitive electricity markets to reproduce themselves and develop in the medium- to long-term. In other words, liberalised markets may have been in some kind of *"grace period"* (Finon et al. 2004), building on the legacy of the former monopolistic markets and the overcapacities that characterised many of them – overcapacities that have indeed been one of the reasons why competition was introduced in the first place. The debate on long-term issues includes the effects of liberalisation on investment and innovation.

2.1.2.1 Investment

It was one of the objectives of electricity market liberalisation to provide more efficient investment by shifting the investment risk from consumers to investors. This has two dimensions: firstly, the efficiency of individual investments was to increase, for example by putting the squeeze on the construction costs of a new power plant; and secondly, the overall level of investment was to be reduced to an efficient level to avoid overcapacities.

The first objective will in most cases be promoted by competition. As for the second one, however, it may well be that the pendulum swings back and over-investment turns into under-investment. Under the headings of generation and network adequacy, investment in competitive generation markets and regulated networks has increasingly become a focus of analysis and political debate. The question is whether and under which conditions the liberalised market model is able to provide sufficient capacity when ageing assets need to be replaced (Roques et al. 2005; Brunekreeft 2005; Neuhoff, de Vries 2004). Providing sufficient investment is sometimes equated with ensuring the sector's sustainability (Lévêque 2006). Joskow (2006b: 20) has adequately summarised the state of the discussion as follow: "*The jury is still out on whether and how competitive power markets can stimulate appropriate levels of investment*".

Investment decisions that used to be based on central planning in monopolistic markets are now based on market prices. Investors make investment decisions on the basis of the profitability of individual projects rather than system requirements. This is how other markets function, too, and orthodox economic theory holds that competitive markets do provide sufficient investment as any scarcity will be reflected in prices and thereby trigger investment to make up for the capacity shortfall.

However, the electricity sector exhibits a number of peculiarities that can undermine this model. These include the high capital intensity of electricity supply, low price-elasticity of demand and the fact that in every single moment electricity generation must exactly match electricity demand and the resulting need for peaking capacity (de Vries 2004: 66-100). Because of the latter point, price spikes would be needed to recover the costs of peaking units with low load factors, but in practice it will be difficult for regulators to distinguish between the exercise of market power and legitimate scarcity rents (Roques et al. 2005: 97). Moreover, because of the central role of electricity supply for the society and economy, price spikes may be politically unacceptable, adding to the risk for investors. In his study of generation adequacy, de Vries (2004: 262) concludes that "*the myth of the invisible hand suggests that supply and demand will always be balanced through the price mechanism, which [this study] showed not necessarily to be true in electricity markets*".

A further issue is the coordination of investments in the unbundled functions of the electricity system in a competitive environment, including coordination of network and generation investments (Baldick, Kahn 1993; de Vries 2004: 195-229).

2.1.2.2 Innovation

The concern about the ability of liberalised markets to provide adequate investment in generation and networks shows that long-term issues of electricity market governance increasingly come to the fore. The ability of these systems to invest in RD&D and to develop innovations is of even greater importance for their long-term development, especially in the light of the sustainability challenge.

Privatisation and the introduction of competition were expected to stimulate innovation (Joskow 2006b: 3; IEA 1999: 11, 45), both in terms of process innovations to reduce costs and product innovations to increase choice for customers. Market prices are to signal to companies where innovation efforts can become profitable.

There are empirical studies showing that liberalisation has stimulated companies to innovate, which is in line with the initial standard model assumption that competition promotes innovation. Competition may have stimulated creativity in companies; according to Markard (2004: 201), who has analysed two case studies (green power and fuel cells), liberalisation has led to "*a greater variety of innovation projects, product innovations and organizational innovations have gained importance (...) and the professionalism of innovation management is improving*".

However, at the same time, there are clear signs that companies have reduced their activities in the development of new technological solutions overall. Explanations include the increased risk and the reduction of collaborative RD&D in a competitive environment as well the trade-off between short-term efficiency and RD&D spending (Dooley 1998; Holt 2005a; Jamasb, Pollitt 2008a). A recent paper by Sanyal and Cohen (2009: 64) analyses the sharp decline in RD&D spending in the US electricity industry and concludes that *"the prognosis for research spending by the electric utilities in the restructured era is not optimistic"*.

2.1.2.3 Complementary mechanisms

What do these potential problems with investment and innovation mean for the governance of liberalised electricity markets? Künneke and Groenewegen have observed that, following increasing concerns over potential destructive effects of liberalisation over the longer term, "*a new balance is sought between various institutional arrangements, including markets, public sector involvement, and private initiatives" (Künnecke, Groenewegen 2005: 1-2).* As a result of the potential short-comings of liberalised electricity markets, even within the liberalisation discourse there are proposals for additional governance mechanisms to complement the price mechanism. This section presents a few examples.

As for power plant investments, there are various mechanisms to complement energy-only markets with capacity mechanisms, so that even peaking plants that do not generate much electricity can earn revenues from selling capacity (de Vries 2004: 107-171). Some of these approaches involve central planning and hierarchical interventions into the market, even though the capacity market itself may then be operated on a competitive basis. One example is the 'capacity requirements' mechanism, implemented by the PJM market in the US, whereby a central planning agency determines the desired generation capacity margin and calculates capacity payments for each retail company. On this basis a capacity credit market is created. This model clearly deviates from a pure-market model where all decisions are made on basis of prices.

With regard to necessary investments in the network infrastructure and the coordination between transmission and generation investments Keller and Wild (2004) state a trade-off between co-ordination and competition, arguing that some coordination beyond markets may be needed, e.g. through a co-ordination group of all parties involved.

Similarly, Hirschhausen et al. (2004) argue that *"design decisions also require vertical coordination. These decisions concern for example systemic innovations, but also trade-offs and complementarities between network and downstream investments. Whether these decisions should be made unilaterally, cooperatively, by state-approved committees or by a regulator is still largely unexplored."* With regard to innovation in competitive markets, Jamasb and Pollitt (2008a) call for a new framework that could involve public and private partnerships.

The brief overview of the discussions on investment and innovation in liberalised electricity markets indicates that competitive electricity markets may have difficulties in bringing about sufficient investment and innovation to maintain the current system and make it more efficient in the long term. Investment and innovation arguably become even more of a challenge once broader sustainability objectives need to be addressed. While the debate regarding the standard model mainly deals with the right *level* of investment and innovation, sustainability also requires the right *kind* of investment and innovation in a certain *direction* (cf. Stirling 2009), as well as at a certain *speed.* This also leads to questions of structural change – rather than investment and innovation within the existing centralised structure of electricity supply based on large-scale plants – and the question arises as to how different innovations can fit together to make up a functioning system. The coordination problems involved are arguably much more severe.

Perez-Arriaga and Linares (2008:149) argue that *"the resolution of the sustainability challenge cannot be left only to market forces, but requires complementary instruments"* and present *"indicative energy planning"* as one such instrument. In the Energy Journal by the International Association of Energy Economics – which published this contribution amidst prominent proponents of electricity market liberalisation – the idea of having some kind of long-term planning may be regarded as a maverick position. However, in the next section, I will present a strand of literature that seeks to re-invent planning to transform infrastructures and make them more sustainable.

2.2 Electricity system transformation

The liberalisation discourse described in the previous section has had a profound impact on electricity systems worldwide. Its main objective has been to increase efficiency of electricity system operation and investment. Apart from changing the governance structure of the market, it has not been particularly concerned with transforming the overall sector structure as a specific governance problem, including for example the technical structure, because in this view in a liberalised market technology choice and the further evolution of the system should be left to the market.

In contrast to the market-based perspective of the liberalisation model a broad literature on the transformation of whole sectors has emerged, often with a focus on infrastructure sectors. This literature is mainly concerned with making these sectors more sustainable rather than increasing their efficiency (Kemp 1994; Rohracher 2008). Instead of merely relying on market prices as the dominant coordination mechanisms, it proposes a number of additional governance approaches that it argues are necessary to achieve structural transformation in line with sustainability requirements.

In this section, the system transformation approach will be presented. The evolutionary and socio-technical view on innovations that is a common feature of these studies will be explained. What is meant by system transformation will be briefly addressed. Finally, a number of proposed governance approaches to influencing system transformation shall be outlined.

2.2.1 Transformation of socio-technical systems

2.2.1.1 An evolutionary and socio-technical view on innovations

Electricity market liberalisation is based on an economic model whereby innovations are seen as exogenous to the economic process, waiting ‘out there’ to be triggered by competition and changing price signals. A different perspective on technological innovation processes has been developed by evolutionary economics and science and technology studies, whereby innovation processes are seen as a social process (Dosi 1988; Bijker et al. 1987).

In this line of thought, technological change is not the result of rational behaviour by individual actors, but is influenced by a whole range of context factors, such as paradigms and routines that guide the search for new solutions. This implies that technical change is not an optimisation process whereby rational actors translate price signals into optimal solutions. Rather, innovation processes are influenced by the bounded rationality of actors, the institutions within which they operate or the dominating ‘techno-economic paradigm’ (Freeman, Perez 1988). Innovation processes therefore follow certain trajectories and may become locked into suboptimal paths.

An evolutionary view on innovations necessarily broadens the perspective from individual technical artefacts to take into account wider context structures. The success of innovations depends on a match with the socio-institutional framework, or in evolutionary terms the ‘variation’ must fit into the ‘selection environment’.

In recent years, this analysis has increasingly been broadened to look at socio-technical *systems*. This perspective was pioneered by historical studies on so-called ‘large technical systems’, with seminal work from Hughes (Hughes 1983; 1987; see Markard, Truffer 2006 for an overview and a link to market liberalisation). This strand of research has often chosen the electricity sector as a case. A similar shift away from innovation in individual technologies to the analysis of contexts, institutions and systems can be observed in the work on national innovations systems (Lundvall 1992), in the technological innovation systems approach (Bergek et al. 2008) as well as the ecological modernisation and industrial ecology literatures (Berkhout 2002). A socio-technical system perspective has also been widely adopted in the literature on environmental innovations and sustainability transitions (Weber, Hemmelskamp 2005; Elzen et al. 2004) in which the system transformation concept put forward mainly by Dutch scholars has had a profound impact (Kemp et al. 2001; Geels 2002a).

These studies extend the analysis of individual technological artefacts in two dimensions: Firstly, rather than looking at individual technologies, they see the system as encompassing different technologies that are connected to a technical system (like electricity networks and electricity generation). Secondly, the analysis comprises both technical as well as social and institutional elements (like electricity generation and network regulation) that are linked together in a 'seamless web' (Hughes 1987) or socio-technical system. Technologies as such do not fulfil any useful function, but need to be embedded in a 'configuration that works', which needs to include appropriate social and institutional elements (Rip, Kemp 1998). This implies that even if technical innovations were to fall from heaven, they may not fit into the existing socio-technical regime and could therefore not fulfil their function, even if "prices are right".

2.2.1.2 Lock-in and path-dependency

One of the implications of the socio-technical systems perspective, with diverse elements in the system being aligned to each other, is that systems cannot adapt 'instantaneously' and switch to a new system design, for example in reaction to price signals as proposed by the liberalisation model. Rather, system development is characterised by momentum or path-dependency, similar to innovation processes on a micro-level that are for example directed by routines. The notion of optimisation based on price signals – which is one of the cornerstones of the liberalisation model – is thus abandoned. Even if new solutions have an economic advantage compared to incumbent technologies and so forth, they may find it difficult to diffuse into or change the dominant regime.

Unruh (2000) has spelt out the lock-in and path-dependency of socio-technical systems for the case of carbon-based energy systems and has coined the term ‘carbon lock-in’. He analyses various institutional and technical lock-in effects and argues that at a system level, individual lock-in mechanisms, e.g. on a firm or user level or within political institutions, tend to reinforce each other to create a “techno-institutional complex”, leading to path dependencies at a system level.

2.2.1.3 System transformation

The system perspective emphasises the momentum and path dependency of socio-technical systems. At the same time, it is one of the core objectives of this approach to develop a better understanding of how momentum and paths are re-directed and how systems are transformed. System transformation, in this view, means that the different elements of a system undergo long-term structural change to make up a new system. The interlinkage of different elements within the system leads to the notion of co-evolution whereby each element is part of the selection environment in which other elements develop.

Evolutionary perspectives on innovation processes highlight the role of institutional and technical context structure or the ‘selection environment’ which innovations must fit into. A concept that has been widely adopted to capture this evolutionary understanding of change is the multilevel perspective put forward by Rip and Kemp (1998) and further developed by Geels (2002b). The dominant configuration is called the regime, which is embedded into a broader landscape of macro-developments. New socio-technical configurations emerge and grow in niches and in order to become successful innovations have to somehow link up with or undermine the dominating regime. The regime thus represents the selection environment for innovations.

2.2.2 Governance of system transformation

The previous section has presented an evolutionary understanding of innovation processes and the system perspective that has developed from it. Much of this work has been about analysing historic case studies in order to better understand transformation processes. However, there is in increasing interest in the governance of future structural system change and the transformation of socio-technical systems, not least of all because of sustainability objectives (Voß et al. 2006).

This section goes on to show what the system perspective presented above means for the governance of system transformation, especially in comparison with the discourse on liberalisation. While the liberalisation paradigm relies on markets and price signals, the governance of transformation literature proposes a number of additional approaches to coordinate different actors and developments in the electricity sector in order to achieve long-term structural change of the sector as a whole in a desired direction. The understanding of system transformation is thus broader than the "electricity sector in transition" analysed by the market liberalisation literature (see for example Joskow 2003), which focuses on the transition of the *governance* structure. While in the liberalisation model the development of the sector structure is to be left to market forces, the system transformation literature argues that due to the systemic nature of these sectors, individual innovations require the coordination of broader structural change to be successful.

Although systems have clearly been built up in the past and transformed without the explicit deployment of any specific governance mechanisms, the need for systems to become sustainable, together with the potential lock-in of systems in unsustainable paths, provides the rationale for developing appropriate governance mechanisms. Another rationale can be urgency and the inability of the standard model to lead to change quickly enough. Based on the evolutionary and systemic understanding of innovation and system change, a number of specific governance approaches are proposed. The following sections present strategic niche management and foresight as two prominent examples.

2.2.2.1 Strategic niche management

In an evolutionary perspective, innovations do not fall from heaven as a result of changing prices, but need to grow over time and need to become embedded in a socio-technical system. System change requires new ‘configurations that work’ to build up. Innovations thus depend on complementary technologies as well as supporting institutions and actor networks, which also need to grow. These usually develop in niches of the dominant regime. Moving from the analysis of the functions of niches to the governance of future developments, the use of ‘strategic niche management’ has been proposed as a way of promoting innovations (Hoogma et al. 2002; Smith 2006). The idea is to make use of purpose-built niches to provide a learning space for innovations and support the development of new ‘configurations that work’. This obviously requires a decision on which innovations should be promoted. Moreover, niches should not be considered independently of each other, but rather should be included into an overall ‘portfolio-management’, taking into account interlinkages between various innovation niches.

2.2.2.2 Foresight

On a system level, the system follows certain paths and cannot adapt instantaneously to switch to any other path. As history matters, it is necessary to develop an understanding of potential future development pathways and how these are affected by decisions taken today. The governance of system transformation literature therefore puts great emphasis on foresight. An understanding of future developments and options also provides the basis for the selection of strategic niches.

Weber (2006: 197-199) describes three recent trends in the development of foresight approaches that reflect the evolutionary perspective on development of socio-technical systems. Firstly, foresight is no longer limited to technical developments, but increasingly includes wider context developments, including markets as well as other institutional and social aspects. Secondly, foresight has moved from only involving expert opinion to a more participatory approach whereby consensus on risks and opportunities of possible future development paths is negotiated between heterogeneous stakeholders or conflicting viewpoints are made transparent. Finally, foresight is no longer merely seen as a tool to sketch out future developments or even predict the future, but is seen itself as a deliberative governance mechanism that can help develop a shared understanding of current problems, goals and emerging development options. Foresight can thus contribute to shaping the future through the coordination of expectations and visions that influence today's actions of heterogeneous actors. This becomes particularly important in a liberalised market where the number and diversity of actors that influence future developments increases.

A prominent approach to the governance of system transformation is transition management, which is being applied in the Netherlands. Visions and goals are developed in so-called transition arenas and are used to select specific projects and experiments, i.e. niches that can help promote these visions (Kemp, Loorbach 2006). Another pertinent example of foresight in practice is the UK Foresight exercise (The Government Office for Science 2008).

2.3 Summary

This final section briefly summarises and compares the two discourses on electricity market liberalisation and governance of system transformation.

Proponents of electricity market liberalisation argue that this model is the most appropriate, not just for providing electricity at low costs, but also for meeting other objectives, including those resulting from the sustainability agenda. According to this view, the most important prerequisite is that markets are allowed to function properly so that all costs, including any environmental costs, are reflected in market prices. This means that policy intervention should be restricted to a minimum so as to not distort the cost reflectivity of prices.

As opposed to this view, a large body of literature based on an evolutionary and socio-technical system view on innovation argues that infrastructure systems like the electricity sector are characterised by path-dependency and may become locked into a structure that is ‘sub-optimal’. It follows from this perspective that one cannot rely on the market alone and the price-signal it generates to coordinate individual market participants to make the electricity system sustainable. As the formerly monopolistic market with hierarchical coordination is not seen as a solution either, this literature has developed a range of proposals as to how the governance of system transformation in a sustainable direction can be achieved.

The following table summarises and compares some of the main features of the two approaches.

Table 1: Comparison of the discourses on liberalisation and transformation

	Electricity Market Liberalisation	**Electricity System Transformation**
Main objective	Efficiency Optimisation of the current system	Sustainability System transformation
Scope	Transformation of the governance structure, changes in other parts of the sector will follow from it.	Transformation of the overall sector structure, look at all system elements and co-evolution between them.
Role of innovation	Focus on individual innovations Innovation as optimisation by rational market participants, based on price signals (e.g. Mayo, Flynn 1988).	Individual innovations as part of system transformation Evolutionary view of innovation and transformation, relevance of institutions, socio-technical systems, lock-in and path-dependency.
Governance	Competitive market and price signal is the main governance mechanism and will foster innovations and will bring about necessary technological change to make system sustainable. Other mechanisms likely to distort price signal	Additional governance mechanisms on top of market prices needed to coordinate the build-up of a new 'configuration that works'. Explicit need for governance of transformation
Instruments	Market design, focus on single instruments to correct market failure, preferably 'market-based', e.g. emission trading.	Market and complementary instruments: foresight and joint vision-building, strategic niche management.

Although the two strands of literature have different theoretical understandings of innovation and sector change, in terms of practical electricity market governance, the system transformation literature does not propose to provide an alternative to liberalisation and the two approaches should not be seen as mutually exclusive, but rather as complementary. As Rennings et al. (2003: 20) have formulated it: *"(…) one could say that transition management = current policies + long-term vision + vertical and horizontal coordination of policies + technology portfolio-management + process management"*. However, much of work on the governance of transformation has been on the design of specific transformation mechanisms, while the "+", the link to 'current policies' and the potential to adapt them have been neglected.

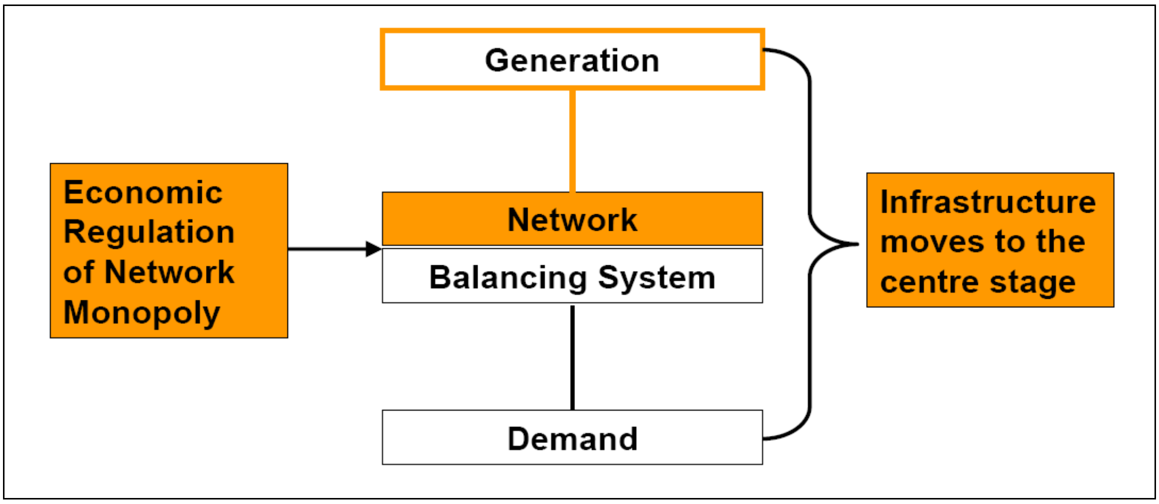
Against this background, the following chapter goes on to present the focus of this study. It shows how the electricity network infrastructure has become a focal point of efforts to make the system more sustainable and how distributed generation has been an important reason for this. It then presents economic network regulation as the governance model proposed by the standard model to deal with the network monopoly that persists in liberalised electricity markets.

3 Distributed generation, electricity networks and network regulation

The previous chapter has described the general background of liberalisation and transformation in electricity systems at large. Within this context, this chapter goes on to present the focus of this thesis: distributed generation and network regulation. This is largely based on a review of the literature on distributed generation and network regulation respectively.

The following figure shows a stylised model of the electricity system, including generation, network/balancing system and demand. The focus of this thesis is on the network as well as the link between the network and generation.

Figure 2: Focus on the network



The infrastructure connecting generation and demand, which was a “sleeping beauty” for many decades, has attracted increasing interest since liberalisation and may undergo significant transformation – not the least because the share of distributed generation is increasing. As part of the standard model of electricity liberalisation described in the previous chapter, economic network regulation is the main governance mechanism for the network monopoly[1].

Distributed generation and the network challenges it entails is used as an example in this study to analyse the capability of the standard model of electricity market liberalisation to deal with new objectives beyond efficiency as the primary objective and developments that may transform the fundamentals of the systems.

The first section of this chapter introduces the focus on networks and distributed generation, while the second part gives an overview of the standard model of network regulation.

3.1 Electricity system development and distributed generation

One of the issues that have put the infrastructure perspective on the agenda is distributed generation. Before explaining in more detail what this means and why further analysis is conducted on this aspect, the following section puts DG in the context of a more general ‘infrastructure revival’.

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[1] As indicated in Figure 2, generation and demand are not just connected through cables, but also through a balancing system to make sure that generation meets demand second by second. With an increasing share of distributed generation and the integration of the demand side into system operation, this balancing system will increasingly require a powerful communication and control infrastructure, which will also be subject to economic regulation as long as it is a monopoly.

3.1.1 The infrastructure moves to the centre stage

One of the main characteristics of the electricity sector is that it is being operated as an interconnected system, connecting plants and customers in large geographical areas, often across national borders, with thousands of kilometres of cables and power poles that have become part of the landscape in many cases. But nevertheless, the electricity network has been rather invisible in many electricity sector debates, largely neglected both by system managers and sustainability advocates.

The process of building this large scale, interconnected grid was described by Hughes (1983) as a major system building effort. However, once this had been completed, the network was no longer perceived as a separate issue and the network structure was rarely called into question. As Coutard (2003: 165) has observed, despite being the core of the electricity system, networks *"were perceived by system managers and regulators as only a by-product of their supply activity with no economic value per se"*. In fact, the more the network was extended and bottlenecks were removed, the more invisible it became: It came to be perceived as a 'copper plate' that does not impose any restrictions, rather than a meshed system built for a certain purpose, exhibiting certain constrains and governed by physical laws that enable certain developments, while impeding others.

Apart from the proponents of the existing system, those who sought to change this system and make it more environmentally friendly and sustainable, have also largely overlooked the network. The electricity network itself certainly has only relatively minor environmental impacts – undoubtedly so, when compared to electricity generation. It is therefore not surprising that it has not figured prominently in the sustainability discourse in the energy sector. Sustainability in electricity has been mainly associated with replacing "dirty" plants by cleaner ones on the generation side and reducing consumption on the demand side. An early example is the "soft energy path" put forward by Lovins (1977) whereby the centralised energy system is to be replaced by end-use efficiency and renewables.

More recently, ‘transition management’ in the Dutch energy sector, although pursuing a systems approach, also seems to neglect the electricity *network* as one of the core elements of the electricity system and, like previous approaches only looks at power plants, rather than the plant-network-interface[2].

Even studies that explicitly referred to the “Greening the Grid” (van Vliet 2002) tend to focus on the consumer, generation or new linkages or roles between the two without consideration of the physical network infrastructure. Another example of this ‘infrastructure blindness’ are studies that have analysed in great detail the future potential of renewables, for example, and the changing generation mix that is required for a sustainable electricity system without considering the infrastructure implications that their generation scenarios would have (e.g. for Germany Wuppertal Institut, DLR 2002).

Since the turn of millennium the network infrastructure has been waking up from decades of sleep. For example, in its European Strategic Energy Technology Plan (SET-Plan) the European Commission lists an integrated, smart European electricity grid as one of the four key challenges for Europe’s energy system (European Commission 2007). The network revival has several dimensions: It is about making sure that there will be sufficient investment to maintain supply security, about upgrading the network and especially interconnectors between systems to open the network for new entrants and facilitate competition and about network innovations to integrate new generators and the demand side into system operation.

The renewed interest in the network can be attributed to a number of developments that result from electricity market liberalisation. First, unbundling between generation, network and supply activities that is one of the cornerstones of the liberalised market

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[2] Personal communication with ECN, 30 June 2006.
See also http://www.senternovem.nl/energytransition/initiatives/index.asp

model, has made the individual elements, including the network, more visible. The fact that a separate governance mechanism has been established for the network adds to this (see section 3.2). More generally liberalisation has highlighted the role of the network as a prerequisite for a functioning marketplace: It connects supply and demand and can be a significant barrier to entry if new entrants cannot get access to the network. While before liberalisation, monopolistic supply areas were interconnected mainly to provide cheaper reserve, liberalisation leads to increasing trade, including international trade, which in turn increases the infrastructure requirements to accommodate that trade. Overall, it can be argued that *"the invisible hand of the market or market forces (…) have forced this rather neglected sector into the limelight"* (WRR 2008: 51).

Another development that has put the spotlight on the electricity grid is the changing generation structure (IEA 2008). Firstly, the competitive market and new technologies like offshore wind plants have triggered changes in the geographical distribution of generation connected to the transmission network and the network needs to be adapted accordingly. Secondly, the share of plants connected to the distribution network increases. Distributed generation and its interaction with the network will be the focus of the further analysis, as outlined in the following section.

3.1.2 Distributed generation

The changing generation structure to a large extent results from an increasing share of renewables and combined-heat-and power plants (CHP) and ambitious political targets exist to promote this development further, e.g., the European 20 % target for the share of renewables in final energy consumption, laid down in the 2009 European renewables directive. Many of these plants are small-scale compared to conventional plants and are often referred to as 'distributed generation' (DG) (Jenkins et al. 2000; IEA 2002a; Pecas Lopes et al. 2007).

Distributed generation has a particularly strong impact on the network because it is connected to a network level that was not designed for that purpose and because DG is not just about connecting new plants to the existing system, but also about innovation and transformation of the system (see section 3.1.2.3). The case of DG shows that the renewed interest in the network infrastructure entails a more systemic view of the electricity system. As indicated in Figure 2, with the infrastructure moving to the centre stage, the interconnections between generation, network and demand also come to the fore. Although unbundling may have made the network more visible, such a system view is at odds with the disaggregated unbundling view of the electricity system put forward by the liberalisation model.

For these reasons, DG can serve as a particularly good example for analysis of the capability of the liberalised electricity market model to deal with developments that are not just about promoting competition and increasing efficiency, but also involve adapting the electricity system to make it more sustainable.

The following sections will provide a brief overview of DG, and will discuss its potential network impacts.

3.1.2.1 Definition and status

There are a number of different definitions for DG (Ackermann et al. 2001), referring to either the location in the network, the plant capacity, the power delivery area, the technology, the environmental impact, the mode of operation or the ownership. It is true that DG plants tend to be small-scale[3] and often, yet not always, have a lower environmental impact than conventional generation.

[3] In many cases, DG will be quite small, below 1 MW or even below 1 kW. Assuming that the maximum voltage level operated as part of the distribution system is 110kV, the maximum capacity for DG can be in the range of 100-150 MW. See Jenkins (2000: 21-48) for a description of DG technologies.

However, only the first definition based on the location in the network can adequately capture the range of plants that can be subsumed under the heading of DG. What makes a plant “distributed” is neither its technology nor its environmental impact, but its location within the network. While power plants have traditionally been connected to the transmission grid, distributed plants are connected to either the distribution grid that was not configured to accommodate generation or on the customer side of the meter.

According to Ackermann et al. (2001), who have attempted to provide a consistent definition, “*DG can be defined as electric power generation within distribution networks or on the customer side of the network”*. A similar definition has been adopted by the UK energy regulator Ofgem (2002): *“DG, sometimes called embedded generation, is electricity generation, which is connected to the distribution network rather than high voltage transmission network.”*[4] In the context of this study it is important to note that this definition includes a systemic perspective, highlighting the interconnection between generation and network.

Although DG plays an increasingly prominent role in political debates and future scenarios of the electricity system, their current contribution is limited in terms of total capacity and generation in most electricity systems. What is more, in most countries which are leaving the “grace period” inherited from the monopolistic era and involving significant over-capacity and are entering an investment phase, there are significant investments in centralised plants.

It is difficult to get hold of reliable and consistent statistical data on the status of DG, both globally and on a country-by-country basis. This is because most statistics report the share of renewables or CHP plants, but do not distinguish between DG plants and

4 The definition of the distribution grid, i.e. the voltage level it comprises, depends on the system at hand.

plants connected to the transmission grid. The other problem is that the definition of DG depends on the study and the country, making it difficult to compare and aggregate data across different statistics (Ackermann 2007: 1149).

The most comprehensive statistical data is provided by World Alliance for Decentralized Energy, an industry association mostly representing members from the CHP industry. According to WADE (2005), the world market share of DG in generation capacity was 7.2 % in 2004. In absolute terms, global installed DG capacity stood at 282.3 GW. Most of these plants are industrial CHP or district heating plants. In 2005, DG contributed about 10 % to total power generation world-wide. In terms of the share of DG in total new generation, this has continually increased from 13.0% in 2002 to around 24.5% in 2005 (WADE 2006), indicating that DG capacity is rising. Unfortunately, this data is incomplete in that it does contain a longer time series.

DG penetration by country is shown in chapter 4 as a basis for the selection of the country case studies. The WADE definition of DG is similar to the one applied in this thesis in that it defines DG irrespective of size, technology or fuel used. There is a slight difference in that it defines DG as electricity production at or near the point of use and does not refer to the electricity network. However, “near the point of use” can be translated as “connected to the distribution grid”, as it will otherwise be difficult to determine which plants are near the point of use and which are not.(WADE 2006; WADE 2006)

3.1.2.2 Distributed generation: General drivers

There are different factors that have led to an increasing interest in DG (Alanne, Saari 2006; DoE 2007; Pepermans et al. 2005; Swisher 2002). The potential advantages of DG include environmental, security of supply and economic aspects.

Electricity market liberalisation can in principle be said to have opened the door for DG in that it has lifted restrictions on building power plants and has opened the generation market to new entrants. However, the drivers for an increase in DG have so far been mainly technical progress of DG technologies and political objectives to increase the share of DG that have led to the creation of niches outside the liberalised market in which these new technologies can operate supported by government policy (e.g. priority dispatch and feed-in mechanism or quota systems).

However, DG has only rarely been recognised as a separate governance field and in most countries there is no explicit DG policy, but policies to promote renewables and CHP (e.g. Haas et al. 2008). Renewables are often small-scale and connected to the distribution network. The same holds for many CHP plants. Thus, the increasing share of DG results to a large extent from political efforts to promote renewables and CHP, mainly for environmental reasons.

Electricity generation from renewables and CHP can generally be said to have a lower environmental impact than conventional fossil-fuel fired electricity only plants because they use renewable primary energy sources with no or lower emissions or heat utilisation increases their efficiency. The benefits are, however, not always unambiguous (e.g. Gulli 2006) and case-specific, depending on the technology, the fuel that is used and the technology it is compared to (e.g. Pehnt, Fischer 2006).

There are different instruments to support the generation from new plant technologies. Most countries now apply either obligations combined with tradable certificates (as in the UK) or feed-in systems (as in Germany). There has been an extensive debate on the pros and cons of different support mechanisms (e.g. Haas et al. 2004; Mitchell et al. 2006; Menanteau et al. 2003). It has been mainly about finding the most effective or efficient support instruments for individual plants, while the network infrastructure has been neglected, much in line with the general infrastructure blindness sketched out above.

In terms of DG plant economics, there are large differences between plant technologies and the economics are highly technology-, site- and fuel-specific (see for example

Pepermans et al. 2005: 793 for investment costs for different DG technologies). However, there are a number of generic developments that can make small-scale plants more attractive and which may become increasingly relevant in the future:

Firstly, it can generally be said that the scale economies that have dominated electricity generation for decades, have been diminishing (Casten 1990). DG may increasingly benefit from a shift from economies of scale to economies of mass production (Magnusson et al. 2005).

Secondly, investments in centralised plants are much lumpier than DG investments and are therefore more difficult to gear towards actual market conditions and demand developments. In traditional power systems an expected increase in electricity demand was usually met by installing a new large-scale power plant, with the risk of overcapacity borne by customers. In today's liberalised markets, building power plants has become a significantly riskier investment. Small-scale plants reduce the risk for individual investors of building capacity that is not called upon by the market. They are therefore better suited for investors to respond to demand changes and market developments (Swisher 2001; Swisher 2002).

In terms of supply security, DG can be attractive for individual power consumers because they can provide on-site back-up power and reduce the dependence on the public grid. This is particularly valuable in regions where reliable power supply cannot be provided via the network (Swisher 2002).

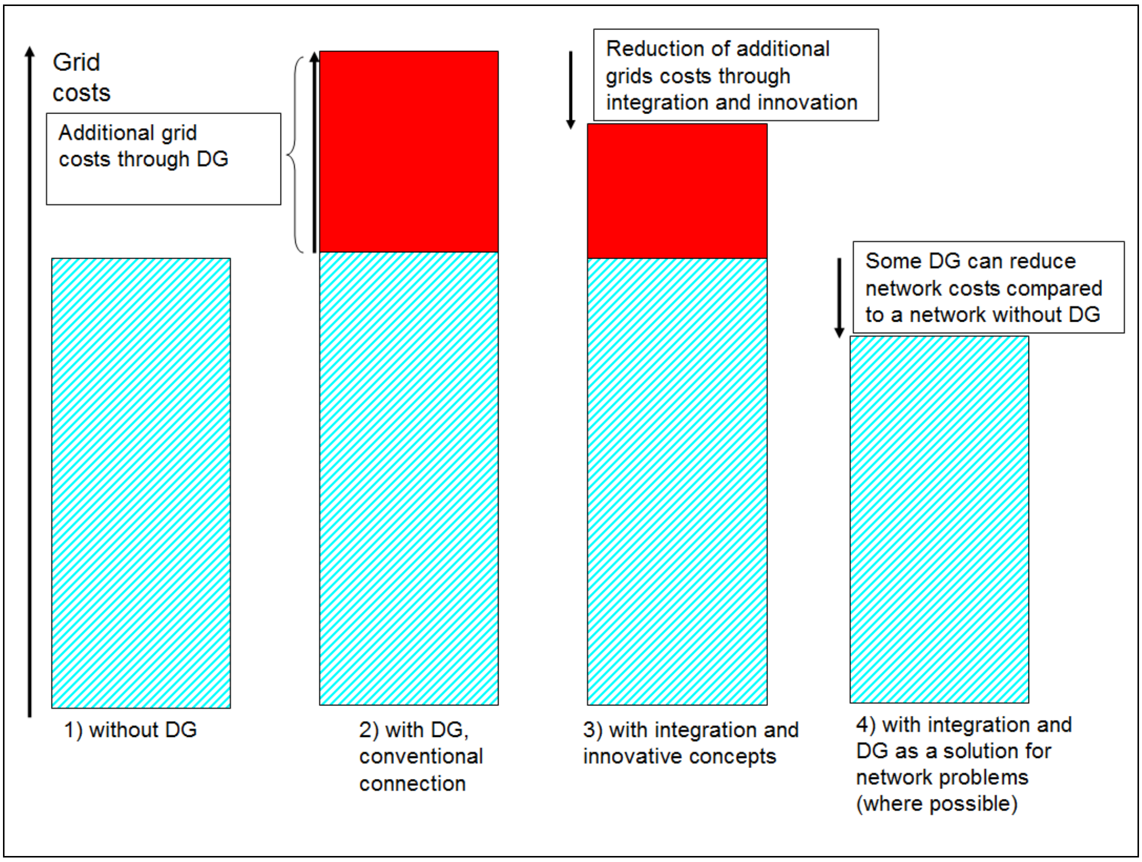
From a societal perspective, an assessment of the impact of DG on supply security is more difficult. Again, it depends on the specific technology and needs to take into account different dimensions of supply security, too (Pepermans et al. 2005: 790-794; for a more general analysis of security of supply see Watson 2009b; Watson 2009a). For example, in terms of fuel supply, if DG is powered by renewables, it can reduce the dependence on fuel imports, whereas gas-driven DG may reduce fuel diversity and increase dependence on gas imports. In terms of the security of the electricity infrastructure, DG plants can both reduce and increase pressure on the infrastructure. On the one hand, generation close to consumers can reduce the dependence on the infrastructure. On the other hand, a changing generation structure which no longer matches the infrastructure as well as the intermittency of many DG plants can make the electricity system more prone to failures. Despite the need for a diversified assessment of the impact of DG on security of supply, in political debates security is often used as an argument in favour of DG (for example European Commission 2003: 9).

3.1.2.3 Distributed generation and electricity networks

While the previous section has already mentioned the main generic energy or commodity related benefits of DG, for this study the impacts of DG on the network infrastructure are most relevant, both in technical and economic terms. The definition of DG as generation connected to the distribution system or on the customer-side of the meter already indicates that DG needs to be analysed “in connection” with the network.

The following stylised figure shows various overall cost effects of DG on the network found in the literature: DG can lead to additional costs in the network (case 2) as compared to a reference case without DG (case 1), but the additional costs can be reduced through network integration and innovative network concepts (case 3). In some cases, DG may contribute to a reduction of network costs (case 4).

Figure 3: How DG can affect network costs



Source: Author's own illustration, based on the following sections

These effects will be explained in more detail in the following sections.

Additional grid costs of DG

In current electricity systems, the distribution system is different from the transmission system in a number of ways (Cardell, Tabors 1997):

- Distribution systems were designed to transport power from the transmission system to the consumers and power flows are uni-directional from higher to lower voltage levels. They do not normally contain generation and their protection systems may need to be adapted to accommodate generators.

- Transmission systems are highly meshed whereas distribution systems are characterised by a radial or looped grid architecture. As a consequence, there are normally only one or maybe two paths to each bus, as compared to several alternative paths in the meshed transmission system.

- The high voltage lines of transmission systems have a low resistance as compared to the lower-voltage lines in distribution systems, especially in rural systems with long lines. As a consequence, if a generator gets connected to the low-voltage distribution system, this can significantly affect the voltage levels.

- In distribution systems, and especially the low-voltage ends, there are usually no control systems available that are standard on the transmission level. As a result, the DSO has no real-time information on the status of the network and can hardly influence its operation to maintain system stability, e.g. when the voltage on the network is about to exceed the rating. In a liberalised market with unbundled network operators and independent generators, this becomes even more of a problem as generators are mainly concerned with responding to market signals or the maximisation of revenues from a support mechanisms rather than network requirements.

There is a large body of literature dealing with the technical problems that result from connecting DG to the distribution network and the costs this entails, e.g. power quality issues (e.g., Ackermann 2004: 222-239; Jenkins et al. 2000: 133-149; Dispower 2006; Ackermann 2004). Distributed plants are not just smaller plants, but plants connected to a network level that was not designed for that purpose. They therefore affect the system in novel ways and require DSOs, who are usually neither used nor equipped to handle large amounts of generation on their network, to deal with new problems.

Given that distribution networks have generally not been designed to accommodate DG, it is not surprising that connecting DG to this network level can entail additional costs (Cao et al. 2006). In addition to the connection costs themselves, there are costs for reinforcing the grid beyond the point of connection to accommodate the additional load, e.g. if DG generation exceeds local demand and additional grid capacity is required to export electricity to the transmission grid, e.g., for Germany see Burges, Twele (2005), for Denmark Bach et al. (2003). What should not be neglected are the additional transaction costs that DG entails for the DSO. With DG, the DSO needs to deal with additional counter-parties, and given the relatively small size and distributed ownership of DG, this makes the DSO’s business more complex.

Reducing the additional costs of DG

If DG plants are only connected, they are basically treated like passive consumers. Instead there are also concepts to integrate them into the system and make them operate more in line with system requirements. According to Strbac et al. (2006), “*in systems with a significant penetration of distributed generation, such as Denmark, there is a clear need to make the next step, which is to move away from connecting generators under the “fit and forget” basis (with the objective to merely absorb their energy production) and move toward integrating this generation in the overall system operation and development*”.

There are different degrees of integrating DG plants into the network. While locating DG plants with regard to the resulting network costs represents a first step, integration mainly refers to the operational phase. DG plants can be made more ‘system-friendly’ if they are designed to provide more flexibility and controllability to be able to react to system conditions, e.g. by adapting their output to system load or by participating in reactive power management. In Germany, for example, the feed-in-law for renewables (EEG) requires renewable plants to dispose of *“a technical facility for reducing the feed-in in the event of grid overload”* (article 4/3). Also, the plants’ protection system can be designed so as to allow them to keep operating when the system experiences disturbances, rather than being disconnected, thereby potentially exacerbating the problem.

Integrating DG into network operation has repercussions on the way in which DG plants are designed and operated, but also requires changes on the network side. If DG plants are to contribute to system security, managing constraints and balancing, the infrastructure needs to be in place to enable DG operators to make this contribution. The more DG capacity increases, the more the network needs to adapt to be able to accommodate these generators (cf. L'Abbate et al. 2008).

Various innovative network concepts are under discussion that go beyond removing barriers for individual plants and aim at upgrading the network to accommodate an increasing share of DG (Varming et al. 2002; EA Technology Ltd 2001; Strbac et al. 2007; Coll-Mayor et al. 2006; Strbac 2006; Strbac et al. 2006; Econnect 2006; BERR 2007; Bayod-Rújula 2009; European Commission 2003).

For example, van Overbeeke and Roberts (2002) have proposed the "active networks" concept. In this approach the current passive distribution networks that simply transport electricity from the transmission grid to the final customers will be replaced by actively managed networks. An important feature of active networks is that they interact with their customers, i.e. DG plants can be controlled to adapt to the network situation. Network constraints are not resolved in a conventional way, through preventive control based on network capacity, but controllable DG capabilities are used to control flows on the network, similar to what is already done on the transmission level.

Van Overbeeke and Roberts argue that this is both technically and economically the best way to facilitate DG in a deregulated electricity market. The following table provides an overview of different concepts under discussion:

Table 2: Overview of innovative network concepts[5]

	Active distribution networks	**Virtual power plants**	**Power cells (Denmark)**	**Microgrids**
Objective	Connect more DG to existing network assets Increase utilisation of existing networks	DG to trade on markets and provide network control and system support	Integrate DG into system operation to achieve a higher level of DG within the existing infrastructure	Utilise DG to reduce the requirement for Transmission and High Voltage distribution assets
How?	Real-time network analysis and control of voltage, flows and fault levels Make distribution more intelligent, instead of investing in network primary plants (wires)	Aggregation of DG plants, increasing diversity and predictability	Decentralisation of control, DSOs operate local control areas and provide system services with the help of DG	Individual micro grids are able to operate autonomously in the case of loss of supply from the higher voltage networks (islanding)

Source: Based on Strbac (2006) and Strbac et al. (2007), see also L'Abbate et al. (2008; Strbac et al. 2007; Strbac et al. 2007; 2007)

If plants are not just connected to the existing grid, but actively integrated into the system the additional network costs that result from connecting DG, for instance due to necessary network expansions, can be reduced.

5 While these innovations mainly pertain to the distribution network, there are also innovative solutions for the transmission network (IEA 2008: 25-26). An example is the FACTS technology (Flexible Alternating Current Transmission Systems) to improve the power flows and voltages on the transmission system.

For example, in a case study conducted in Austria Prüggler et al. (2008) compare conventional grid extension strategies based on new cables with alternative solutions that actively use DG as well as network assets to perform voltage control in the distribution network. They show that in this case all innovative strategies applied are significantly more economical than the conventional grid reinforcement approach.

While in the Austrian case study grid reinforcement is the most expensive option, Cao et al. (2006) have analysed different cases in the UK and Finland, again with different DG penetration levels, densities and distinguishing between rural and urban networks. They come to the conclusion that traditional network reinforcement can be the most economical option in some cases. Yet overall, their results confirm that active management can reduce the network costs caused by DG, as shown in scenario 3 in Figure 3.

Reduction of overall network costs through DG

As we have seen, DG is often discussed as a new problem and in terms of additional costs for the network and how these can be reduced. However, there can also be benefits to the system and there is also research on the potential of DG to reduce network costs (cf. scenario 4 in Figure 3). According to this argument, DG does not increase costs because the network needs to be expanded to accommodate DG, but DG becomes an alternative to the use of some parts of the network in both the transmission and distribution grid, generating electricity locally and thus replacing or deferring the need for network investments. This also requires DG to be integrated into network operation.

Especially in the USA a number of studies on the costs and benefits of DG have been conducted (Gumerman et al. 2003; Iannucci et al. 2003; DoE 2007: section 3.6; Arthur D.Little Inc. 1999). These studies all stress the benefits of deferred investment in both transmission and distribution networks as DG can be a substitute for new lines. For example, Arthur D. Little (1999) have estimated typical grid-side benefits at US$ 30/kW per year for the deferral of transmission and distribution upgrades. Yet this potential benefit is highly case-specific and critically depends on whether network capacity is already sufficient. If it is, then the installation of DG generally has no major cost benefits, as network costs are largely sunk costs. If, however, new DG can avoid or defer network expansion, it may be the more economical option. Mendez et al. (2006) have proposed a methodology for assessing the impact of DG on investment deferral. They show how this effect depends amongst other things on the DG technology and the concentration of DG plants.

Using DG as an alternative to network investment requires these plants to be integrated into overall system operation to provide capacity rather than energy only, i.e. they need to generate power when needed by the system (e.g. because demand is high). Otherwise back-up power would need to be provided by central plants and via the grid. This additional value of DG is often referred to as distributed capacity (Ackermann et al. 2001: 201). Again, this may require changes not just on the plant side, but also on the network side. The potential of DG to replace network investment has been translated into article 14/7 of the 2003 EU electricity directive that requires DSOs to consider DG as an alternative to network expansion.

Beyond individual networks

The innovative network concepts presented above can in principle be implemented in one distribution network, while other distribution networks can continue to operate in a conventional way, i.e. some networks may choose to integrate DG through network expansion while others may decide to implement innovative control technologies. Beyond these individual innovations in single distribution networks, there is a discussion about the transformation of the overall grid structure being necessary if electricity generation is to become distributed and more sustainable. The electricity network infrastructure thus becomes an example of system transformation as presented in the previous chapter.

With an increasing share of DG, the distribution grid is expected to become more similar to the transmission grid, controlling generation and connecting generation and load.

This is not just about resolving local network constraints, but about overall system control, including the balancing system. DG may entail a shift in the control philosophy from entirely central control to some control taken over by the distribution system operators. For example, such a shift is implied in the cell concept presented in Table 2. This will affect the interaction between transmission and distribution network and will eventually entail changes in the overall infrastructure architecture (cf. European Commission 2006: 18).

There are different scenarios describing potential future development paths of the system as a whole, including scenarios where the current top-down grid architecture is largely maintained, scenarios where long-range electricity transport for example from Northern Africa to Europe becomes more important or where offshore-wind plants will generate a significant amount of electricity with important repercussions on the grid structure or scenarios that foresee a mainly decentralised network and control structure (Thielens, Vaessen 2005).

The International Energy Agency (IEA 2002a) has sketched out the increasing penetration of DG and the potential system impacts this entails in three stages: accommodation, decentralisation and dispersal. Against the background of the above discussion, I interpret these stages as follows:

In the first stage, ‘accommodation’, DG is introduced into the existing system with centralised control over network remaining in place. This stage is about ‘technical fixes’ allowing distributed power plants to be connected to the existing grid, while the overall technical structure remain virtually unchanged.

In the second stage, ‘decentralisation’, with a higher share of DG, new communication systems for controlling the network and the plants connected to it will be used, i.e. instead of just connecting DG to the existing network the infrastructure is adapted to the changing requirements.

Finally in the stage of ‘dispersal’ DG becomes dominant in the electricity market, based on ‘microgrids’ that can operate independently of the transmission grid and may be connected to other networks for back-up purposes only. The top-down structure of the traditional grid is transformed into a decentralised system architecture. Rather than only introducing individual new technologies in the existing system to upgrade it as in the previous stage, the overall system architecture is transformed: *“Distribution operates more like a coordinating agent between separate systems rather than controller of the system”* (IEA 2002a: 98).

3.1.3 Summary of the DG and network discussion

This chapter started off by stating that the infrastructure that connects supply and demand is moving to the centre stage. The discussion on DG has shown how small-scale plants connected to the distribution network have become a network issue. Summarising this discussion, the interaction between DG and the network can be divided into several dimensions. The technical and economic discussion of DG in the context of the electricity network ranges from ‘simple’ connection issues to ‘visions’ of future network structures that replace the existing top-down network. As a basis for the further analysis I propose to structure the debate as follows:

First, there is a debate on the technical and economic issues arising from *connecting* DG to the network. As DG penetration increases and in order to reduce costs, it becomes necessary to not just connect plants to the network, but to *integrate* them into network operation. In other words, DG can not merely feed electricity into the grid, but can provide capacity and replace network investments wherever possible. Connecting new plants to the existing grid may require network expansions, but leaves the basic network structure largely unchanged. However, in order to integrate DG, it is not just for the DG plants to adapt to the network, but the network needs to adapt, too. There will therefore be an increasing need and scope for network *innovations* and a number of innovative network concepts are under development, i.e. based on new control technologies. Finally, *transformation* refers to a more comprehensive change of the system architecture, linking up and going beyond incremental innovations in individual parts of the network, to achieve an overall transformation of the system structure and control, covering both the distribution and the transmission system.

The following table summarises the interaction between distributed generation and electricity network in four stages.

Table 3: From DG network connection to system transformation

	Connection	**Integration**	**Innovation**	**Transformation**
'Technical' issues	Connection of DG to distribution level of existing network (incl. network expansions) DG contributes energy	Integration of DG into operation of existing network (load and voltage management) DG takes over responsibility for system support DG contributes capacity	See Integration; Development and deployment of innovative network technologies to integrate DG into network operation	Transformation of network structure beyond innovations in individual parts of the network, including overall system design and control (transmission and distribution)
Economic issues	DG entails additional network costs	Additional network costs of DG can be reduced; DG can help reduce network costs	See Integration; Additional costs and benefits of RD&D	Costs and benefits of transforming the network architecture Usefulness of cost-benefit less clear for the analysis of system transformation Is coordination of different actors and innovation activities through price signal sufficient?

In practice these stages may be difficult to separate, for example when innovative concepts are applied to improve network connections and especially network integration. Especially integration and innovation are likely to be closely intertwined, as integration of DG into distribution networks is itself an innovative concept. Nevertheless, the above stages can provide a useful heuristic for the analysis of governance mechanisms in general and network regulation in particular. A system where DG connection is the main issue is likely to require different governance mechanisms compared to a system where innovative distribution networks are being developed.

3.2 Network regulation

The previous section 3.1 has explained how networks in general and the integration of distributed generation into networks in particular have become an important issue in electricity systems. Within the standard model of electricity system liberalisation outlined in chapter 2, the dominant governance model to deal with the natural monopoly that still exists in electricity networks is ‘economic network regulation’. This section explains the main features of this standard governance approach for electricity networks. It explains what exactly is meant by regulation in this context, why networks still need to be regulated and how the standard model proposes to go about this.

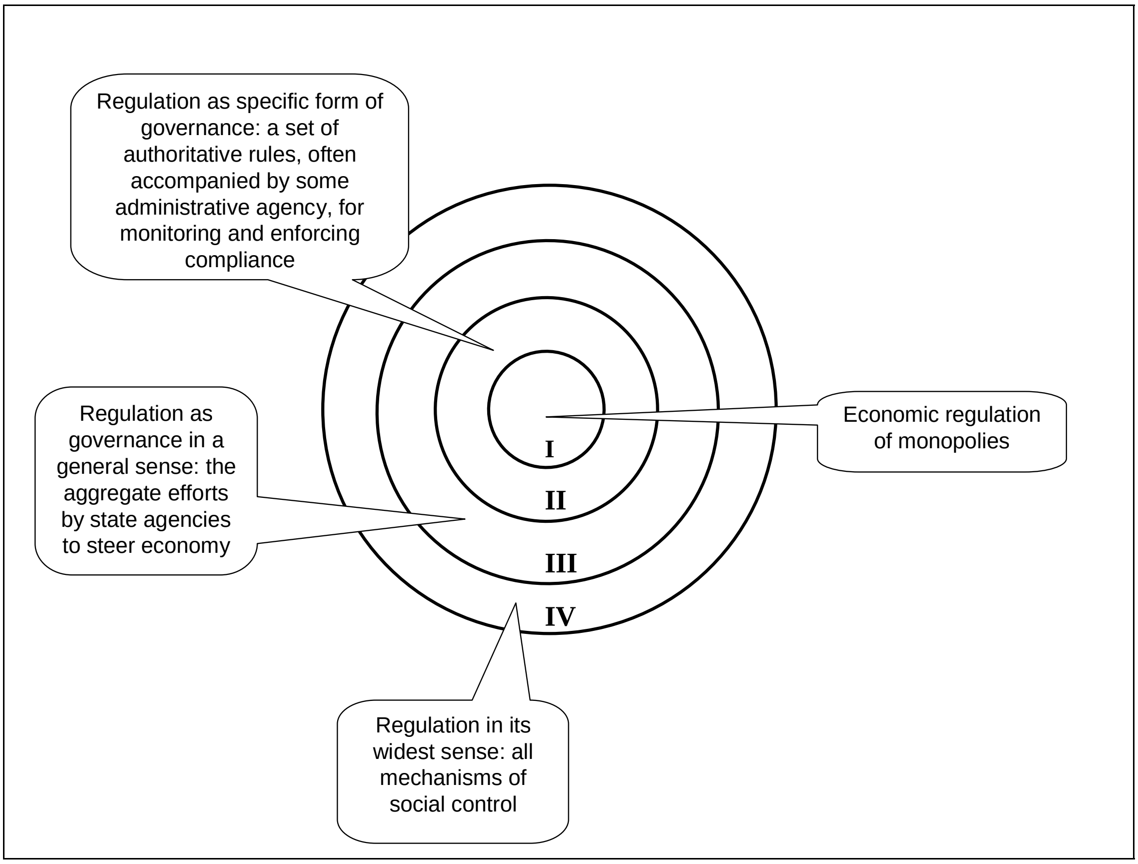
It may seem strange that the analysis of the standard model of liberalisation focuses on network regulation. The standard model proposes competitive markets and market prices as the main governance mechanisms, while in the regulated part of the sector, the regulator is the main governance mechanism and prices are not set through the market. However, network regulation is an important element of liberalisation. Much in line with the overall liberalisation model, the main objective of the standard model of network regulation is to promote competition and efficiency, and it has been designed to mimic the market mechanism for the network monopoly. It is therefore a relevant example to analysis the potential of the standard model of liberalisation to promote new objectives.

3.2.1 Network regulation in the context of the regulatory state

Before explaining the standard model of network regulation, it should be briefly placed in the context of a broader debate on regulation (cf. Jordana, Levi-Faur 2004). Establishing a regulator to set the rules for the privately-owned electricity network is a development that is specific neither to the electricity sector nor liberalised infrastructure sectors in general. Regulation, or in other words the increasing emphasis of 'rule-making' by the state, is rather seen by some as the major aspect in the development of governance in capitalist economies since the 1980s. In any case, it is something that has gained more prominence (Majone 1997). This development has been condensed into the notion of the 'regulatory state'. The regulatory state can be defined as a *"[...] rule making state, with [...] a predilection for judicial or quasi-judicial solutions"* (McGowan, Wallace 1996: 563). The regulatory state is mainly contrasted with the welfare state that is based on taxing and spending as well as re-distributional objectives on the one hand and public ownership on the other hand.

The following graph shows four different meanings of regulation in four circles, with the most precise meaning, which is applied in this study, in the inner circle (meaning I). The development towards the regulatory state is captured in meaning II, which describes a specific form of governance based on rule-making. In contrast, regulation according to meaning III also includes mechanisms such as taxation, subsidies, redistribution and public ownership. In the outer circle, regulation refers to all mechanisms of social control, rather than simply those used by the state.

Figure 4: Different meanings of regulation



Source: Adapted from Baldwin et al. (1998), quoted in Jordana, Levi-Faur (2004)

Regulation according to meaning II can target different market failures in different policy areas and can make use of different kinds of rules. As indicated it has indeed been assessed that the ‘regulatory state’ has been expanding to include an increasing number of issues. There is for example environmental and social regulation, including health and safety regulation and consumer protection, which targets externalities or information deficits and sets for example standards in the respective field.

The focus of this thesis is on economic regulation of natural monopolies, which regulates the prices companies are allowed to charge (meaning I in the figure above). This represents one specific regulatory field within the broader concept of the regulatory state. In the case of electricity as well as other utility industries, privatisation and regulation of private companies has in many cases replaced the state as an owner that was steering through public ownership and acting directly as a service provider.

Economic regulation is generally embedded in a specific governance arrangement according to meaning II, based on a specialised and independent agency. The ‘regulatory state’ is not only characterised by placing more emphasis on rule-making; rather there is also a specific institutional set-up proposed for that purpose. It is one of the main characteristics of the regulatory state that it delegates a large part of its rule-making functions to agencies. As compared to traditional bureaucracies, these are specialised in a narrow range of policy issues, are staffed by experts in that field and are to be independent of politics (Majone 1997; Pollitt et al. 2001).

This attempt to separate policy and regulation is also part of a broader effort – often labelled ‘New Public Management’ – to organise public administration much like a business and perform it as a mainly technical task based on scientific evidence (Hood 1991; Gray, Jenkins 1995).

3.2.2 The standard model of economic regulation

Chapter 2 has provided a brief overview of the standard model of liberalised electricity markets. This model comprises a standard way of dealing with the residual natural monopoly in electricity networks. Its principles are rooted in the liberalisation paradigm presented in the previous chapter. This means that regulation is justified by market failures and has the objective of promoting competition and mimicking the market in the network monopoly as much as possible. As with electricity liberalisation in general, the standard model of economic network regulation was pioneered in the UK. The following sections explain why regulation is necessary in the liberalisation paradigm, spells out the theoretical foundations of the standard model and describes its main elements.

3.2.2.1 Why is network regulation needed?

The reason why networks are still regulated while the rest of the electricity sector has been opened up for competition is that the network is a natural monopoly with irreversible or sunk costs – a combination that leads to a ‘monopolistic bottleneck’ with stable market power (Knieps 2001).

In one product markets, natural monopolies are always characterized by economies of scale, resulting from continuously declining average costs, i.e. marginal costs are always below average costs. A more general and more recent definition refers to subadditivity of costs, i.e. in a natural monopoly the production by a single firm minimises cost. This may also result from economies of scope. As a consequence, a single firm can supply the market at lower costs than more than one firm. In a natural monopoly market, competition is therefore not sustainable and usually inefficient. Furthermore, irreversible costs represent an entry barrier and prevent potential new entrants from contesting the natural monopoly.

In the electricity network, high upfront capital investment requirements lead to economies of scale as network costs are mainly fixed, with relatively low marginal costs.

Since these have no alternative use they represent irreversible costs (WRR 2008; Baldick, Kahn 1993).

Besides economies of scale there are also economies of scope in the electricity network as an integrated network benefits from diversified loads, increased security of supply and reduced reserve requirements. As a consequence of these characteristics, competition between separate network operators would be less efficient than having networks run by one company and there is no threat of entry for the incumbent.

There are two main rationales for regulating the monopoly: firstly, without regulation the monopoly company would be free to set prices to extract a monopoly rent, leading to welfare losses. Before liberalisation, this argument could be applied to the entire sector. In the formerly monopolistic markets, most electricity companies were vertically integrated from generation through to supply. There were virtually no companies whose business was limited to networks. The vertically integrated companies were treated as natural monopolies and were either state-owned, like the former CEGB in the UK (Surrey 1996) or EdF in France (Finon 2001), or their integrated business was regulated as a whole, like RWE in Germany (Mez 1997). With the introduction of competition in generation and supply, it is only the residual network monopoly that needs to be subject to this kind of regulation.

The introduction of competition in the other parts provides a second rationale for regulating the network. In a liberalised environment, regulation of the network becomes necessary because competition in generation and supply depends on all market participants having equal access to the network bottleneck – the network becomes an 'essential facility' for companies and customers to get access to the market and thus for competition to work.

If the network company is not completely unbundled from generation and supply, as for example in Germany, regulation becomes even more necessary to avoid control over bottleneck facilities being utilised to keep competitors out of the market. Network regulation is often regarded as a two-dimensional approach that comprises ‘structural regulation’ to separate competitive and regulated businesses and ‘tariff regulation’ to determine the prices of the residual monopoly (Brunekreeft 2003).

For the above reasons, the introduction of competition in electricity generation and retail requires some sort of governance mechanism to deal with the market failures in the residual network monopoly, i.e. to provide for the efficient and reliable operation of the network infrastructure, and for non-discriminatory access to the electricity grid, combined with an appropriate tariff structure. This governance mechanism is provided by the standard model of regulation.

3.2.2.2 The principles of the standard model

How does the standard model of network regulation work? Networks are generally run by privately-owned, profit-oriented network operators that are unbundled from other parts of the industry and the governance of electricity networks is based on economic network regulation through independent, sector-specific regulatory authorities.

Generally, a number of alternative models are available: Even within a competitive electricity market it would be possible to operate the network infrastructure by the public sector. In other sectors, like the UK railway sector for example, a degree of competition is introduced through periodical tenders for operating franchise businesses.

Within the standard model, a major innovation that has developed is the so-called ‘incentive regulation’ (Joskow 2006a). This has become the dominant regulatory approach proposed by the standard model and adopted in most countries and network bound sectors, replacing the previously predominant cost-based regulation. Incentive regulation explicitly seeks to mimic the incentive structure of competitive markets, to make up for the lack of competition in the network monopoly. The core of incentive regulation is to provide companies with an economic incentive to improve efficiency by temporarily (i.e. within one regulatory period of three to five years) decoupling prices network companies are allowed to charge from costs. To that end, the regulator sets a price- or revenue-cap for a regulatory period that is fixed ex-ante

New economics of regulation

The standard model emerged in the wake of the liberalisation agenda and is often associated with Stephen Littlechild proposing the RPI-X framework for the regulation of the privatised British network industries and especially telecommunication (Pollitt 1999: 10). However, the standard model is also rooted in more general economic theory, providing the foundation for this approach. Seminal work has been contributed by Laffont and Tirol (1993). The main characteristic of 'modern regulatory economics' or 'new economics of regulation' is that it leaves behind the notion that regulation is a command-and-control-instrument and the regulator directly influences corporate decisions through licences and sanctions. This is in line with a broader debate on the limited capability of the state to steer the society, often expressed as a shift 'from government to governance' (Kooiman 1993; Rhodes 1996).

The new economics of regulation emphasises that companies pursue their own objectives that are different from the ones that the regulator wants to achieve (Laffont, Tirole 1993: 34-35). The relationship between the regulator and company is characterised by strategic behaviour, with the company having an advantage due to an information asymmetry (Laffont, Tirole 1993: 1-2). This means that the company has better access to the relevant information, namely the efficient costs of its network. Information economics and a principal-agent-framework, with the regulator being the principal and the company the agent, is thus at the heart of modern regulatory economics (Agrell, Bogetoft 2004: 5).

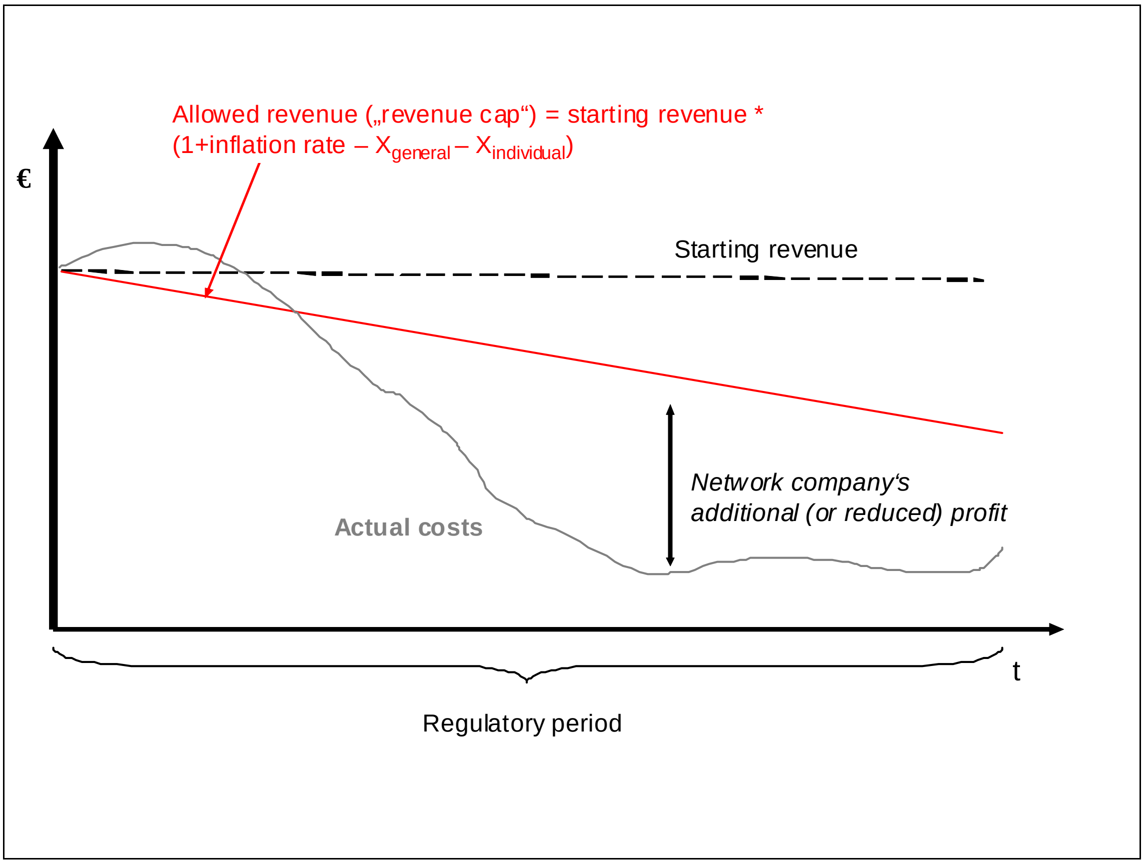
Since the regulator does not have full access to cost information, it has to deal with the trade-off between putting pressure on costs with the danger to drive the company out of business or relaxing that pressure with the danger to accept costs that are above efficient levels and entail undue profits. It therefore wants to give companies an incentive to become more efficient. However, it then has to deal with the *"basic trade-off between* incentives *and* rent extraction*"* (Laffont, Tirole 1993: 39).

Incentives for efficiency

These economic insights have made their way into the standard model of network regulation (Brunekreeft 2003: 69-88; Joskow 2006a). In order to give companies incentives to become more efficient, they are allowed to keep some of the profits resulting from efficiency improvements during a regulatory period. In other words, the regulator acknowledges the information asymmetry and concedes companies a rent on their informational advantage. Hence, productive efficiency gains through which a company can reduce its costs are at least temporarily promoted at the expense of allocative inefficiencies, with prices lying above marginal costs.

The following figure shows how incentive regulation works in principle and how the incentive to become more efficient is set. The regulator sets a revenue cap (or price cap) for typically between three to five years that must not be exceeded by the company. It is an important innovation of incentive-based regulation that it explicitly fixes the regulatory period in what can be regarded as a regulatory contract between the regulator and the regulated company (Beesley, Littlechild 1989: 460) This is done ex-ante and the length of the regulatory period is not adapted with regard to the actual cost development.

Figure 5: Incentive regulation: How does it work?



Source: Author's own illustration. This is a typical illustration of incentive regulation, a similar figure can be found for example in (Boltz 2005)

This mechanism should give companies an incentive to increase efficiency in two ways:

Firstly, during a regulatory period, the cap imposed by the regulator usually decreases. This is widely known as the RPI-X formula. This reflects the fact that the regulator expects companies to become more efficient – either because there is a legacy of inefficiency or because there is a frontier shift whereby even the most efficient company can reduce costs in the future. There is therefore both a general efficiency target for the industry as a whole and one for individual companies. Companies which are less efficient than others may face a steeper decrease of their cap to make them catch up with more efficient companies as a result.

Secondly, if companies beat the regulator's efficiency target and reduce their costs further below the cap, these will increase their profits, at least during a regulatory period. At the same time, if a company's costs exceed the revenue allowed by the cap, they will lose money.

As opposed to this, under cost-based regulation, network tariffs are not fixed ex-ante, but are in principle always adjusted to the development of network costs. This means there is a guaranteed rate-of-return and no incentive to reduce costs.

A main task of the regulator will typically be to regulate the network tariffs which network companies are allowed to charge. However, it is important to note that although the standard model and contemporary regulatory economics are mainly about providing regulated companies with financial incentives, regulation in practice is not only based on incentives. Rather, there are also other mechanisms such as licences that require network operators to comply with certain standards (e.g. technical or service standards) and connect plants to their network, etc. (for an overview of different 'regulatory strategies' see Baldwin, Cave 1999: 34-62). These command-and-control type-of instruments could in principle replace economic incentives, yet the different types of instruments can also be employed to complement and reinforce each other. As Baldwin and Cave have pointed out (1999: 57), *"in most regulatory contexts combinations of regulatory* *methods tend to be employed"*. For example in the context of network regulation a licence requirement on the DSO to connect DG can be combined with a financial incentive to do so. In this thesis, the focus is on economic incentives, which is at the heart of the standard model.

The regulatory process

Having described the main rationale and functionality of the standard model, this section goes on to outline briefly the regulatory process in the standard model. Setting use-of-system tariffs usually includes the following steps (see Figure 6),

1) Determination of an "acceptable" cost base, consisting of (foreseeable) operational costs (OPEX) and capital costs (CAPEX) for the duration of the regulatory period.

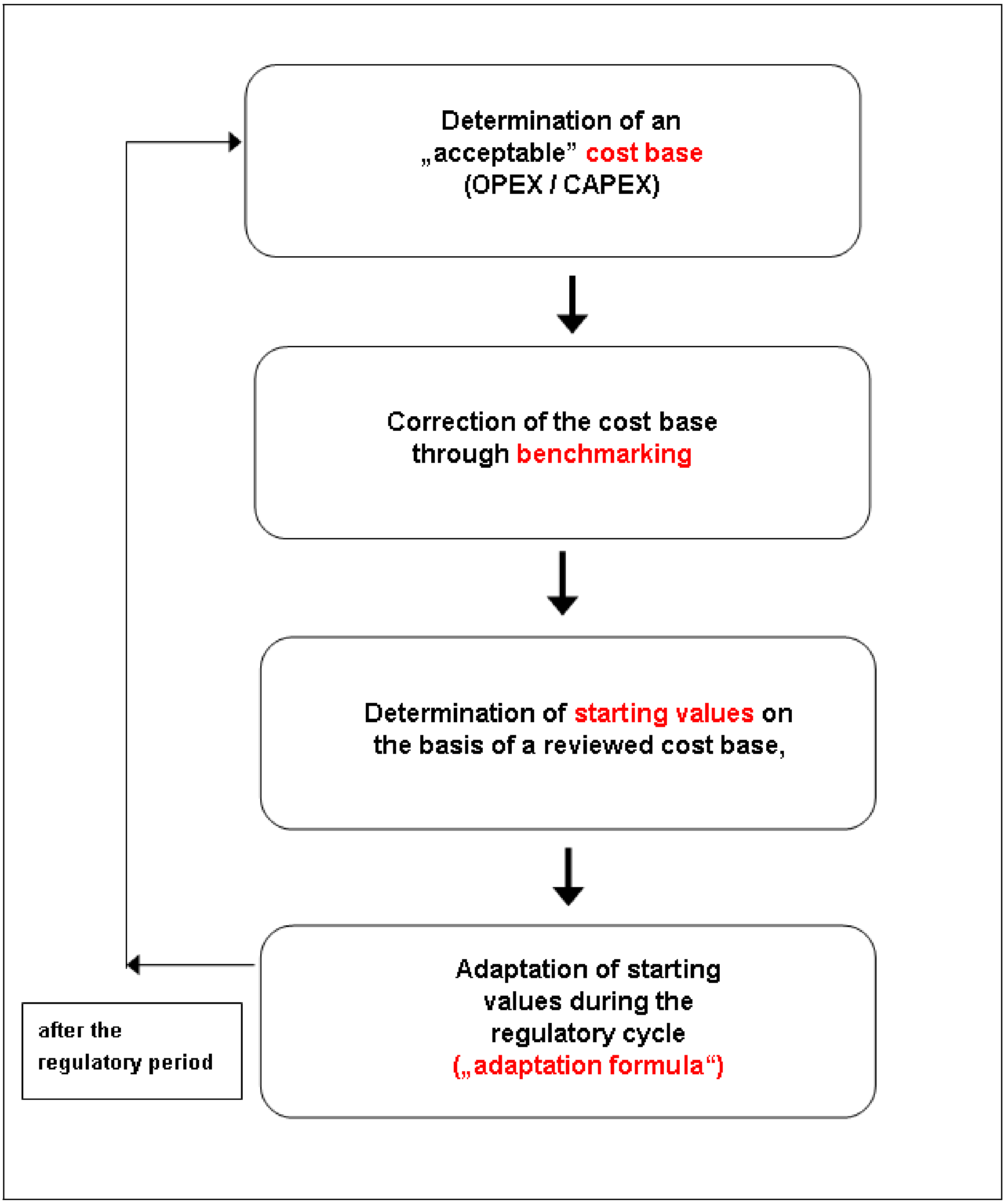
2) Determination of possible reductions of the (controllable) cost base on the basis of a comparative efficiency analysis or benchmarking procedure. As it is one of the core ideas of incentive regulation to decouple prices from costs, a method needs to be designed to determine the prices a company is allowed to charge. This is usually based on a comparative cost analysis, where regulated companies are benchmarked against each other. One potential drawback of this approach is that the cost peculiarities of individual companies are neglected and prices deviate too much from costs, although higher costs may be justified for the individual company.

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 6: The procedure for setting use-of-system tariffs



Source: (Bauknecht et al. 2007)

Sector-specific, independent regulators

Besides the incentive mechanisms described above, another component of network regulation is to determine who should be in charge of regulation (Baldwin, Cave 1999: 63-75). There are a number of 'traditional' organisations that could in principle take over this role, such as the government department that is in charge of energy or the anti-trust authority. As noted before, the regulatory state is characterised by rule-making functions being delegated to specialised agencies (meaning II in Figure 4). This is also part of the standard model of network regulation. Many countries have followed the standard model and have set up independent, sector-specific regulatory authorities to oversee network monopolies (IEA 2001b). The idea is to separate government and politics on the one hand from the concrete implementation and management of network access rules on the other hand. A prominent example is the UK energy regulator Ofgem.

The main rationale for the independence of the regulator, at least from the normative perspective of the textbook model, is to overcome the problem that it is difficult for policy-makers to credibly commit themselves to a long-term strategy (Majone 1997). While preferences of policy makers are likely to change over time (often referred as time-inconsistency problem), a stable framework is needed to provide network operetors with an efficiency incentive. It is supposed to be easier for an independent agency with a clear economic objective to adhere to a regulatory decision than would be the case for policy makers in the face of various trade-offs, changing political circumstances, upcoming elections and the temptation to exploit decisions by regulated parties ex post.

4 Research question and methodology

Having presented the research topic and the literature on liberalisation and transformation of electricity systems in general and distributed generation and network regulation in particular in chapters 2 and 3, I can now elaborate on the research question that was briefly introduced in chapter 1, as well as the methodology and research design.

4.1 Research question: Governance of DG integration and network transformation

4.1.1 Research question

At a general level, the study analyses to what extent the standard model of liberalised electricity markets that was developed to increase the efficiency of electricity supply can deal with new objectives, namely in terms of making the sector more sustainable and reducing its climate impact. How can the standard model be adapted for that purpose and to what extent can insights from the system transformation literature be integrated into the standard model?

Against the background of governance mechanisms in liberalised electricity markets more generally and the question of how the market mechanisms can and must be complemented by other coordination mechanisms, the study focuses on the development of the electricity network infrastructure and the integration of distributed generation.

In the standard model of liberalised electricity markets, the governance of the network infrastructure is mainly based on network regulation in the form of incentive regulation by an independent, economic and sector-specific regulator.

Thus, the main question of my research is how DG integration and network development can be integrated into this governance regime and whether and how the regulatory framework needs to evolve.

Chapter 2 has presented the liberalisation and transformation literatures as two alternative perspectives on the governance of the electricity system. The starting point of the analysis in this thesis is the liberalisation perspective. The main question therefore is not whether the liberalisation or the transformation model is better suited to promoting the network integration of DG, but rather whether and how the standard model can be adapted. The liberalisation model is used as a starting point for the following reasons:

1) Liberalisation and the standard model of economic regulation is currently the dominant regime with clearly spelt-out governance mechanisms for the electricity network. It therefore provides a clear reference point for the analyses, both for the conceptual part and the case studies.

2) The transformation literature has delivered a number of governance proposals, but has not put forward a comprehensive alternative concept for the governance of electricity systems or networks. Rather, it can be regarded as an 'add-on', providing governance mechanisms to complement the standard model or shift the focus within the standard model.

The transformation perspective is used as a basis for challenging the standard model. It helps to think 'outside the box' of the standard model and can provide ideas for the further development of the standard model.

In order to analyse the research question in this thesis, it will be broken down according to both different governance issues that need to be addressed and different governance levels where these issues can be addressed. This structure will be explained in the following two sections.

4.1.2 How the standard model of regulation is defined in this thesis

The main object of the analysis carried out in this thesis is the standard model of regulation that was introduced in chapter 3. The thesis asks how this governance model needs to evolve to accommodate DG. Before explaining in more detail the methodology applied to answer this question, a few words need to be said about the scope of the standard model under investigation, based on the overview of the standard model in chapter 3.

Chapter 3 has shown that price or revenue cap regulation to increase efficiency in the network is a core element of the standard model of regulation in liberalised electricity markets, both in terms of the theoretical foundations and in terms of practical implementation in the regulatory process (e.g. benchmarking procedures). Yet if in this thesis the standard model was limited from the outset to this narrow understanding in terms of objectives and instruments, this would imply that any governance mechanism to promote additional objectives like DG or network transformation would need to be located outside the standard model. Based on this definition, the thesis could still analyse any negative effects of the standard model on DG, but should not attempt to analyse how the standard model can be adapted to pursue DG objectives. However, the further analysis in this thesis is based on a broader understanding of the standard model beyond the narrow definition that was outlined in the previous paragraph. This comprises two dimensions.

First, in terms of economic incentive mechanisms, the broader definition of the standard model put forward by this thesis does not limit the incentive mechanisms to price- or revenue cap mechanisms to increase efficiency. Rather, based on the economic foundations outlined in chapter 3 the standard model can also be understood more generally as a regulatory approach to deal with the principal-agent problem between the regulator and the regulated company, irrespective of the objectives that are to be pursued. The standard model offers a toolbox for the regulator to design incentive mechanisms. The objectives pursued with the help of these mechanisms can go beyond efficiency objectives and are not necessarily only based on price or revenue caps. Such mechanisms are still located within the standard model if they are drawn up by the regulator as one element of regulating network tariffs.

Second, there is more to the standard model than economic incentives to mimick the market mechanism. Rather, the standard model can also be understood as a broader governance arrangement that relies on incentives-based mechanisms, but also comprises other governance mechanisms (see for example the command-and-control mechanisms mentioned in section 3.2.2.2. It is based on 'independent regulators' that determine network tariffs and other rules for the network operators. This understanding of the standard model does not only include meaning I in Figure 4 ('economic regulation of monopolies'), but extends to meaning II ('Regulation as a specific form of governance').

Based on this broad definition of the standard model, the following sections outline the further research process on how the standard model can evolve. The broad definition will be elaborated throughout the thesis. In section 5.2.2 the first dimension of the broader definition of the broad understanding is explained in more detail, which provides the basis for the detailed discussion of various incentive mechanisms in chapters 5and 6. In chapter 7, the second dimension of the broad definition is analysed.

4.1.3 Governance issues

Chapter 3 has presented four stages of interaction between DG and network, which differentiate between connection, integration, innovation and transformation (Table 3). This was mainly based on the technical discussions on DG integration.

These different forms of interaction between DG and the network are likely to have different implications for the governance of the electricity network. Therefore, this table makes it possible to operationalise the overall research question in different steps. It will be used as a heuristic device to structure the analysis of the standard model of network regulation and its potential to integrate DG as a new objective.

This structure enables a differentiated view on the standard model as well as on the comparison between the liberalisation and transformation literatures in chapter 2. For example, it may well be that the standard model economic regulation may be suited to promote DG connection and integration, yet when it comes to innovation and system transformation additional mechanisms as proposed by the transformation literature may be required.

4.1.4 Governance levels

Having presented the connection-to-transformation framework as one dimension structuring the analysis, the governance levels which this thesis seeks to address need to be clarified. The standard model of network regulation generally focuses on the relationship between the regulator and the regulated, i.e. the distribution system operator in this case.

However, when discussing DG integration, the relationship between the DSO and the DG plant operator are of similar relevance. The principal-agent framework that the standard model generally applies to the relationship between regulator and the DSO can be extended to include the relationship between the DSO and the DG operator, with the DSO as the principal and the DG operator as the agent (Jamasb et al. 2005: 6). In other words, what is relevant are both the regulatory incentives for the DSO towards DG, and the mechanisms to coordinate network and generation and the (short-and long-term) signals DG operators receive through the structure of network charges.

Furthermore, the independent regulator that is a core element of the standard model is embedded in the broader institutional context of energy policy-making, so that the regulatory structure is two-tiered, including the regulator on the one hand and government, parliament, etc. on the other hand that draw up the energy policy framework within which the regulator operates and supervise the regulator. Again, this relationship is often portrayed in principal-agent terms (Laffont, Tirole 1993: 477; Majone 1997: 154).

Thus, four different levels and the relationships between them can be distinguished overall:

1) General energy policy

2) Economic network regulation through an independent regulator

3) Distribution system operators

4) DG plant operator

On all of these levels, the connection-integration-innovation-transformation heuristic can be applied.

This thesis focuses on the relationship between the regulator and distribution system operator. It also analyses the relationship between regulation and the wider institutional context and asks whether DG integration affects the policy-regulation relationship. The DSO-DG relationship will only be examined in as far as it is relevant to the other levels of interaction. More information on this aspect can be found for example in (Vogel 2009; Brunekreeft, Ehlers 2006; Jamasb et al. 2005; Späth et al. 2006; Bauknecht, Brunekreeft 2008).

4.1.5 Overview on research framework

The following table summarises the different dimensions of the research question as explained above. The horizontal dimension shows the connection-integration-innovation-transformation heuristic, the vertical dimension the different governance levels. The thesis analyses the first two levels highlighted in yellow.

Table 4: Framework for analysis of the governance of network and DG

	Connection	Integration	Innovation	Transformation
Network regulation in the political context	Is DG just an additional problem for efficiency-oriented economic regulation (level playing field)? Or is regulation to support additional energy policy goals?		What kind of innovations should regulation promote?	Transformation in which direction? Is transformation still a technical question that can be addressed by an independent regulator?
Regulation – DSO	Connection incentives for DSOs	Integration incentives for DSOs	Innovation incentives for DSOs	How to coordinate different actors and innovation activities to achieve overall system transformation?
DSO – DG	Coordination mechanisms between DG investment decision and network requirements/development	Coordination mechanisms between DG operation and network requirements	Coordination between DG and DSO innovation	

Based on the horizontal and vertical dimensions discussed above as well as the broad definition of the standard model outlined in section 4.1.2, the overall research question can be specified as follows:

The first step is to analyse (incentive) regulation mechanisms with regard to DG and mechanisms to promote DG connection in this framework. This is followed by an analysis of how the regulatory framework can facilitate DG integration. In chapter 5, connection and integration will be analysed jointly, as both rely on the same mechanisms within the incentive regulation framework.

Taking into account the policy-regulation interface, the rationale of the regulator to include DG into its regulatory framework needs to be explored: Is DG included because it is a new market actor that needs to get access to the network or is it because DG is an energy policy objective?

If DG capacity increases, the regulatory challenge is not merely to reduce connection barriers for DG and integrate DG into the existing network, but also to introduce innovative network concepts. The impact of the standard model on innovation and the possibility to incentivise DSO innovation through the regulatory framework are analysed in chapter 6. Again, the political dimension of innovation support needs to be taken into account.

Chapter 7 asks whether the standard model of incentive regulation is sufficient when it comes to transforming the network and generation structure, rather than ‘simply’ maximising the efficiency of the existing system or introducing innovations in individual networks.

Using the insights from chapters 5 and 6, this chapter also discusses the policy-regulation interface and how it is affected by the different steps in the connection-integration-innovation-transformation heuristic.

It is important to note that this thesis is not so much about developing detailed guidelines or proposals for adapting the standard model. Rather, it explores the principle mechanisms for taking into account DG. It analyses the potential of the standard model for integrating DG as a new issue, as well as its limits.

4.2 Research design and method

Following the presentation of the research question in the previous section, this section presents the research design and the methods of data collection and analysis.

4.2.1 Overview

The research question will be analysed from two angles: Firstly, part two of the thesis consists of a mainly theoretical analysis of the standard model of network regulation and its potential to accommodate DG as well as network innovation and transformation. Various approaches to amending the standard model of network regulation are discussed.

Secondly, while the conceptual part analyses *design options*, part three contains two country case studies of the *actual development* of network regulation in the UK and Denmark, complementing the analysis in part two. The structure of both the chapters in part two as well as the case studies is based on the ‘connection, integration, innovation and transformation’ heuristic presented earlier.

Combining the conceptual analysis in part two and the case studies in part three is a form of triangulation in a double sense: The research question is approached from two different perspectives and two different methods are used (Flick 2006: 108-109).

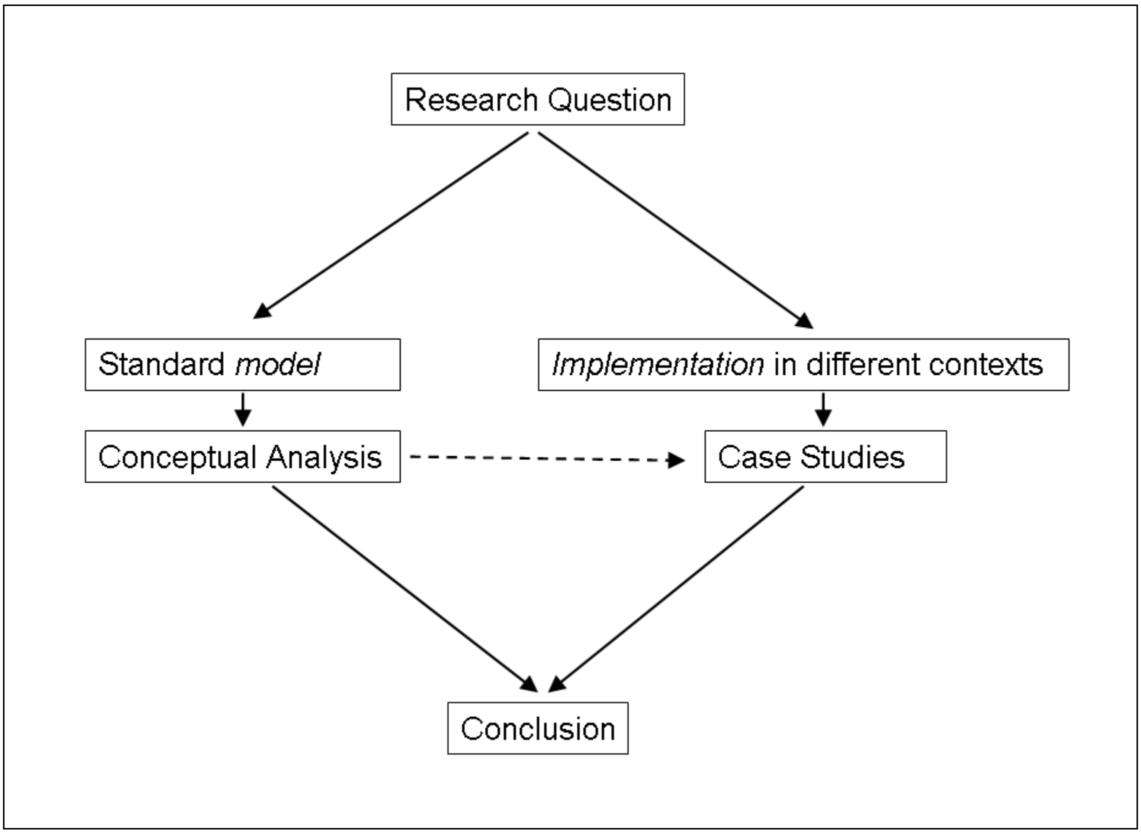
Part two asks how the standard model could be adapted in principle and part three analysis two empirical cases to find out how the standard model is applied and adapted in practice. Part two provides a conceptual discussion mainly based on the economic literature on regulation as well as the system transformation literature, while part three applies a case study approach.

The distinction between the analysis of the model and its implementation is relevant to answer the research question, because the standard model must prove its adaptability both in conceptual terms as well as in concrete political contexts. Network regulation in practice is not simply a result of functional requirements, but develops in a political process. Adaptations of the standard model always need to fit into specific political contexts. As was pointed out in chapter 2, the development of the standard model is an ongoing process and a multi-country experiment. The case studies analyse how this experiment deals with DG in two different countries and studies different patterns of the development of the standard model.

At the same time, the conceptual part analyses the potential of the standard model, which may not be completely visible in the case studies due to the specific political context and process, because design options have only partly been implemented in practice and because the case studies can only examine two cases. The conceptual part also provides an input for the case study analysis, as the case study findings can be compared against the design options discussed in the conceptual part.

The following figure shows how part two and three relate to each other as well as to the research question.

Figure 7: Triangulation through conceptual analysis and case studies



Overall, the conceptual part and the case studies complement each other and their combination renders their respective weakness less severe. The case study results themselves based on only two cases make it difficult to draw conclusions about the standard model or even the potential development of network regulation in other countries. Yet together with the conceptual part they can contribute to the evaluation of the standard model and its development. The conceptual part does not take into account 'real-life' settings. It is therefore useful to check its findings in the case studies.

4.2.2 Conceptual part

The conceptual part does not analyse the implementation and development of the standard model in the context of specific countries, but analyses the principle effects of the standard model and possible design options to adapt this model. This will be illustrated by country-specific examples where appropriate.

The conceptual analysis is partly based on the economic literature on regulation, and partly on the insights found in the transformation literature.

In the conceptual part, the following aspects will be analysed:

1) how the standard model affects the new objectives (DG connection and integration, innovation and transformation),

2) how the mechanisms provided by the standard model can be applied to pursue these new objectives, and

3) what the limits of the standard model are.

This is based on:

1) a review of the relevant literature, including academic literature, the results of national and international research projects on DG integration and various consultancy documents, and

2) examples of relevant governance mechanisms implemented in different electricity systems.

Based on these, this part of the thesis provides a discussion of the standard model and its development options. As previous studies have focused on technical issues or individual aspects of governance mechanisms or have analysed the standard model with regard to more traditional questions like network investment, this study contributes a comprehensive analysis of the standard model's potential to adapt to new issues and objectives.

4.2.3 Case studies

The second main part of this thesis is made up of two detailed case studies. The case studies analyse governance mechanisms on a country level because these mechanisms for the network are usually put in place for a country as a whole. In Denmark, it needs to be taken into account that there is a difference between the eastern and western part of the country, both in the development of DG penetration as well as the traditional structure of the electricity system.

The case studies investigate what kind of governance mechanisms addressing connection, integration, innovation and transformation are emerging in the two countries. More specifically, the case studies analyse the extent to which DG integration and network transformation are being integrated into the standard model of network regulation, whether and how the regulatory framework evolves and the extent to which other governance mechanisms can be observed that go beyond adaptations in incentive regulation. This analysis is compared with the more conceptual analysis in part two.

As compared to the conceptual part, the case studies to some extent include a process perspective. This means that they do not just analyse a snap-shot of governance mechanisms, but their development process, too. This is important for understanding the adaptability of the standard model and how it evolves. However, the case studies do not include a full-blown policy analysis that seeks to identify all the factors that have driven this development in the specific context of the case study, including the interests and influence of different actors and their interaction with the institutional context.

Both case studies provide a qualitative analysis of governance mechanisms. The main period of study is between 2000, when DG started to become a network issue in both countries, until 2007.

4.2.3.1 Selection of case studies

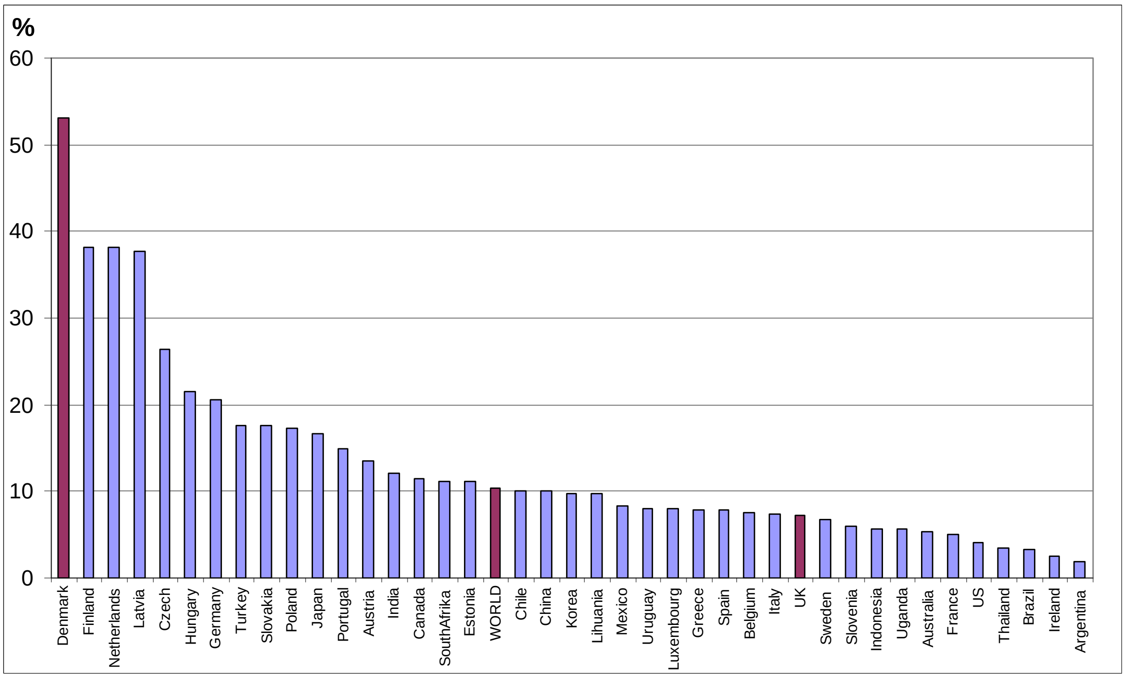
The selection criteria for the case studies are based on the research question: "How can the standard model of network regulation adapt to enable an increasing share of DG?" Selection criteria are thus the share of DG and the role of standard model in the respective country.

The case studies should exhibit a certain degree of similarity in that DG should be a relevant issue and the standard model should be implemented in both countries. However, there should also be differences, as the main reason for the case study approach is to find out how the standard model is adapted. Therefore, the reason for analysing two case studies is to generate a broader variety of insights into different governance patterns in different implementation contexts of the standard model. Based on these criteria, I have chosen to study Denmark and the UK.

In terms of the first criteria (share of DG), DG has become an issue in both countries and the share of DG has been increasing, so the two countries neatly tally with the general problem description in chapter 3. Despite the difficulties of comparing DG statistics mentioned in chapter 3, it can be argued that Denmark is well ahead of other industrialised countries in terms of its share of DG. This is confirmed by the data from WADE shown in Figure 8, the overview of different DG studies by Ackermann (2007) as well as the IEA country review on Denmark (IEA 2002b: 5, 99), according to which Denmark has the highest share both in wind and CHP.

At the same time, Denmark has started to develop a new system architecture and can be regarded as a *"laboratory for the future electricity grids in Europe"* (Bach et al. 2003). Denmark, having a share of DG that is over 50%, is a pioneering country when it comes to implementing and testing new network concepts.

Figure 8: Share of DG in electricity generation in 2005



Source: (WADE 2006)

The UK on the other hand has a relatively low share of DG, but has political objectives to increase its share, so that the standard model of network regulation has been confronted with this new objective, yet in a different way than in Denmark.

In terms of implementing the standard model, both countries have in principle put into practice the same standard model of network regulation. The UK has been a pioneer in developing governance mechanisms for liberalised electricity markets in general and in terms of network regulation in particular and has been said to represent the *"gold standard of effective incentive or performance-based network regulation"* (Joskow 2006b: 17).

In principle, Denmark has subscribed to the same standard model of liberalised electricity markets and network regulation. However, while the standard model has to a large extent been developed in the UK, Denmark has adopted it from the outside and has adapted it to its own governance context.

The case study selection can be summarised as follows: on the one hand the UK is analysed as the pioneer of the standard model, in which DG has become a relevant issue. Denmark, on the other hand, is analysed as the pioneer of DG development, which has adopted and adapted the standard model. Hence, in both countries the governance mechanisms which have developed to integrate DG based on the standard model can be analysed, albeit with different perspectives.

4.2.3.2 Data collection

The data collection was structured by the research framework presented in Table 4, which allows for data on different governance mechanisms to be categorised, either because these mechanisms have explicitly been put in place to achieve connection, integration, innovation or transformation, or because they aim at the technical challenges presented in Table 3 in chapter 3.

Using the standard model as a reference point has also facilitated the data collection process as any governance mechanisms could be contrasted with the governance approach proposed by the standard model.

Besides data that describes these governance mechanisms, data was collected on the reasons for the development of these mechanisms in a process perspective as explained above, as well as data that allows evaluating these mechanisms. Regarding the latter aspect, the aim was not a comprehensive evaluation, but rather to find at least some indications of their functioning in practice in order to complement the conceptual analysis.

The data is mainly qualitative since the main objective was to describe the governance mechanisms applied and their development process. In some cases, quantitative data was used to describe the governance mechanisms, especially because economic regulation is to a certain extent about getting the numbers right, and evaluate their outcomes.

The data collection for the case studies relies on different data sources (Yin 2003: 97-101), partly because this was necessary to obtain a comprehensive picture and partly because different sources allow for cross-checking or data triangulation. Data sources consist mainly of written material, i.e. primary documents published in the regulatory or policy process (e.g. published by the regulator) as well as studies on different aspects of network regulation.

This is complemented by semi-structured interviews with various stakeholders. Interviewees were chosen based on their proximity to the governance process under examination as well as the need to cover a broad range of stakeholders and perspectives (regulators, network and DG operators, industry associations, government departments, equipment manufacturers, research). A total of twenty-three semi-structured interviews were conducted. A list of interviewees can be found in the reference section.

It became clear at an early stage of the research process that Denmark has adopted the standard model, but when it comes to DG integration and transformation it heavily relies on a number of governance mechanisms which lie outside of the standard model. In contrast, in the UK the standard model plays a key role also with regard to the new objectives. This difference between the two cases needs to be reflected in the research strategy and therefore also in the questionnaires for the two countries: The questionnaire for the UK interviewees places more emphasis on the development of the standard model whereas the Danish questionnaire gives more room to other governance mechanisms while still including questions about the standard model (for the questionnaire see appendix).

This difference between the two countries is also reflected in the availability of data. In the UK, the standard model and the regulator Ofgem represent a clear institutional focus of the regulatory process. The development and implementation of network regulation is relatively well documented and largely based on public stakeholder consultations that provide a rich source of material. In some cases, minutes or summaries of relevant meetings are available.

In Denmark, it has been more difficult to access the relevant information, partly because governance structures are more dispersed and sometimes less explicit, partly because the Danish discourse seems to be more technically-oriented, and partly because of language problems. Interviews have therefore been a more important data source for the Denmark case study.

Having presented the research question and methodology based on the literature review in chapters 2 and 3 the following part two of the thesis goes on to present a conceptual analysis of the standard model. This will be complemented by the two country case studies in part III.

Part II:
Conceptual analysis

5 Network regulation and DG

In chapter 3, the standard model of network regulation was presented as part of the liberalised market model. How incentive regulation was designed to reduce the costs of electricity networks in order to support the efficiency objective of liberalisation was shown. In chapter 3, I have also discussed literature which argues that DG can increase the costs of the electricity network. Thus, DG clearly runs counter to the objective of reducing costs.

This chapter deals with connection and integration of DG as shown in table (chapter 4). The chapter consists of three sections: The first section elaborates on the potential conflict between the incentives provided by the standard model on the one hand and the objective of connecting more DG on the other hand. The second section discusses the relationship between efficiency and the DG objective. It presents a differentiated view on the standard model in order to move beyond the incentive regulation vs. cost-plus regulation dichotomy. Finally, the third section presents design options for integrating the DG objective into the standard model framework.

5.1 DSO incentives resulting from DG

This section provides an overview of the mechanisms through which DSOs are affected by DG and how this translates into economic costs or benefits for the DSO under different regulatory regimes.

DG can have the following effects on the network and the network operator:

- DG can cause additional costs, both operational and capital expenditure (Opex and Capex),
- DG can reduce the volume of electricity sold over the network; and

- DG can entail network benefits, e.g. it can replace or defer network investments.

This section provides a generic overview. Country-specific studies can be found in (Späth et al. 2006; Connor, Mitchell 2002; Frey et al. 2008; Skytte, Ropenus 2005).

5.1.1 Additional network costs

Additional costs do not hurt the DSO under a cost-plus approach, assuming that they are accepted by the regulator. However, the cost-cutting environment that is being established in most liberalised markets through the standard model can be detrimental for DG. Under this type of regulation, the incentive for the DSO is to cut costs (see chapter 3.2). As a result, the DSO under pure price-based regulation will want to avoid additional costs caused by DG.

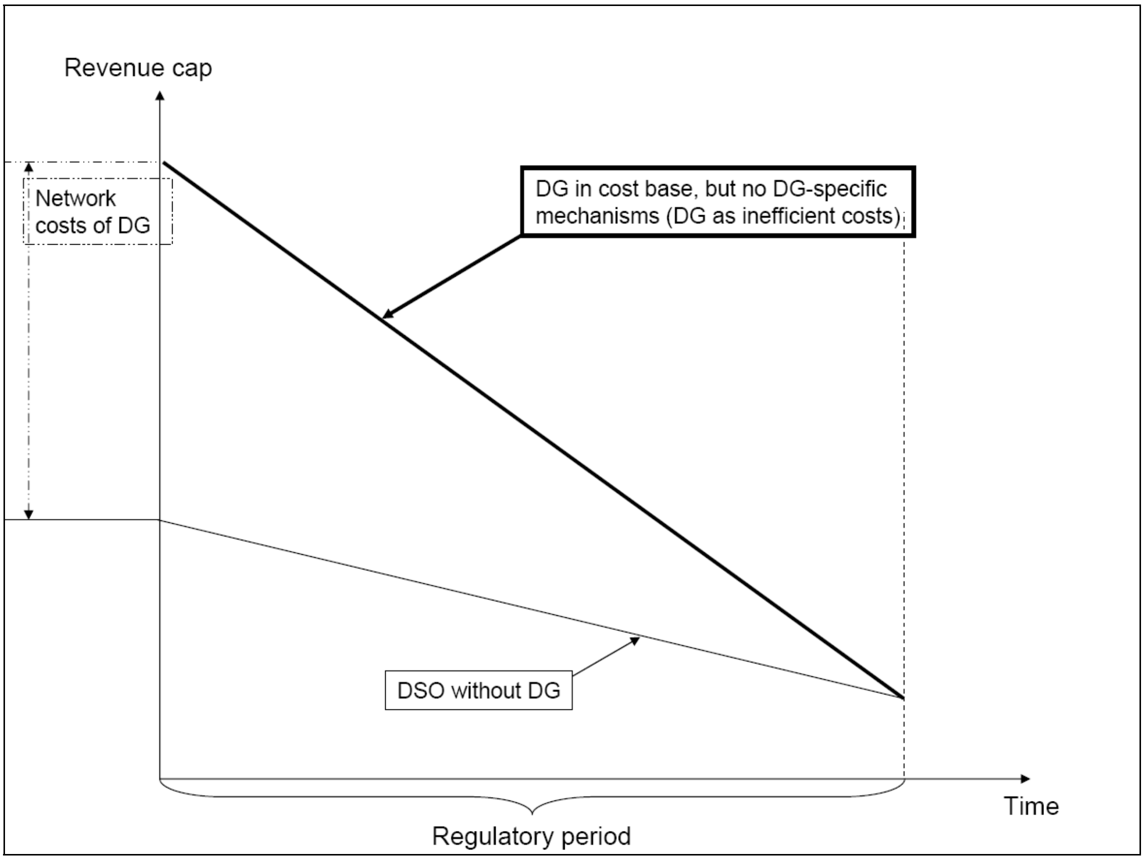
It is sometimes argued that price- and revenue-cap regulations have different effects with regard to DG and that *"price cap regulation generally discourages distributed resources. Revenue cap regulation does not"* (Moskovitz 2000: 3). While this argument can be valid with regard to the volume reduction caused by DG (see 5.1.2), the argument that a revenue-cap (as opposed to a price-cap) allows the network company to increase network tariffs if DG causes additional costs (Ackermann 2004: 285) does not hold. As revenues are capped, increased costs cannot be offset through higher revenues, at least not during one regulatory period. Consequently, both price- and revenue cap regulation tend to provide an incentive against DG.

When analysing the costs of DG and the way in which they affect the DSO, it is important to differentiate between different cost categories, namely between operational costs (Opex) and capital costs (Capex). Depending on the regulatory treatment of these cost categories, the DSO may benefit from shifting costs between them. This is likely to influence its attitude and strategy towards DG. Separate treatment of Opex and Capex tends to focus on incentivising operating cost efficiency, while Capex is often still subject to cost-based regulation. The separate treatment of Opex and Capex is likely to promote network investment but also to distort overall cost optimisation.

If the network is upgraded to accommodate additional DG, Capex will increase. Other approaches to network management (see chapter 3) can reduce the need for network upgrades and hence Capex, but can entail additional Opex, especially if the lower network capacity needs to be managed actively. If Opex is subject to price-based regulation and Capex is not, the DSO is likely to be in favour of the more capital-intensive option, even though the overall costs can be higher. Price-based regulation with a focus on Opex reduction can thus have a similar effect on the DSO's choice as rate-of-return regulation with its incentive against capital-saving investments. The separate treatment of Capex and Opex in the UK is a case in point (Mitchell, Connor 2002: 12).

The following graph shows how the revenue- or price-cap develops in the standard model within one regulatory period for a DSO without DG and one with DG. The assumption is that the regulator accepts the costs of DG in the company's cost base, but does not take them into account when determining the company's efficiency. DG costs are essentially treated as inefficient costs which are not necessary to run the network in order to supply electricity customers. The revenue path for the DSO with DG forces the company to reduce its costs to those of a network without DG within one regulatory period. The DSO with DG would be even worse off if the regulator did not even accept the DG costs in the cost base. In this case, its revenue path would match the one shown for the network without DG.

Figure 9: Development of the revenue if DG costs are not taken into account



Source: Author's own, first published in German in (Frey et al. 2008: 194)

5.1.2 Load reduction through DG

Another concern for network operators with regard to DG is that it reduces the electricity volume and/or the peak load on their network. Reducing the load on the network indeed runs counter to efforts to increase the load factor that has driven the development of the electricity system from the very beginning (Davies 1995; Hughes 1987). In those cases where DG reduces network utilisation, it can be seen as a new competitor to the network that can lead to stranded network assets.

The incentive to maximise the load factor is further increased under incentive regulation because – as Newberry (2001: 51) has pointed out – it is a distinctive feature of this type of regulation *"that the utility receives no return on unutilised capacity"*. This is closely related to the objective of incentive regulation to reduce costs. A reduction of the numbers of kWh sold over the network has negative effects on the revenue of DSOs. As network costs are largely fixed costs, reducing the electricity volume distributed over the network does not entail a significant decrease in network costs. If DSOs cannot increase the revenue per kWh, profits will be diminished accordingly.

Exactly how the deployment of DG reduces the utilisation of the network depends on the specific case. For an analysis of generic cases see Ackermann (2004: 186-210). Especially if DG is installed on the customer-side of the meter and mainly provides on-site power production, DSO sales are adversely affected (RAP 2000). Developments that enable the deployment of micro-generation by small consumers or microgrids serving a specific area, and where the meter is situated between the utility network and the microgrid, could exacerbate this problem for the DSOs. In Germany, for example, there have been extensive discussions as to whether local networks have a right to be connected to the medium- rather than the low-voltage network (Mevert, Hobbeling 2004). This could increase the attractiveness of these local networks and reduce the revenue of the DSOs.

While revenue- or price-cap approaches have the same effect with regard to additional costs of DG (see 5.1.1), the reduced utilisation of the network can have different repercussions under the two regimes. Under a price cap, the network operator is not allowed to offset a volume reduction that is due to DG with higher tariffs. In contrast to a price-cap regime, this would in principle be possible under a revenue cap. This gives the company an additional degree of freedom besides cost reduction. However, the company may prefer in practice to meet the volume forecast that was made at the beginning of the regulatory period rather than to increase tariffs. Under a price cap, DSOs will therefore try to maximise sales,while under a revenue cap it will at least try to meet the volume forecast.

5.1.3 Network benefits

As compared to a rate-of-return regime, incentive regulation in principle increases the incentive for DSOs to utilise DG to reduce network costs since the DSO can keep part of the efficiency gains to itself. In practice, however, it may be difficult for the DSO to actually benefit from DG having a positive effect on the network.

The first problem is that once DG has been connected it may be used to reduce network costs. Yet taking into account the connection costs DG will often still increase the overall costs, which is clearly a problem under price-based regulation (see figure in chapter 3)

For the DSO to be able to reap the associated benefits, it is important that DG is not only connected, but also integrated into network operation and operated in line with network requirements. While costs will be incurred simply by connecting DG, benefits will only become visible in many cases if the system adapts. Additional costs may thus be incurred upfront but cost savings only emerge much later and are uncertain (e.g. because this also depends on overall system development). This is particularly problematic because incentive regulation gives an incentive to reduce short-term costs at the expense of long-term benefits.

Integrating DG often also means that costs are reduced. Yet at the same time costs are shifted between cost categories or new types of costs become necessary, which may also be at odds with the regulatory process. For example, in Germany there have been problems with regard to the DSOs gaining the regulator's acceptance for new DG-related costs (Frey et al. 2008)

The regulatory problems with cost reductions through DG become particularly visible in cases where DG can replace network investments. It is often claimed (e.g. the studies mentioned in chapter 3 by A.D. Little (1999), Iannucci et al. (2003), Gumerman et al. (2003)) that one of the main advantages of DG is that it can replace or defer network investment that becomes necessary either because old network equipment needs to be replaced or because demand increases in a network area and can no longer be covered by the existing capacity. Instead of building additional network capacity, a DG plant could provide the generation capacity locally, provided that it meets certain reliability requirements. Article 14/7 of the 2003 EU Electricity Directive (Directive 2003/54/EC) requires DSOs to consider DG as an alternative to network expansion.

Although this is clearly a potential network-related benefit of DG, the DSO may be opposed to it. Under pure cost-based regulation, it is clear that the DSO has no incentives to reduce costs. If it can earn a fixed rate-of-return on its network assets, the DSO would not want to replace its own network assets with other companies' assets.

With incentive regulation a DSO can stand to benefit from reducing costs by deferring or replacing network investments. Yet even with this regime replacing the network with DG also means replacing the DSO's business with the generator's business, introducing a form of competition to the network. For the DSO, this will be particularly problematic if the DSO is unbundled from other functions and can therefore not invest in DG itself and has to leave this up to third-party generators (Brunekreeft, Ehlers 2006).

As increasing DG to replace network assets would reduce Capex but increase Opex costs, the incentives of the DSO also depend on whether these cost categories are treated in a way that allows for overall optimisation. If Capex regulation is still cost-based, there would be a disincentive to shift costs from a cost-based into a price-based regime.

Furthermore, on top of shifting costs from Capex to Opex a network solution can lead to new costs and risks that may not be taken into account by the regulator. For example the DSO may have to remunerate the DG operator for adapting plant operation to network requirements. Relying on third parties and assets that typically have a lower lifetime than network assets also increases the risk for DSOs. These new costs also need to be reflected as an additional cost in the regulatory process.

5.1.4 Summary

Table 5 summarises the effects of DG on the DSO under different regulatory regimes.

Table 5: The effect of DG on the DSO under different regulatory regimes

Potential network effect of DG	**Mechanism to determine the level of network tariffs**		
	Cost-based regulation	**Price-based regulation (Price-cap)**	**Price-based regulation (Revenue-cap)**
If DG causes additional costs (Capex/Opex)	No incentives against costs of DG. In principle incentive to increase capital base through DG.	Higher costs lead to lower profits/losses during the regulatory period. ->Incentive against DG If only Opex is benchmarked, incentive to shift Opex to Capex (e.g. expand network instead of using DG to improve network operation).	
If the load on network is reduced through DG	Lower volume can be offset with higher tariffs to meet profit target.	Lower volume leads to lower revenue ->incentive against DG	DSO may be able to offset volume reduction through a price increase.
If DG causes network benefits	No incentive to reduce costs through DG.	DSO can benefit from reduced costs through DG. Long-term benefits may entail short-term costs. Incentive regulation can give an incentive to reduce short-term costs at the expense of long-term benefits.	
If DG replaces network investments	Against DSO's incentive to maximise rate-base.	Reducing or deferring costs can be attractive, but DSO may not like to shift costs from Capex to Opex. New costs and risks may not be taken into account by the regulator.	

Source: Adapted from (Bauknecht, Brunekreeft 2008)

Overall, it can be stated that there is a mismatch between the incentives to reduce costs provided by the standard model on the one hand and the additional costs of DG and the stranded network assets DG can entail on the other hand. In those cases where DG benefits could be used by the DSO to reduce costs and thus meet the objective of the standard model, this may not be facilitated by the regulatory process.

5.2 Integrating new objectives and incentives into the standard model

The previous section has shown how the objective of the standard model to increase the efficiency of networks can run counter to the objective of integrating DG. Before discussing various options for designing DG incentives within incentive regulation, more detail needs to be given on why the regulator should deal with DG as well as on the relationship between the efficiency objective and the DG objective. Also, a more differentiated view on the cost-based vs. incentive regulation paradigm is needed. This shows that the main question is not to choose between the two, but within these paradigms there is room for designing specific incentives.

5.2.1 Regulatory objectives beyond efficiency

5.2.1.1 Rationale for considering DG within network regulation

The DSOs' incentives against DG that result from incentive regulation will be a significant barrier for DG. Assuming that DSOs are profit-maximising companies, this remains the case even if the DSOs have a statutory obligation to connect DG. The fact that obligations are generally not sufficient for implementing regulatory objectives was the very reason for introducing incentive regulation in the first place (Weisman, Pfeifenberger 2003).

But why should the regulator consider DG as an issue, given that its objective is to increase the efficiency of the network? There are two options: Firstly, DG can increase overall efficiency despite higher short-term costs in the network. In this case, DG is used as a means to support the efficiency objective. Secondly, DG is introduced as an additional objective, alongside the efficiency objective.

In terms of the first option, DG may be able to support the efficiency objective despite higher short-term costs in the network for two reasons: Firstly, within the network, it could be argued that DG leads to higher network costs in the short term, but can potentially reduce network costs in the long term, thereby contributing to the efficiency objective in the network. However, this is rather uncertain and requires the regulator to deal with the trade-off between short-term and long-term costs. Moreover, it is scarcely possible to analyse the resulting long-term network costs on a case-by-case basis for individual DG connections; rather, an assessment of the benefits of a new, more decentralised electricity system compared to the traditional centralised one would be required. This would go beyond the objective to increase efficiency and beyond the remit of an economic regulator to evaluate and promote decisions by individual network operators. Therefore a political decision on the future network infrastructure is required. For these reasons, as well as the political expectation that there is a short-term potential for cost reductions resulting from the monopolistic era, this trade-off between short- and long-term costs will eventually become a political decision.

Secondly, higher costs in the network may be outweighed by more competition in the generation market, with lower overall cost. The rationale for the regulator to consider DG can in principle be derived from the objective to provide the network as a level playing field for different market players in the competitive part of the market, including DG. Introducing a regulatory framework that provides incentives against DG is not in line with the requirement of providing non-discriminatory access. If this rationale is applied, higher costs in the network would essentially be justified by lower generation costs due to stronger competition.

This means that the level playing field approach would be broadened so that it is no longer restricted to providing access to the existing network, but also includes access for technologies that require a different network, at least as long as this increases overall system efficiency. Again, the net benefits of DG are rather uncertain. Moreover, this approach requires the regulator to deal with the trade-off between the benefits of competition in the national market and additional costs in individual networks.

As for the second option, if DG is introduced as an additional objective, this would go beyond the remit of the regulator in the standard model and could only be based on a political decision. As discussed in chapter 3, a main driver for DG in practice has been political objectives rather than economic benefits. It can be argued that it would be counterproductive to provide political support for these technologies on the one hand and incentivise network operators against DG on the other hand. Integrating DG into the standard model thus becomes a matter of policy integration.

However, this should not be confused with setting up a support scheme for DG within network regulation. With this approach, support for DG technologies as such would still be located outside network regulation. Yet network regulation would ensure that the network can accommodate these plants and enable network connection and integration of DG, rather than providing incentives against DG within the standard model.

In summary, DG can in principle be taken up by the regulator as part of its efficiency objective even if it increases network costs. However, if DG is only seen as a way to support the efficiency objective and the level-playing field approach, regulation of DG costs would only take into account DG plants that contribute to this objective. All other plants would not be considered. Moreover, it is difficult in practice for regulators to deal with the cost trade-offs this involves. Therefore, regulators will most likely require political backing even though this approach in principle remains within the remit of the regulator. Irrespective of the cost savings that can be achieved through DG, DG regulation requires the introduction of DG as an additional regulatory objective. In this case, DG is no longer treated within the 'apolitical' efficiency framework of the standard model; rather a political mandate is needed for the regulator to design DG-specific instruments and deal with the economic constraints of DG deployment.

5.2.1.2 The relationship between the efficiency and the DG objective

How does such an additional DG objective relate to the original efficiency objective? Is the DG objective, which will lead to higher network costs in many cases at least in the short term, contradictory to the efficiency objective? Importantly, incentive regulation was introduced to increase network efficiency, but efficiency is not an end in itself.

Rather, the objective was to increase the efficiency of supplying electricity consumers via the network. If efficiency or cost reduction becomes an end in itself, this can undermine the supply objective and threaten the quality of electricity supply. This has led to the debate on quality regulation that needs to complement incentive regulation (Ajodhia, Hakvoort 2005). At the same time, increasing the share of DG and adapting the network accordingly should not lead to a waste of resources, either. Therefore, the efficiency objective should apply to DG, too.

The tension outlined in section 5.1 does not occur between the efficiency and the DG objective, but between supplying electricity via the network in an efficient way and increasing the share of DG in an efficient way. Both objectives are to be reached via the same network, but for different target groups. Increasing the efficiency of electricity supply via the network is an objective that is internal to the network and its customers whereas increasing the share of DG for political reasons (or to promote competition) is external to the individual distribution network. If more DG in one distribution network contributes to meeting political objectives, society as a whole would benefit. Yet from a supply perspective in the individual network, the costs will appear as inefficient, even if DG is connected in an efficient way.

While this general mismatch between internal and external objectives cannot be overcome within the regulation of individual network companies, what regulation can do is to remove the disincentives for the DSO to help reach the external objectives. However, within the framework of economic regulation, this means shifting the costs to the customers of this individual network company.

The following sections on the design of DG mechanisms are mainly based on the assumption that DG is introduced as an additional objective.

5.2.1.3 Principles for the design of DG mechanisms

Having analysed the general relationship between the DG and the efficiency objective, this section puts forward a number of principles on which the design of regulatory instruments should be based.

Section 5.1 presented three different effects of DG on the DSO. The discussion on designing DG incentives in section 5.3 will focus on how additional costs of DG (see 5.1.1) that are likely to prevail in the short term can be dealt with in the regulatory framework. As for the other aspects, the volume reduction (section 5.1.2) is considered less of a problem, at least as long as most DG plants are connected directly to the DSO's network. I have already pointed out that a revenue cap is in principle superior to a price cap for dealing with this issue. Other options discussed in the literature are compensation for volume reductions through, for example, regulatory accounts or multiple-driver cap schemes (Bundesnetzagentur 2006; Thomas 2001; Takahashi et al. 2005). In the case of network benefits of DG (section 5.1.3), the regulatory process needs to take into account additional cost categories that enable net benefits, e.g. remunerations for DG because the plants are operated in line with network requirements.

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 as to how these additional costs can be taken into account. Combining the DG and efficiency objective, the following principles should apply:

- The DSO should not be penalised if there is a lot of DG connected to the network, leading to higher network costs. For example, the high network costs may be due to a lot of primary energy potential for renewables in this network area. Otherwise, DSOs will be opposed to DG. DG-related costs should therefore explicitly be recognised in the regulation of allowed network tariffs/revenues. As explained in the previous section, this entails an increase of network tariffs for the customers in the respective network area.

- The DSO should connect a given amount of DG as efficiently as possible. While the number and type of DG connections in a network area are exogenous to the DSO, the DSO does have an influence on the costs of individual connections and reinforcements of the network that become necessary due to DG. DG integration can further reduce network costs.

Given these objectives, it is clear that DG-related network costs should be included in the calculation of allowed revenues or tariffs, but a DSO should not simply be reimbursed for all the costs which it declares. A balance must be struck between the connection incentive and the efficiency incentive. Before discussing mechanisms to achieve this in section 5.3, the following section provides a basis to this end by putting forward a differentiated view of the dichotomy between cost-based vs. incentive regulation.

5.2.2 A differentiated view of the cost-based vs. incentive regulation paradigm

The standard model I have presented in chapter 3 is often called 'incentive regulation' and contrasted with previous models like cost-plus or rate-of-return regulation. A few points need to be made about this distinction that I consider particularly important for the further analysis of the potential to integrate DG into the standard model.

This relates to the broader definition of the standard model that was introduced in section 4.1.2 as part of the research framework. While the implementation of the standard model in liberalised electricity markets is typically equated with the introduction of price- or revenue cap-mechanisms to increase efficiency, the standard model can also be understood as a framework for designing incentive mechanisms, irrespective of the objectives.

First of all, although the new regulatory paradigm is called "incentive regulation", it is important to note that every regulatory approach creates certain incentives for the regulated company. Indeed, even without regulation, the company would have certain incentives, e.g. to set tariffs so as to maximise its profit. The most well-known unintended incentive resulting from rate-of-return regulation is the so-called Averch-Johnson effect whereby companies have an incentive to overspend on capital (Averch, Johnson 1962). Similarly, an incentive regulation framework that does not take into account DG is not neutral towards DG, but rather incentivises the DSO to avoid DG as discussed in section 5.1.

Secondly, although every regulatory framework leads to specific incentives, there is nevertheless a good reason for why “incentive regulation” is an appropriate term for the standard model. As opposed to previous approaches, the standard model was deliberately designed to give the network operators specific incentives, namely the incentive to become more efficient. More generally, based on new regulatory economics (see chapter 3), the standard model provides a framework within which specific incentives can be explicitly designed. Yet the approach also recognises that the ultimate incentive of the regulated companies is to increase their profit and acknowledges the shortcomings of a simple command-and-control approach which neglects the companies’ self-interest. The regulator can thus only set incentives and try to make use of the companies’ profit incentive.

Thirdly, incentive regulation as applied in the standard model is in essence a price-based approach while prior to liberalisation cost-based approaches were more prominent. Cost-based approaches determine network tariffs on the basis of each company’s individual costs and are mainly concerned with avoiding monopoly rents. In contrast, price-based regulation decouples prices from costs and sets the tariffs for all companies irrespective of individual costs. This is the mechanism that is to mimic the competitive market and give companies an efficiency incentive.

Fourthly, price-based regulation and cost-based regulation represent two theoretical polar cases that tend to be mixed both within the standard model and its predecessors. Although the standard model does represent a new regulatory paradigm, incentive regulation in practice has significant overlap with cost-based approaches (Joskow 2006a).

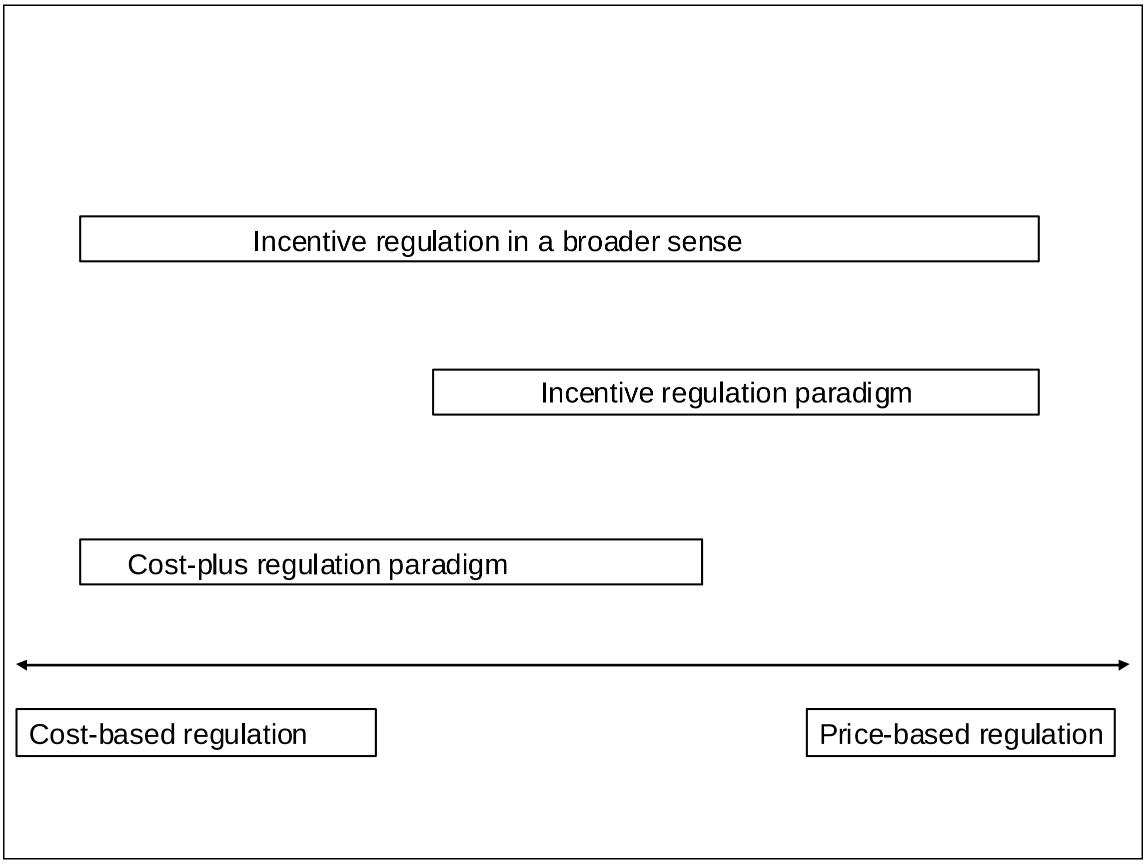
Incentive regulation does shift the emphasis towards price-based mechanisms, but there are still cost-based elements. While it was one of the core ideas of price and revenue cap-regulation to decouple prices from costs, this is only carried out for one regulatory period. At the beginning of each regulatory period, the cap is adjusted to a company's new cost level which was achieved at the end of the previous period. Also, even under predominantly price-based regimes, certain costs can be passed-through to customers on a cost basis. For example, as (Joskow 2006a: 21) has pointed out that *"although it is not discussed too much in the empirical literature, the development of the parameters of price cap mechanisms using statistical benchmarking methods have typically focused primarily on operating costs only, with capital cost allowances established through more traditional utility planning and cost-of-service regulatory accounting methods including the specification of a rate base"*. There are also profit-sharing rules, establishing a band of maximum and minimum profits, so that pre-determined tariffs can be adjusted if profits become either too large or too small. All this can add a cost-based element to 'incentive regulation'.

Similarly, approaches like rate-of-return regulation which are primarily cost-based can include price-based elements. Under incentive regulation, there is a regulatory period that is fixed ex-ante; cost-based approaches also tend to be characterised by a regulatory lag between rate cases. This is usually shorter than the regulatory period and rate cases will eventually be triggered by cost changes. Nevertheless, during a regulatory lag prices can deviate from the fair rate-of-return determined by the regulator. Also, even under the previous cost-based regime, regulators did not normally accept all costs, but adopted mechanisms like use-and-useful clauses, stipulating that the costs of an investment can be passed through to network tariffs only if the investment is used and is useful (for the U.S. see Joskow 1989: 161). In order to decide whether or not to accept certain costs, the regulator will typically look at other companies, with the result that the pure cost-based approach is complemented by some form of benchmarking which is typical for price-based regulation.

Fifthly, and summarising the previous points, incentive regulation can have a broader meaning and is not just about replacing cost-based regulation with price-based regulation to increase efficiency. Rather, it refers to a regulatory framework where incentives for the regulated company are explicitly designed to pursue specific objectives. These objectives can be broader than just efficiency and the menu of regulatory options becomes broader, too. Generally speaking, the incentive resulting from cost- and price-based elements can be explicitly combined to create an appropriate incentive structure. This means that incentive regulation in this sense contains cost-based elements not just because the shift to price-based regulation has not yet been completed or because cost-based mechanisms have crept in during the practical implementation of incentive regulation. Rather, the incentives properties of cost-based elements can deliberately be used to pursue certain objectives. For example, with this understanding of incentive regulation cost-based regulation would be deliberately applied to capital expenditures (see quote from Joskow above) to give companies an incentive to invest – rather than just being a relict that the regulator has not yet got around to replacing with price-based regulation.

The following figure illustrates the above analysis. The horizontal dimension shows price-based and cost-based regulation as two distinct regulatory mechanisms, opening up the space of potential regulatory regimes. Incentive regulation as applied in the standard model and cost-plus regulation are shown as two distinct regulatory paradigms. However, comparing them in terms of price- and cost-based regulation, they appear less distinct, but with significant overlap. Finally, "incentive regulation in a broader sense" uses the whole range of both cost- and price-based mechanisms to design incentives to pursue its objectives.

Figure 10: Incentive regulation vs. cost-plus regulation



In summary, the standard model was initially designed to promote efficiency in the existing network (narrow understanding of the standard model). Yet it also provides a framework to explicitly design incentives for network companies to pursue certain objectives set by the regulator or the policy process – not just incentives for efficiency (broader understanding of the standard model). Incentives can be designed using a mix of cost- and price-based elements.

This differentiated view of incentive regulation is helpful for the following discussion on the concrete design of regulatory schemes to promote the objectives discussed in the previous section.

5.3 Designing DG incentives for DSOs

Having presented the main problems with regard to DG connections to the network under different regulatory regimes as well as general regulatory objectives, this section presents possible solutions for giving DSOs incentives to connect DG as efficiently as possible. The section builds on the distinction between cost- and price-based approaches as well as the regulatory objectives presented in the previous section.

5.3.1 Cost-based approaches

A well-known mechanism within incentive regulation is the so-called z-factor (for a brief overview see RAP 2000; for a practical example taken from the US see Jamasb, Pollitt 2000). The z-factor is an adjustment factor outside the incentive regulation mechanism used to deal with extra costs beyond the control of the DSO, such as costs resulting from changes in laws, taxes or extreme weather conditions. It is essentially a cost-based mechanism that can be used to exempt certain costs from price-based regulation within the standard model. The rationale for this approach is that the efficiency incentive of price-based regulation should not be applied to costs that cannot be controlled by the DSO and where the DSO cannot therefore increase efficiency. The z-factor can also be regarded as a mechanism for allocating risk between DSOs and network customers. If a 100% z-factor is applied, risk is fully passed to customers.

The z-factor can also be applied to the costs of DG in order to address the problems of additional costs of DG described in section 5.1.1. With a z-factor, the regulator not only accepts the costs in the DSOs’ cost base as shown in Figure 9, but also introduces a separate mechanism for these costs. Under a full cost pass-through mechanism, the revenue cap of DSOs is directly linked to the costs incurred as a result of DG.

There is a difference between applying a z-factor to, for example, tax changes on the one hand and DG on the other hand. In the case of tax changes the DSO cannot possibly increase the efficiency of these costs and it would therefore be unfair to impose an efficiency objective on the DSOs for them. In the case of DG, the introduction of a z-factor is based on the analysis in section 5.1.1: Incentive regulation without any allowances for DG provides a disincentive against DG. While in the case of tax changes the z-factor is indeed about exempting costs from incentive regulation, the z-factor in the case of DG aims at changing the incentives for DSOs. This refers to the broader meaning of incentive regulation discussed in section 5.2.2.

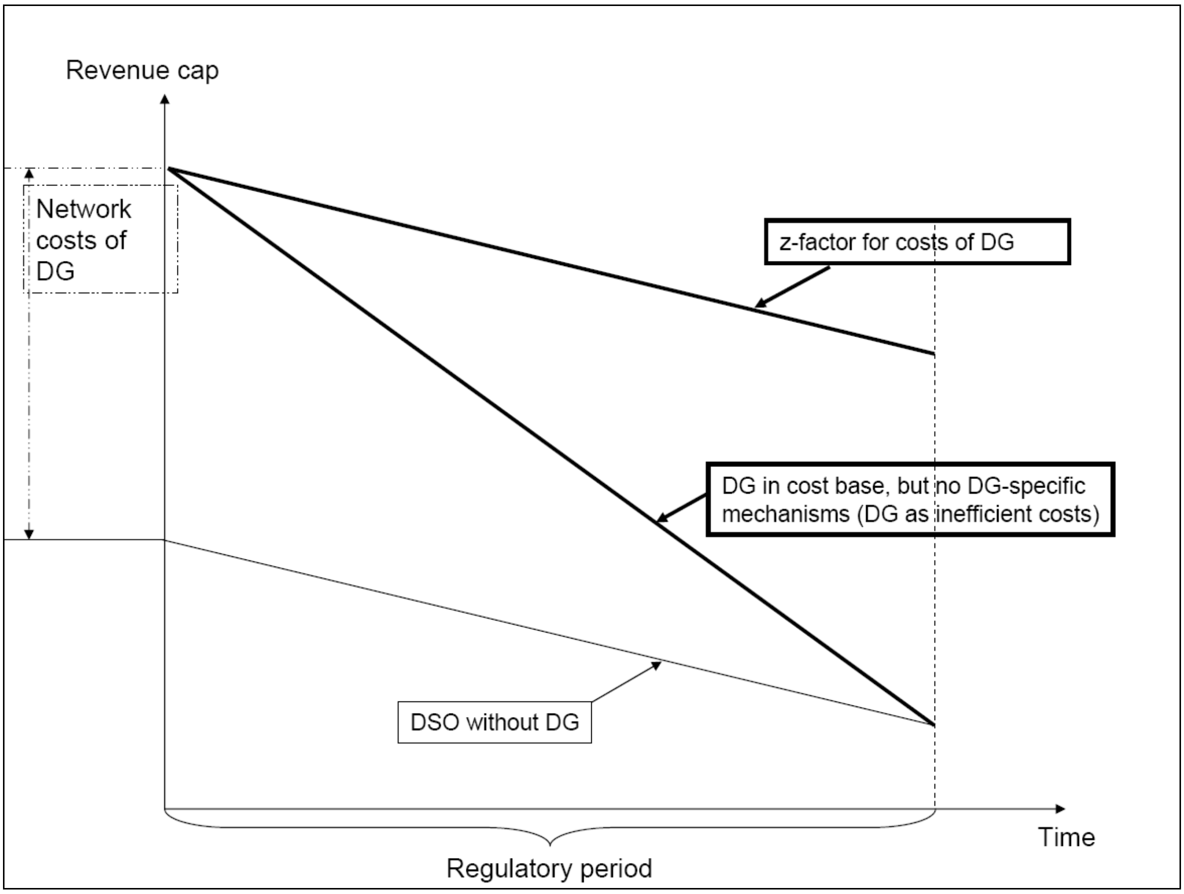
If a z-factor is applied, the assumption is that DSOs cannot influence DG connection costs. This is only partly true. On the one hand, DG costs may differ between DSOs because the volume of DG differs. It will also be easier for some DSOs to connect DG plants than for others – for example, because the DG potential in a network area is more in line with the existing network structure. Both aspects cannot be controlled by the DSO and therefore justify a z-factor. However, on the other hand, the DSO can influence how efficiently a given DG potential is connected to the network and whether intelligent solutions like active management are chosen when it is more cost-effective. A full cost pass-through does not incentivise the DSOs to look for more efficient connection options or to integrate DG into network operation, as described in chapter 3.

If DSOs can simply pass through any DG-related costs they incur, they do not carry any risk, either upside or downside. Therefore, they would lack the incentive for efficient DG connections. With a cost-based approach DSOs may no longer resist DG, but they would not actively promote DG either. In terms of network connection and integration, DSOs may willingly connect DG, but are unlikely to make any effort regarding the integration of DG to reduce the network costs of DG or regarding its use as a solution to network problems (see Figure 3).

Moreover, the DSOs will be tempted to game. They will try and label costs that do not involve DG as DG-related costs and shift costs from the general price-based mechanism to the separate DG regime. Therefore, a full cost-pass through would not be appropriate.

The following graph compares the development of the price- or revenue cap for three different scenarios: first, a DSO without DG or where the regulator does not even accept the costs of DG in the cost base and thus the revenue cap; second, a regulatory regime where the regulator accepts the costs of DG but treats them as inefficient (see section 5.1.1); and finally the situation discussed in this section whereby DG costs are subject to a cost-based regime and the cap is increased accordingly.

Figure 11: Revenue- or price-cap with cost-based regulation



Source: Author's own, first published in German in (Frey et al. 2008: 200)

5.3.2 Price-based approaches

In contrast to cost-based approaches, price-based approaches are not based on the actual costs that a network operator incurs when connecting DG. Rather, the regulator determines a fixed price or revenue for connecting DG to the network. This is not specific to individual companies, but the maximum which all companies can charge their customers.

In line with the general principles of incentive regulation the DSO carries the risk of exceeding or outperforming the cap, as it is exposed to the difference between the cap and its actual costs. The more the costs of a DG connection remain below the general cap, the higher will be the additional profit of the DSO. Above the cap, the DSO would lose money from connecting DG. While a cost-based approach only neutralises incentives against DG, the DSO can make a business out of DG on the basis of price-based approaches if the company manages to outperform the cap. At the same time, there is still an incentive against DG with network costs above the cap.

If a price-based mechanism is applied, the DSO is incentivised to reduce connection costs below the cap. This can be done by:

- improving the efficiency of connecting a DG plant to achieve connection costs below the cap.
- integrating DG into network operation to reduce the overall network effects of a DG project or even generate network benefits.
- ‘cherry-picking’, i.e. preventing DG projects that entail network costs above the cap.

The first two incentives are clearly positive while the third one biases the DSO against projects with high network costs, even though these may be viable from an overall economic point of view or may be needed to meet political targets.

Note that the positive incentive resulting from price-based approaches also establishes DG integration as an attractive option for the DSO. DG integration can enable additional efficiency gains and price-based approaches allow the DSO to benefit from these.

This refers to the argument that neutralising incentives against DG is not sufficient and DSOs should have an opportunity to earn an extra profit from DG connections. For example, Edison Electric Institute and NERA (2006) have argued that *"utility involvement in distributed resources cannot be optimized or maximized merely by the removal of disincentives or barriers. This removal is a necessary step, but it is not sufficient. To elicit the commitment of time, energy, and creativity needed to fully exploit the potential for efficient distributed resource development, utilities must be allowed to make a business out of DR"*. It can be argued that positive incentives are necessary to overcome organisational path dependencies of DSOs and help them evolve from organisations whose planning routines and know-how are geared towards running the passive end of central systems to "active DSOs" that facilitate optimal network development, taking into account distributed resources.

With price-based mechanisms DSOs can make a business out of DG. However, such a mechanism should not be confused with simply providing additional funding for DSOs that connect DG. Rather, price-based mechanisms do allow the DSO to benefit from *efficient* connections and DG integration that reduce their network costs. Thus, it is in line with the general mechanism of incentive regulation where companies are rewarded for achieving objectives in an efficient way, reflecting the information asymmetry between the DSO and the regulator (see chapter 3). Nevertheless, the potential benefits for DSOs can help stimulate their commitment and promote the transformation of the organisational set-up of DSOs.

With a cost-based approach the main task for the regulator is to come up with an appropriate representation of the DSO's costs. A price-based approach has the advantage that the regulator does not need to determine the costs of each individual company. In a price-based regime, the regulator needs to take a stance on the efficient costs of connecting DG in order to determine an appropriate cap. This means that two decisions need to be taken.

Firstly, a price-based approach requires pre-defined network parameters on the basis of which the overall price- or revenue-cap is adjusted to take into account DG. A parameter that suggests itself in this context is the DG capacity connected to the network. A more sophisticated set of parameters could also, for example, account for the type or size of DG or their generation output, but this would require further analysis. Further elaborating and differentiating the cost drivers would move the price-based approach closer to cost-based regulation. It could help to reduce the risk for DSOs and reduce a preference for low-cost DG ('cherry-picking'), but would also render the regulatory process more complicated.

Secondly, given these parameters it needs to be decided what the cost target should be which the DSOs have to meet. For example, the cap could be calibrated to reflect the average incremental costs of connecting DG.

On the one hand, the cap should not be set too low to allow the DSOs to recover their costs and at the same time provide an efficiency incentive. The higher the cap, the more attractive DG becomes for DSOs. On the other hand, the cap should not be set too high, either, as this would lead to excessive rents for the companies at the expense of network customers.

A related question is how a general cap can account for genuine cost differences between companies. A low cap would exacerbate the cherry-picking problem described above and would frustrate a large share of DG projects. If the cap is set at the upper end of the efficient cost range so as to ensure that all efficient costs are recovered, this could mitigate the cherry-picking problem and would allow companies with high cost DG to connect these plants, but would also lead to high rents for DSOs with DG at lower costs. The regulator faces the problem that it wants to introduce a price cap to counter the information asymmetry between itself and the regulated companies. Yet if the efficient costs vary widely between companies a generic price cap across all companies leads to the above-mentioned distortions.

Two different price-based approaches can be distinguished: setting up a standardised revenue driver and including DG in the general benchmarking of DSOs.

5.3.2.1 Standardised revenue driver

The allowed price or revenue can be directly linked to a set of DG-related parameters as mentioned above. In other words, the regulator determines standardised costs across all network operators that result from a certain DG structure defined by these parameters. For example, if the DG capacity connected to the network is used as a parameter, the allowed revenue or price directly increases depending on the amount of kW connected.

Both steps – the definition of parameters and appropriate costs – are taken out of the normal regulatory process and need to be completed before the start of the regulatory process to determine the cap for each company. This can be seen as an advantage of this approach because the price cap for the DG objective is established separately from the price cap for the supply objective. It thus becomes more transparent for the DSO in terms of what is regarded as an efficient DG connection, rather than mixing the efficiency of the DG objective with the supply efficiency. This transparency should have a positive effect on the incentives for the DSOs.

In order to establish an appropriate level for the cap, the regulator could use a benchmarking process. A revenue driver approach was adopted as part of the UK DG hybrid incentive (see UK case study in chapter 8).

5.3.2.2 Including DG in the comparative efficiency analysis

As an alternative to a standardised revenue driver the DG costs could also be included in the general comparative efficiency analysis or benchmarking. While the standardised revenue driver approach requires the efficient costs to be determined ex-ante, i.e. before the regulatory process starts, the benchmarking approach would determine the efficient costs of DG in combination with the efficient costs of providing the network in general.

If the costs of DG are included in the benchmarking, the DG-related cost drivers need to be included, too. Otherwise the DG costs appear as inefficient, as discussed before. If both costs and cost drivers are accounted for in the benchmarking process, a DSO with additional costs due to DG is not automatically penalised because of these additional costs, but rather only if the DG-related costs themselves are inefficient.

Integrating DG as an additional cost driver into the general benchmarking procedure carries the risk that the number of parameters used as cost drivers to calculate a company's efficiency becomes too large. As a consequence, the benchmarking procedure may become too complex and intransparent, without increasing its accuracy (Jamasb, Pollitt 2008b: 1792).

Little practical experience has been gathered to date in terms of the inclusion of DG in benchmarking procedures. In Germany, the ordinance which lays down the detailed incentive regulation rules ("Anreizregulierungsverordnung") stipulates that the DG capacity can be taken into account by the regulator as an optional benchmarking parameter, which the regulator decided to do. Some network operators have argued that a broader set of parameters would be needed to capture the costs of DG. As it would be difficult to further increase the number of parameters used in the efficiency analysis, one option would be to combine different cost drivers in one parameter for the efficiency analysis, although a method for aggregating cost drivers would still need to be developed (Frey et al. 2008: 230).

Overall, designing an appropriate set of parameters to take into account the costs of DG is more straightforward and the results are easier to comprehend in the revenue driver approach. A further difference between the two approaches is that the revenue driver approach is completely price-based, i.e. the price cap is imposed from the very beginning of the regulatory period. In contrast, under a benchmarking regime the DSO typically has some time to reduce its costs to the efficient cost level, e.g. over one regulatory period. The revenue driver approach therefore involves a higher risk for the DSO.

5.3.3 Hybrid mechanisms

5.3.3.1 Combining cost-based and price-based elements

The previous sections presented cost- and price-based mechanisms to include the costs of DG in the standard model. The main difference between the two approaches is the distribution of the cost risk of DG connections between the DSO and its customers. While a cost-based approach shifts the entire risk to the customers, price-based approaches leave it with the DSO. Both approaches exhibit shortcomings: The cost-based approach assumes that the costs of DG connections are completely exogenous to the DSO, which is not the case, as discussed in chapter 3. The price-based approach assumes that the DSO has total control over the DG-related costs in its network. However, this is also not the case because the type of DG that wants to connect to the network and the network impacts are likely to vary widely between network operators, leading to broad range of costs (Frontier Economics 2003; for on overview on relevant references see Bauknecht, Brunekreeft 2008).

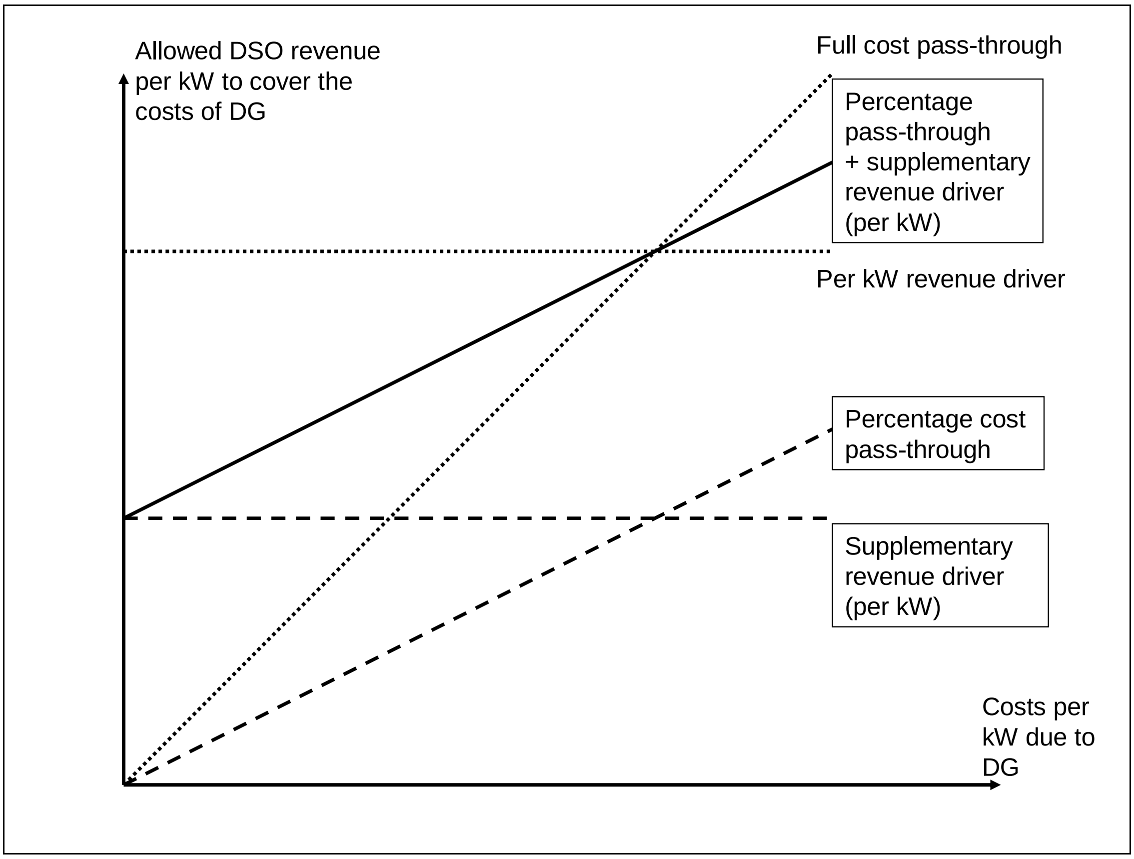
This cost diversity makes it difficult to standardise the DG-related costs in a price-based approach. A cost-based approach removes the cost risk for the DSO, but also any efficiency incentive. A price-based approach can turn DG into a business opportunity for the DSO, but makes it also riskier, especially if the cost diversity is not reflected in the methodology to determine the cap, as described earlier.

Given the advantages and disadvantages of cost- and price-based approaches, a further option is to combine the two in order to balance the incentives for the DSO. As discussed in section 5.2.2, price- and cost approaches are theoretical extremes that can be explicitly combined to create an appropriate incentive structure. This is often referred to as a hybrid mechanism or sliding scale regulation. It enables the development of an incentive scheme for DSOs which balances different incentives. This can be done for the general supply objective of network operators, but also for the DG objective.

Combining the two approaches means that part of the costs can be directly passed through to customers and part of costs need to be recovered through a revenue driver that increases the price cap. Recovering part of the costs that are not passed through directly through the benchmarking procedure would make it even more difficult to comprehend the results of this process. This is a further argument for the revenue driver approach discussed in section 5.3.2.

The price or revenue cap resulting from a hybrid approach is shown by the continuous line in Figure 12. In this example, the price-based element is based on the costs per kW of DG connected. While the dotted lines show a pure price- and cost-based mechanism respectively, the dashed lines represent the (reduced) price- and cost-based elements that together make up the hybrid mechanism. The cost-based element reduces the risk for the DSO and takes into account the cost differences between networks resulting from DG connections. The price-based element ensures that there is still an efficiency incentive.

Figure 12: Combining cost- and price-based elements



5.3.3.2 Menu of sliding scales

With a combination of cost and price elements the regulator can design a balanced incentive scheme. However, the question remains as to how exactly the two elements are to be combined. The hybrid mechanism presented in the previous section mitigates the problem of a price-based approach in the face of cost differences between networks, but still represents a one-size-fits-all approach. On the one hand, for some network companies a hybrid mechanism with a strong price-based element may be better suited to stimulating efficiency improvements, while for companies with relatively high DG connection costs this may render DG unattractive. On the other hand, a strong cost-based element reduces the risk for high-cost companies, but reduces the efficiency incentive across all companies.

Given these problems, Bauknecht and Brunekreeft (2008) have proposed the use of a menu-of-sliding-scale approach to the regulation of DG costs. This mechanism was proposed by Laffont and Tirole (1993; see also Joskow 2006a). A practical implementation can be found in the UK for the regulation of electricity network investments under the 2005 price control review (Crouch 2006).

Under such a scheme, the regulator offers the regulated company a menu with different combinations of cost- and price-based elements: the higher the cost pass-through element, the lower the revenue driver element. The regulator leaves it up to the individual company to decide which combination best fits the company’s cost structure.

As firms can choose themselves, they will reveal their DG related cost structure. If in a network area there is a potential for low cost DG or the DSO has potential to connect DG efficiently, this DSO will choose a price cap; thereby it selects the incentives to be efficient and connect low cost DG. If, on the other hand, in a network area there is high cost DG or the DSO knows it will not be able to connect DG at low costs, it will opt for a cost-pass through. Thus, the hybrid scheme is geared to each company’s cost structure without the regulator needing to know the individual cost structures.

The benefit of this approach is that there are no excessive rents for low cost companies, while high cost companies do not face a price cap that is too low and can therefore still recover their costs. However, as a consequence high cost companies which choose a high cost pass-through element are no longer incentivised to strive for efficient DG integration. This can be seen as the price that the regulator has to "pay" in order to avoid excessive rents for low-cost companies, while still enabling high-cost companies to connect DG.

However, this is particularly problematic if a significant number of companies are high-cost. A further problem arises if companies with high DG connection costs, which would choose a high cost-based element, have a particularly high potential for cost reduction, e.g. through DG integration. This potential would be lost if the menu approach guarantees an efficiency incentive for low-cost companies, but provides no such incentive for high cost companies.

For example, a DSO with many small-scale and highly distributed photovoltaic plants connected to its network may have high costs per DG capacity connected compared to another company that connects one large wind farm. With a menu of sliding scale approach, this company will opt for a high cost-based element because it cannot cover its cost with the price-based element that is geared towards the low-cost companies. However, despite its overall high costs, there may be significant potential for this company to better integrate the PV plants. Indeed the potential for cost reduction relative to the costs without any integration measures may be even higher than in the case of the low cost company with the large-scale wind park connected.

The fact that the efficiency potential and the absolute cost level do not necessarily correlate in the case of DG connections is an argument for differentiating the regulatory scheme based on a broader set of parameters, as proposed in section 5.3.2. In the above example, the revenue driver would distinguish between the costs of connecting PV and the costs of connecting wind, or the costs of connecting small-scale and large-scale schemes.

5.3.4 Rationale for DG integration and regulatory design

Having discussed various mechanisms for including the DG objective in the standard model, I now briefly come back to the rationale for the regulator to integrate DG into network regulation, which was mentioned in section 5.2.1. The question is how the different arguments to include the additional costs of DG in network regulation affect the design of the regulatory mechanism discussed earlier in this section.

As discussed before, DG can in principle be taken into account within the efficiency objective of the regulator if this is extended to the competitive part of the market or future network costs. If DG regulation is justified on the grounds that DG leads to more competition and thus reduces overall costs, the regulator could in principle set the cap based on the expected cost savings in the competitive market – although it will be difficult in practice to quantify this value. A price-based approach would be sufficient; a hybrid mechanism or even a cost-based approach would not be necessary, as the value of DG would only be assessed in efficiency terms. DG with connection costs below the benefits in the competitive part of the market would get connected while other DG plants would be neglected.

A similar argument can be applied if lower short-term network costs are justified by lower long-term costs. However, in this case, it would be even more difficult to define an appropriate cap. While in the case of competition it can be assumed that all DG have the same effect on competition in principle, the potential of DG to reduce future network costs varies widely and cannot be determined on a case-by-case basis, as it very much depends on the future network structure.

The mechanisms presented above and especially the combination of cost- and price-based mechanisms to balance connection and efficiency incentives are chiefly relevant when DG is introduced as an additional objective. It is only then that a price-based DG element cannot ‘simply’ be based on the assumed efficiency benefits resulting from DG. A regulatory mechanism to support DG as an additional objective requires a balance to be struck between the connection and efficiency incentive and can use price-based elements to make DG more attractive for DSOs.

Designing a regulatory mechanism to support DG as an additional objective not only presupposes a political decision to introduce the DG objective in the first place. Rather, the regulatory design itself also involves political decisions to be taken. Setting the various parameters described above and especially the combination of price- and cost-based elements represents a decision on the costs that are acceptable for increasing the politically desired connection of DG.

5.4 Conclusions

This chapter has analysed the potential of the standard model of network regulation to accommodate DG connection and integration as a new issue. It has shown the mechanisms through which distribution network operators are affected by DG and how this translates into economic costs or benefits for the DSO under different regulatory regimes. In particular it has shown how incentive regulation makes it difficult for DSO to connect DG and recover the resulting costs.

At the same time, this chapter has argued that DG can be integrated into the standard model. In terms of the additional network costs resulting from DG, these may be taken into account by the regulator within its efficiency remit. In this case the incentives of DSO against DG would not be tackled because they represent a barrier against the further deployment of DG capacity, but rather because they undermine the efficiency objective. With this approach, there would be no generic connection incentive for DG, but only for those plants that contribute to overall system efficiency.

However, if the objective is to increase the share of DG, then DG needs to be introduced as an additional regulatory objective, which in the end requires a political decision to broaden the remit of the regulator. Although at first sight, such an additional DG objective seems to be at odds with the efficiency objective, a closer look reveals that efficiency should serve as a guideline both for the supply of electricity via the network as well as the integration of DG. The apparent tension between the efficiency and the DG objective results from diverging target groups: a more efficient network benefits network customers in one network area, whereas a higher share of DG can benefit society as a whole.

Importantly, a broader understanding of incentive regulation was put forward, which is no longer based on price-based approaches that are applied to increase efficiency. Rather it comprises both cost- and price-based approaches that can be combined in different ways to achieve other targets, too. Thus, the basic idea of the standard model – that the regulated companies have an information advantage and decisions should therefore be guided by economic incentives – can be extended to the DG objective.

Based on this understanding of incentive regulation, it is proposed that the very mechanisms of the standard model be used to overcome the problems that the standard causes for DG. Different options have been discussed for taking into account the additional network costs of DG in the regulatory framework, namely a full cost pass-through, price-based approaches using a separate revenue driver or DG as a benchmarking parameter as well as a combination of both. The latter is preferable to both individual instruments as it can combine connection and efficiency incentives. Efficiency incentives become particularly relevant when there is potential for cost reduction via network integration of DG.

A central problem faced by the regulator is the cost differences between network operators that are difficult to capture with a generic approach. A DG-specific menu-of-sliding approach has been proposed. However, it removes any efficiency incentive for high-cost DSOs that may have a high potential for cost reduction through DG integration. An alternative would be a differentiated set of cost drivers which takes into account cost differences, e.g. between different DG technologies. If DG is an additional objective, the fine-tuning of these instruments involves political decisions, too.

Overall, the chapter has shown the potential of the standard model to integrate new objectives, at least in terms of incentive regulation mechanisms. The policy-regulation interface and how it is affected by DG as a new objective will be discussed further in chapter 7.

6 Network regulation and innovation

The previous chapter discussed various mechanisms through which network regulation can provide incentives for DSOs to connect DG plants. Such a general DG-oriented regulatory framework may also promote network innovations if it leads to more DG activity which makes DSOs think about how these plants can be best integrated.

Nevertheless, in order to promote the innovations necessary for an efficient large-scale deployment of DG, the question is whether network regulation should provide additional tailor-made instruments for DSOs to get involved in RD&D and try out new approaches to running their network and how this could be done.

This chapter is structured as follows: The first section provides a brief introduction to a number of general issues involving regulation and innovation. The second section examines how cost-based and price-based regulatory schemes influence RD&D by regulated companies. This section picks up on what was said in chapter 2 about the potentially detrimental effects of the standard model of liberalisation on innovation. Clearly, on the generation side, RD&D is conducted under competitive conditions with potential market failures associated with RD&D that are very different from the regulated environment in which network companies operate. Against the background of the general debate on liberalisation, the section therefore contributes to a disaggregated analysis of the innovation effects of standard model of liberalisation, focusing on the regulated part. This is followed by a discussion of various regulatory instruments to stimulate innovation. The fourth section provides a more general discussion of the ins and outs of promoting network innovations in general and innovative network concepts to cope with DG in particular.

6.1 Network innovation: some basics and definitions

6.1.1 Process or product innovation and innovation externalities

In chapter 3, it has already been shown that electricity networks have become much more dynamic than they used to be, and that a range of innovative network concepts are under development. Before analysing the effects of regulation on these innovations, network innovations to promote DG will be briefly categorised. They include both technical and institutional innovations.

Innovations can be classified as either product or process innovations (Tidd et al. 1997: 6). Product innovations enable a company to offer new products while process innovations reduce the costs of producing existing products or make it possible to increase their output. Incentive regulation generally aims at making processes within the network company more efficient in order to reduce costs.

In many cases DG-related network innovations aim to accommodate a higher share of DG at lower costs where more conventional network upgrades would otherwise be necessary. In that sense, they can be seen as process innovations. Nevertheless it is important to bear in mind that the network innovations sketched out in chapter 3 can go beyond improving the processes within the current infrastructure to accommodate DG at lower costs, but can lead to a new type of infrastructure.

Importantly, even if we regard the network innovations under discussion in this thesis as cost-reducing process innovations, they do not necessarily reduce the costs of the traditional objective of distribution networks, i.e. to serve network customers with electricity. Rather, they aim to reduce the costs of a new objective, i.e. to accommodate DG. These costs may still be higher than the network costs of a network that serves only demand customers without any DG connected to it (see Figure 3). The innovations can be seen as cost-reducing process innovations to pursue new objectives at lower costs. If these objectives are not part of the objectives a network operator is to pursue, the benefits of these innovations appear as externalities for the network operator.

6.1.2 Market structure and innovation

Since this chapter deals with innovations in a monopolistic market, it should be noted that there has been a long-running debate on the effect of market structure on innovation. This debate is often associated with Schumpeter on the one hand who argued that large firms and monopolies favour innovation and Arrow on the other hand who took the opposite view that competition stimulates innovation. They have triggered numerous studies on the issue, which have not yielded conclusive evidence, but have shown that a more differentiated view is necessary, e.g. much depends on property rights (for an overview see Gilbert 2006).

Given the monopolistic nature of electricity networks, this thesis focuses on the regulation of these monopolies and on how regulation can be amended to promote innovation, instead of comparing the pros and cons of different market structures.

6.1.3 Regulation and innovation in general

The effect of regulation on innovation is discussed in this chapter for the specific case of economic network regulation. It is worth noting that there is also a more general debate about the effects of regulation on innovation; it has been argued that regulation both promotes and constrains innovation (Eifert, Hoffmann-Riem 2009).

A prominent example is the debate on environmental regulation which is often associated with the so-called “Porter hypothesis” (Porter 1991; Porter, van der Linde 1995). It suggests that environmental regulation can improve the international competitiveness of domestic firms by stimulating innovation. This hypothesis has been very contentious, and empirical counter-evidence has been provided by Jaffe and Palmer (1997). A more normative strand of literature has examined how regulation can be designed to promote innovations and guide them in certain directions, especially in the case of environmental regulations (Hemmelskamp et al. 2000).

In contrast to the debate on the Porter hypothesis and more in line with the approach mentioned above, the following analysis on the innovation effects of economic network regulation does not focus on the pros and cons of regulation with regard to innovation. Rather, it takes regulation of network monopolies as given and analyses specific regulatory arrangements and their potential to promote innovation that facilitates the integration of DG.

6.1.4 Network innovations and innovation networks

Finally, when discussing the innovation effects of economic regulation, it should be noted that RD&D efforts by regulated network monopolies are embedded in broader innovation networks with other actors who are not subject to economic regulation, e.g. suppliers of network equipment (Heyes, Liston-Heyes 1998).

The question may be asked why network operators should get involved in developing innovations themselves. While they are indeed unlikely to take part in more basic research activities, it can be crucial for DSOs to get involved in applied research activities. This can be important to establish a link between research and the needs of the DSOs as well as 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 RD&D capabilities in-house to be able to appropriate the results of external RD&D.

6.2 The effect of different regulatory mechanisms on innovation

In this section, cost-based and price-based regulation of network tariffs as the two theoretical polar cases (see chapter 5) are analysed with regard to their effect on network innovations. The main mechanisms through which they affect the innovation activities of DSOs are discussed. The focus of this section is on cost-saving process innovations in order to understand the basic mechanisms.

6.2.1 Cost-based regulation

One type of regulation is cost-based regulation. The effect of regulation on innovation has traditionally received less attention than the impact of the market structure on innovation in the literature (Mayo, Flynn: footnote 1). In the 1970s and 1980s there were some studies on the effects of regulation on innovation, mainly in the US (Bailey 1974; Müller, Vogelsang 1979; Sweeney 1981; Schoppe, Wass von Czege 1984; Mayo, Flynn 1988); for an overview from an electricity sector perspective, see Jamasb and Pollitt (2008a). They examined the cost-based regulation that was predominant at the time. The focus of most studies on innovation under regulation has been on vertically-integrated monopolies rather than unbundled networks in liberalised markets.

In its pure (theoretical) form, cost-based regulation constantly monitors a company's costs and revises the tariffs a company can charge accordingly. The effect of this extreme type of cost-based regulation on innovation can be summarised as follows: It would enable companies to conduct RD&D as companies would not bear any cost risk and additional costs would be immediately reflected in higher tariffs. However, it gives them no incentives to do so since any cost savings arising from RD&D would directly lead to lower tariffs. There are no additional profits arising for the company. As a consequence, engineers or managers that are keen to develop innovations and work in an innovative company will find a low-risk environment to try out new things under cost-based regulation. But from a profit point of view there is no reason for the company to make any effort to venture into new technologies or processes. This is in line with the more general point that cost-based regulation does not give the company any incentive to become more efficient.

In contrast to this theoretical extreme, where all costs are accepted and tariffs instantaneously adjusted, cost-based regulation in practice normally means that the regulator does not blindly accept all costs, but will evaluate costs, e.g. based on "used and useful tests" (for the US see Joskow 1989: 161).

More importantly in the context of this discussion, cost-based regulation is normally characterised by a regulatory lag, i.e. adjustments by the regulator of the company's allowed revenue or tariffs due to changes in its cost base lags behind these cost changes. To the extent to which the regulator does not require an ex-post refund at the regulatory review, efficiency gains can therefore be kept by the company for some time, thus providing an incentive for the company to engage in RD&D (Bailey 1974).

This adds an element of price-based regulation. Assuming that RD&D costs have been included in the company's cost base, the regulatory lag allows the company to earn extra profits if its RD&D efforts are successful while there is still no downside risk if an innovation fails.

At the end of the regulatory lag, when the regulator reviews the company's costs, tariffs will be adjusted and cost-savings passed on to consumers so that the rate-of-return a company can earn on its RD&D investments is capped.

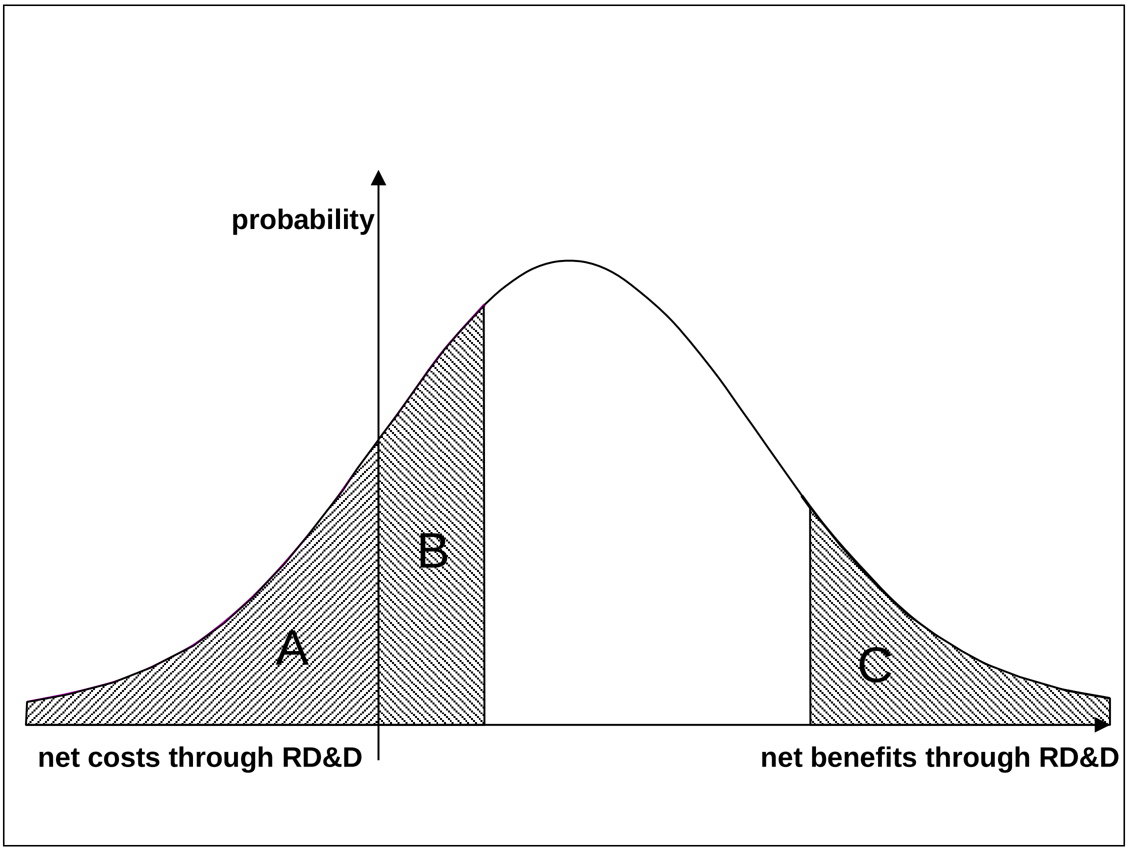
Overall, this version of cost-based regulation provides stronger incentives for a company to carry out research than the pure cost-based approach described above.

The following graph summarises the effects of cost-based regulation (cf. Mayo, Flynn 1988). It assumes that the net cost savings resulting from RD&D, i.e. innovation benefits minus innovation costs, follows a normal distribution. In some cases the net benefits will be negative, with the result that RD&D costs are higher than the savings achieved, partly due to the risky nature of innovation. However, it is assumed that there is a positive outcome overall.

Since costs can be passed on to consumers under cost-based regulation, a company is not exposed to losses, even if innovation costs exceed the benefits of innovation. Area A in Figure 13 is therefore not relevant for the company's rate-of-return distribution resulting from RD&D. Capping the downside risk for the company will be referred to as lower-end truncation in the following. At the same time, some of the innovation benefits will be passed on to consumers too, with the result that the net benefits are reduced from the company's point of view. This is represented by area C in Figure 13 and will be referred to as upper-end truncation. Together lower- and upper-end truncation determine the ability as well as the incentive of the regulated company to innovate.

If the regulator capitalises RD&D expenditures, the lower-end truncation would be even stronger as the company could always earn a positive rate-of-return on RD&D. This is shown by the shaded area B in Figure 13 (Mayo, Flynn 1988; see section "Capitalisation of RD&D costs", page 147). Under pure cost-based regulation, the entire area under the curve would be 'truncated' as the company would not be exposed to any risk, neither upside or downside.

Figure 13: Truncation effects under cost-based regulation



6.2.2 Price-based regulation

Against the background of the innovation effects of cost-based regulation, I now turn to price-based regulation, which has become the dominant regulatory regime in the electricity sector and beyond. When price-based regulation as we know it today or ‘incentive regulation’ was first proposed by Littlechild in 1983, the assumption was that it is superior to cost-based regulation both in promoting productive efficiency and innovation (Armstrong et al. 1994: 167; Littlechild 2006a: 2). The main argument is that companies benefit from cost reductions they can achieve, including cost reductions from process innovations, and would therefore make an effort to innovate. However, the effects of price-based regulation on innovation are more ambiguous, both theoretically and empirically, than many promoters of price-based regulation have suggested. This ambiguity can be seen in the literature, but will also be derived from an analysis of the truncation effects of price-based regulation.

6.2.2.1 Evidence from the literature

Most studies on regulation and innovation are either not related to a specific sector or focus on the telecommunications sector (for an overview see Bourreau, Dogan 2001; Gerpott 2006). Especially price-based regulation in the telecommunications sector has received more attention compared to the electricity sector. It was introduced in this sector before the electricity sector and in fact, price-based or ‘incentive regulation’ in the form of ‘RPI-X’ was first developed to regulate British Telecom after privatisation. More importantly, while in the electricity sector, the network has not changed much since liberalisation and network innovations have not been an issue until very recently, the telecommunications sector has seen a highly dynamic development of its network infrastructure and innovations abound. One of the main rationales of liberalisation in this sector was indeed to foster technical change and network innovations.

The telecommunications sector therefore provides useful material for the analysis of economic regulation and lessons can be drawn for the electricity sector. However, the sector also exhibits a number of peculiarities we need to bear in mind. Most importantly, the majority of telecommunication networks are not natural monopolies anymore and the sector is characterised by (potential) infrastructure competition. The interplay between incentive regulation and competition is likely to lead to innovation dynamics that are different from the ones in the electricity sector, where infrastructure competition is only a fringe issue. In the telecommunications sector, innovation can be a way for companies to gain market shares whereas in the monopolistic electricity network, this will not drive companies to innovate. In the UK, for example, RD&D intensity in all major utilities sector has been falling except in the case of the telecommunications sector (Holt 2005a).

The effect of different types of regulation on innovation has not been studied in much detail and the results that are available are ambiguous. Back in 1988, Mayo and Flynn (p. 32) concluded that the innovation effects of cost-based regulation have not received much attention and *"that research to date has shed only limited light on the impact of regulation on the innovative propensities of regulated firms"* (cf. Müller, Vogelsang 1979: 91-92). More than a decade later and after much more research has been carried out on regulation in general, Bourreau and Dogan (2001: 170) still find that *"the literature on regulation, in particular for an oligopolistic setting, is inadequate in presenting general results of the effect of ex ante regulation on the incentives for innovation"*. Regarding the comparison between cost-based and price-based innovation, Jamasb and Pollitt (2008a: 1005) conclude that *"the effect of ROR* [rate-of-return] *versus price cap regulation on the rate of technical change has not been studied in detail"*.

There are arguments that price-based regulation promotes innovation (Magat 1976; Clemenz 1991)[6], but there is also the opposite reasoning (Kahn et al. 1999). Although

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[6] Magat analysed price ceilings already in 1976, which was later to become one important element of Littlechild's 'incentive regulation' mechanism.

incentive regulation in principle provides a framework for efficiency improvements including efficiency improvements through technical change, it can undermine the development of innovations at the same time.

In empirical terms, it is clear that the introduction of price-based regulation in the telecommunications sector coincides with a surge of new technologies. However, this has not been the case in the electricity sector; it would therefore be difficult to ascribe the innovation in telecommunications solely to the introduction of price-based regulation. There may be many other factors; as Ai and Sappington (2002: 134) have pointed out in their empirical study of the telecommunications sector, *"the task of isolating the impact of incentive regulation in a dynamic, complex industry like the telecommunications industry is a difficult one"*.

In a detailed overview on studies that have analysed the empirical effects of price-based regulation in the telecommunications sector, Gerpott (2006: 145-148) comes to the conclusion that the introduction of price-based regulation coincides with a significant increase in investments into network modernisation and increasing productive efficiency by incumbents. However, there is no conclusive empirical evidence of the effects of price-based regulation on RD&D and the innovation output by the industry. For the electricity sector, there is some evidence that price-based regulatory regimes have contributed to a decline in RD&D and innovation (Holt 2005a; Jamasb, Pollitt 2008a).

6.2.2.2 Main effects of price-based regulation

While the literature on price-based regulation and innovation is not conclusive, it is still possible to summarise the main arguments in this section and identify the main mechanisms through which price-based regulation can affect RD&D and innovation in a regulated industry. I use the discussion above on cost-based regulation as a reference point and once again differentiate between upper-end and lower-end truncation of risk.

Upper-end truncation

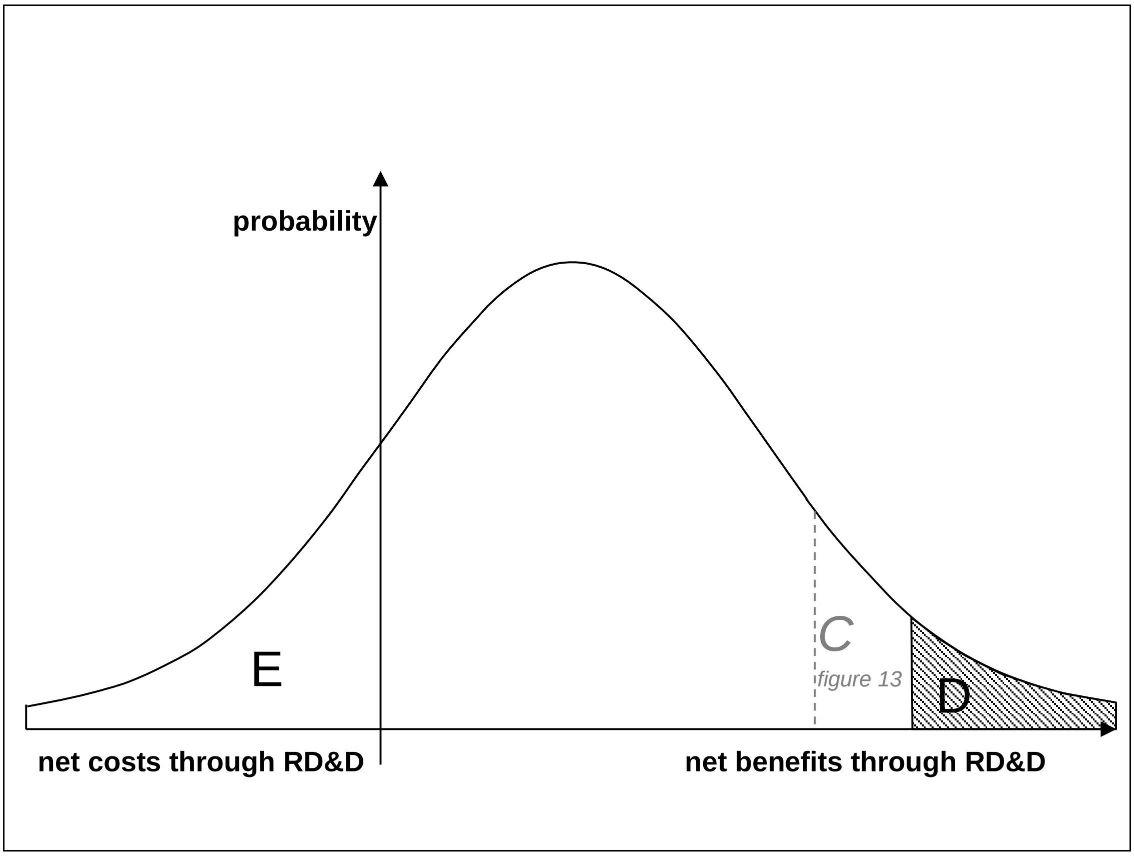
In terms of upper-end truncation, price-based regulation generally allows the company to retain a higher share of the innovation gains as compared to cost-based regulation. This is basically the main argument in the literature as to why price-based regulation is more innovation-friendly.

This is certainly true compared to pure cost-based regulation where tariffs are instantaneously adjusted. But also in comparison with 'regulatory lag' cost-based regulation described above, price-based regulation tends to leave a higher share of any innovation gains to the company. Area D in Figure 14 therefore tends to be smaller than area C in Figure 13.

The differences in the upper-end truncation are due to the following reasons. Firstly, the regulatory period under price-based regulation tends to be longer than the regulatory lag under cost-based regulation, giving the company more time to appropriate any benefits. Secondly, the regulatory period is fixed ex-ante. This increases the certainty for the company as to how long it can benefit. Fixing the regulatory period ex-ante in a regulatory contract also protects the company against the regulator initiating a regulatory review precisely because the company has become more efficient due to innovations, which could potentially reduce the benefits for the company. In a cost-based regime, the regulator will generally be more inclined to introduce some kind of profit-sharing whereby the rate-of-return is capped and excessive profits have to be refunded to customers.

Overall, upper-end truncation under price-based regulation will be lower than in the case of cost-based regulation, i.e. a company can keep a higher share of the innovation gain it has generated. Nevertheless, companies under price-based regulation still face a truncation of innovation gains. While the rate-of-return is in principle not limited during a regulatory period, the truncation occurs at the next regulatory review. Upper-end truncation after the regulatory period can be especially significant if innovation gains accrue over a long time period. It may then be difficult for a DSO to recover the costs of an innovation within one regulatory period.

Figure 14: Truncation effects under price-based regulation



Lower-end truncation

With price-based regulation, truncation of benefits is generally lower than under cost-based regulation. However, the remaining truncation of benefits can be problematic if it is not matched by a corresponding lower-end truncation, through which the company does not only share innovation benefits, but also costs with its customers. With cost-based regulation, the upper-end truncation is combined with lower-end truncation: companies are not exposed to any significant cost-risk as additional costs will lead to higher tariffs. As a result, companies will not lose out if their RD&D efforts fail. If RD&D costs are treated as capital expenditures there may be even a positive rate-of-return on any RD&D costs, irrespective of the innovation outcome.

This lower-end truncation ceases to apply under price-based regulation. Under pure price-based regulation, RD&D costs in principle need to be recovered through resulting efficiency improvements.[7] As a consequence RD&D efforts that do not generate enough benefits will entail losses for the company (area E in Figure 14). With price-cap regulation companies thus face the problem that they need to recover RD&D costs through efficiency gains, but those are still shared with customers after the regulatory period.

Overall effect of price-based regulation

Overall, price-based regulation has the following effects: Firstly, it introduces a higher upside and downside risk for companies compared to cost-based regulation. It generally allows a higher rate-of-return, but a company can also lose money. The probability distribution of additional returns that can be earned through RD&D becomes broader under

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7 In practice, the company may be able to recover some of the costs directly, e.g. if RD&D costs result in the company being classified as inefficient in a comparative efficiency analysis, but needs to reduce this inefficiency only over a certain time period, or if other companies also spend on RD&D, and the related costs therefore do not show up as inefficient when companies are benchmarked against each other.

price-based regulation, and the lower end can become negative. While under cost-based regulation, companies can normally earn a reasonable rate of return within a certain range, the rate-of-return can vary more widely with price-based regulation. This feature of price-based regulation becomes particularly relevant in the case of RD&D where the risk distribution is inherently higher.

Secondly, the mean of the rate-of-return distribution can be reduced from a company point of view compared to cost-based regulation. This is the case if price-cap regulation changes the truncation of the upside- and downside risk asymmetrically, i.e. if companies on the one hand bear the entire cost risk of RD&D, but on the other hand still have to share innovation gains with their customers relatively quickly.

In principle this problem applies to all cost-saving efforts undertaken by a company, not just RD&D. However, in the case of 'normal' cost-saving efforts, there is more certainty for the company in terms of the savings that can be achieved. It is also easier to calculate the net present value based on the costs, the savings that can be achieved and the proportion of savings it can retain. The company can counter the regulatory upper-end truncation by not carrying out measures that are not profitable anymore given this upper-end truncation.

In the case of innovation, there is inherently more downside risk as RD&D results are more uncertain. This however is not reflected in the upper-end truncation as the regulator does not normally differentiate between cost savings resulting from 'standard efficiency improvements' and those that have been achieved through riskier RD&D; in both cases savings will be shared with customers according to the same rules.

These arguments show how RD&D becomes riskier under price-based regulation; companies may therefore not spend on RD&D. At the same time, under price-based regulation companies are forced to reduce costs since the regulator generally imposes a revenue path which declines over a regulatory period and is partly based on benchmarking network operators against each other. On top of that, companies can increase their profits in the short term if they manage to outperform this revenue path. This gives companies an incentive to reduce costs in the short term, including RD&D costs. 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.

Taking away the lower-end truncation and exposing the company to the cost of RD&D means that price-based regulation comes closer to a competitive market where companies also do not have the possibility of passing on any costs of RD&D to consumers. However, in terms of upper-end truncation, a competitive market with protection of property rights through patents can impose a weaker upper-end truncation on companies, with patents protecting innovation benefits for up to 20 years. Under price-based regulation, upper-end truncation is set by the length of the regulatory period, which is geared towards normal efficiency improvements rather than innovations.

6.2.3 Conclusion

Price-based regulation was thought to overcome the problems of cost-based regulation, not least of all with regard to innovation. However, both theoretically and empirically, there are only ambivalent and rather tenuous results regarding the effect of regulation on innovation, for cost- as well as price-based approaches. Price-based regulation is not necessarily superior to cost-based regulation. There are a number of arguments and also some empirical evidence that price-based regulation can stifle innovative activities. Also, even if price-based regulation as such provided stronger incentives for regulation than cost-based regulation, it may still not be enough to match the innovation requirements, for example those resulting from the increasing share of DG.

What is certainly positive about price-based regulation is that it shifts the focus from RD&D inputs to innovation outputs, which may lead to more effective and efficient RD&D. However, the other side of the coin is that price-based regulation increases the risk for the regulated company: it exposes the companies to the RD&D costs while still truncating the innovation benefits.

These findings are reminiscent of the general argument made about the standard model of electricity liberalisation in chapter 2, namely that the model may encounter more problems in achieving objectives beyond short-term efficiency, including innovation, than has been previously envisaged.

The arguments made in this chapter can be applied to cost-saving process innovations that help DSOs to become more efficient and thus meet or outperform the regulator's efficiency targets. It has become clear that even for these innovations, price-based regulation may weaken the incentives for RD&D; it may be more attractive for DSOs to reduce RD&D expenditures to meet the efficiency targets, rather than trying to reduce its costs through innovations.

The innovation incentives become even more ambiguous once the innovations not only aim at reducing the network costs, but also at enabling other objectives outside the network or at meeting these objectives at lower costs, as in the case of DG-related innovations discussed in this thesis. In this case, at least part of the innovation benefits emerge as externalities for the DSOs and the innovations facilitate a development that may increase the overall network costs. It is clear that in a regime in which innovations costs need to be recovered through innovations benefits, the fact that at least some of the benefits are external to the DSOs further reduce the incentive for the DSOs to engage in such innovative activities.

The practical effects of the regulatory regimes under discussion and the actual lower- and upper-end truncation will depend on a number of parameters that need to be set by the regulator (e.g. which costs are accepted, what the short-term efficiency improvements demanded by the regulator are). How the different mechanisms I have identified interact in a real-life regulatory setting, is an empirical question. Overall, it is more useful in this context to move beyond comparisons of cost-based and price-based regulatory regimes and examine how these regimes can be designed in practice to promote innovation.

6.3 Regulatory approaches to innovation

Having looked at the way standard regulatory approaches affect innovation, I now turn to specific mechanisms to make network regulation more innovation-friendly. This is not a question of comparing both and choosing between cost-based or price-based regimes for the regulation of network tariffs, but of adapting these regimes to the requirements of RD&D and innovation by introducing specific instruments to promote RD&D and mixing cost- and price-based elements for that purpose (see chapter 5.2.2 on price- and cost based mechanisms within price- and cost-based regimes). However, as regulatory regimes are generally price-based nowadays, the focus is on how various innovation-specific mechanisms, partly cost-based and partly price-based, can be added to this regime.

The literature on this issue is even more incomplete than the above-mentioned literature on the innovation effects of regulation. In terms of practical regulation, there are hardly any examples of regulators that have addressed this issue. The only major exception is the UK, which will be analysed in the case study in chapter 8. The section attempts to structure different proposals that have been made and discusses the pros and cons.

When discussing instruments to promote innovation activities, one should bear in mind that there can also be too much innovation efforts and that RD&D can be inefficient from the point of view of social welfare. For example, capitalising RD&D costs as discussed below can lead to ‘gold-plating’ RD&D projects, i.e. spending too much on such projects to benefit from the guaranteed rate-of-return. RD&D should not be an end in itself and innovations should not just increase efficiency or yield new products or services, but rather they should do this in an efficient way. Although it will be impossible in this context to determine the right level of RD&D and the necessary costs in practical terms, efficiency should nevertheless inform the debate on regulation and should be used as a guideline when designing regulatory instruments.

There are a number of approaches to regulating RD&D and innovation in networks. In the following, I present them and distinguish between cost-based or input-based approaches on the one hand and price-based or output-based approaches on the other hand. Before discussing these approaches, the next section briefly discusses the issue of innovation externalities and additional objectives already mentioned in this chapter.

6.3.1 Removing innovation externalities for the DSO

In the previous section it was argued that price-based regulation can provide insufficient incentives for DSOs to invest in innovation, even if the innovation increases network efficiency and thus contributes to meeting the efficiency objective imposed on the company by the regulator. If the innovation contributes to meeting other objectives, the innovation benefits can appear as externalities for the regulated company, which further reduces the incentive to pursue these innovations. If DSOs do not have the objective to connect DG, they do not have an incentive to connect them in an innovative way, either.

This is why incentivising DG connections as discussed in chapter 5 is an important prerequisite for promoting innovative DG connections. However, if companies do have an incentive to connect DG, they still face the general innovation problems described above that can result from regulation in general and price-based regulation in particular. It is therefore not sufficient to rely on DG objectives and incentives to promote DG-related network innovations, just as it is not sufficient to rely on the efficiency objective prescribed by incentive regulation to promote innovations that make the network more efficient.

It is therefore not convincing when Abildgaard et al. (2003: 4) propose that in order *"to prompt active networks and innovation, the revenue should become more dependent on network performance/output"*. The argument is that this approach would not prescribe the company what to do to meet these performance targets. The regulator would not need to judge whether innovations are necessary, but can observe how its performance criteria affect RD&D.

This would clearly simplify the regulatory process, but faces the same problems as incentive regulation in general. Under standard incentive regulation the performance criterion is based on efficiency and the regulated company can in principle choose how to meet this criterion. However, the asymmetric truncation of costs and benefits can lead to a bias towards short-term measures. The same would happen with additional performance criteria, unless they are set at such a high level that innovations are the only possible way to meet them.

What is positive about performance criteria in terms of innovation is that they could 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 retaining the performance criteria beyond one regulatory period.

Since removing externalities by adding new performance criteria is not enough, the following sections explore additional mechanisms to promote innovations.

6.3.2 Input-based mechanisms

Input-based or cost-based approaches target the costs of RD&D and explicitly include them in the regulatory scheme. In line with the discussion in chapter 5, it needs to be stressed that such cost-based approaches to innovation can be implemented well within a regulatory environment that is generally price-based. In this case, cost-based regulation of RD&D costs exempts these costs from the price-based regime.

First of all, a cost-based approach requires that the regulator recognises these costs when it determines a company’s cost base. This in itself would send a signal to companies that the regulator sees innovation as an important issue and expects network operators to participate in development and demonstration projects. Alternatively, the regulator could argue that network operators should not spend money on developing innovations themselves, that these costs unnecessarily increase network tariffs and are therefore not included in the accepted cost base. Clearly, this exacerbates the disincentives against innovation compared to the analysis in section 6.2, as there is no truncation of costs whatsoever. If the regulator accepts the RD&D costs, then this would make the DSO less efficient in a comparative efficiency analysis with other network operators, but the less efficient DSOs may still be able to recover some of these "inefficient" costs. If the regulator does not accept any RD&D costs, then none of these costs can be recovered.

Most regulators have not explicitly addressed this issue yet (for the EU-15 see Skytte, Ropenus 2005), which in many cases means that companies will find it difficult to get RD&D costs accepted in a regulatory review. In the case of Australia, the former regulator for New South Wales, IPART, has explicitly decided not to allow the recovery of costs associated with learning by doing in the case of network-related demand-management projects (IPART 2004).

If the regulator accepts RD&D costs in principle, the next question is whether RD&D costs are accepted, but treated as any other costs, or whether the regulator acknowledges that RD&D is not sufficiently incentivised under normal price-based regulation and requires special treatment.

In the latter case, two approaches can be distinguished: firstly, there can be a direct pass-through of costs to customers, secondly, research costs can be capitalised and treated as investment. They are not entirely separate, but as I discuss below, may be combined in different ways, depending on the overall regulatory regime.

Any separate treatment of RD&D related costs with cost pass-through or capitalisation is faced with the problem of how these costs can be clearly separated from other costs and poses the risk that DSOs will seek to shift costs that are not related to innovation into this special regime. It is therefore recommendable for the costs that can be passed through or capitalised to be capped.

6.3.2.1 Pass-through of RD&D costs

The first cost-based approach is a cost pass-through mechanism. In the previous chapter, I explained how a cost pass-through can be used to protect a network operator against the financial risks of connecting DG. In the same way, this approach can be applied to pass the costs of RD&D to customers. Cost pass-throughs are often used for costs which a company has no control over by directly including these costs into network tariffs. In the case of passing through RD&D costs, the instrument is used to shield DSOs from the uncertainty of RD&D. The costs are not subject to any benchmarking, nor is the ability of the company to recover these costs capped by a price-based mechanism, even if the overall regulatory regime is price-based. In terms of the truncation effects discussed above, the approach introduces the lower-end truncation that is typical for cost-based regulation in a price-based regime.

Cost pass-throughs as specific instruments will typically be employed in a price-based environment, because with cost-based regulation all costs are passed through anyway. In a price-based environment, however, it represents a special treatment of the respective costs.

If RD&D costs are completely included in the pass-through mechanism in a price-based environment, RD&D essentially does not increase the company costs it has to recover via efficiency improvement. At the same time, the innovation can help the company to become more efficient, thereby benefiting from the increased gap between price-cap and costs during a regulatory period. In other words, network customers pay for the RD&D efforts which then benefit the company, at least partially.

This combination of ring-fencing costs from the price-cap mechanism on the one hand and on the other hand allowing the company to keep, at least temporarily, the resulting benefits under that same price-cap mechanism should give the company an incentive to spend on RD&D and try and develop useful innovations. The approach can thus remedy the potentially weak innovation incentive in a price-based regime.

At the same time, however, the approach exhibits at least two potential short-comings: Firstly the risk distribution between the network company and its customers is uneven. The downside risk if RD&D does not generate any results lies completely with network customers, whereas the upside risk of useful innovations is shared between them and the network company. Secondly, and as a result of the first point, network companies have incentives for useful RD&D, but are not incentivised to be efficient – unless the amount of costs that can be passed through is capped.

6.3.2.2 Capitalisation of RD&D costs

Under the cost pass-through approach presented in the previous section, a large part of RD&D costs will be treated as operational expenditure. Alternatively RD&D costs can be categorised as an investment, i.e. RD&D costs are regarded not just as operational expenditure, but are capitalised, included in the regulatory asset base (RAB) and depreciated. As a result, the regulated companies can earn a rate-of-return on RD&D expenditures, irrespective of any efficiency or quality improvements resulting from the innovation.

While a cost pass-through is not an option for promoting innovation in a cost-based environment (where costs are passed though anyway), capitalisation of costs (that are passed-through, but normally treated as operational expenditures) may be applied both in a price-based and a cost-based environment to promote innovations. A number of studies have analysed RD&D capitalisation in the context of ‘traditional’ cost-based regulation in the US (e.g. Mayo, Flynn 1988).

In a price-based environment, there are two options. Firstly, if price-based regulation applies to OPEX only, with investment still mainly cost-based, capitalisation would have a double effect: RD&D costs are both taken out of the price-based regime and the company can earn a rate-of-return on these costs. If price-regulation applies to total expenditures, capitalisation would only imply a rate-of-return on costs that were previously OPEX, but no cost pass-through. In this case, capitalisation would not be a cost-based mechanism anymore.

The capitalisation approach raises two questions: Firstly, how can it be justified that costs that are normally operational costs in accounting terms, are classified as investment by the regulator (except that this may serve the objective to promote innovation). The second question is whether the capitalisation approach actually promotes innovation?

Regarding the first question, Holt (2005: 3) has pointed out that, “the economic rationale for capitalising the value of RD&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”. In a similar vein Damodaran (no date) argues that RD&D expenses should not be treated as operating expenses, because they are not incurred to generate income in the current period, but to provide benefits over multiple periods. There are examples that such costs have been capitalised in other sectors (Competition Commission 2002).

The second question is whether the capitalisation approach actually promotes innovation. Based on an analysis of empirical data, Mayo and Flynn (1988) find that capitalising RD&D expenditures into the rate base significantly increases the amount of money spent on RD&D by the regulated company. This supports the theoretical argument that this approach takes away the downside risk from companies and insures that regardless of whether RD&D expenditures lead to innovations and cost reductions sufficient to justify the costs of RD&D they will in any case generate the allowed rate-of- return (lower-end truncation).

Already we arrive at the first problem: Capitalising RD&D expenditure may increase the amount of money spent on RD&D, but it should not be equated with an increase in useful innovations. In other words, companies have an interest in RD&D, but not necessarily an interest in the productive outcome of innovations. Increasing RD&D expenditure, however, is not an end in itself, and does not necessarily translate into innovations. With this approach, there is a danger that capitalising RD&D expenditures can lead to an inefficient over-investment in RD&D or ‘gold-plating’ of RD&D projects, similar to the more general problem that rate-of-return regulation can lead to excessive capital expenditure (Averch-Johnson effect, see section 5.2.2).

A further problem of capitalising RD&D expenditures can be that it gives companies an incentive to declare as many costs as possible as RD&D costs. Since DSOs will not get involved in basic research in most cases, but will test how an innovation can be implemented in its network in, for example, demonstration projects, most innovation costs will not be incurred in a specialised RD&D centre, but will more likely be linked to ‘normal business’. In practice it will therefore be difficult to assign costs to the RD&D budget that is to be capitalised.

Under price-based regulation, the positive effect of the capitalisation approach on RD&D should be even stronger in principle, because the upper-end truncation is generally weaker. As opposed to cost-based regulation, this gives companies some incentive to aim for useful innovations.

Finally, if capitalisation increases the amount of money spent on RD&D, it may reflect an inefficient RoR set by the regulator. As Holt (2005: 4) has pointed out, *“capitalising or expensing expenditures should not have any present-value effect for the firm if the allowed rate of return is set at the level of the cost of capital (determined by the regulator). Therefore, any additional R&D spending could reflect a generous cost of capital, and it would be difficult to determine whether these additional expenditures were ‘efficient’.”*

6.3.3 Output-based mechanisms

While the approaches discussed in the previous section tackle the input side of RD&D, I now turn to mechanisms that are based on RD&D outputs, i.e. actual innovations. While input-based approaches basically take away the cost risk from companies (introducing lower-end truncation), output-based approaches make the innovation outputs more attractive for them (relaxing the upper-end truncation). Under these approaches, companies can only benefit from successful innovations. I present the following output-based approaches:

- including innovation outputs in price-based regulation through additional revenue allowances, raising the cap imposed by the regulator;

- extending the regulatory period;

- regulatory holidays, effectively removing the cap on the regulated company for a limited period of time.

One general problem of output-based approaches is that innovation outputs are even more difficult for the regulator to define and identify than innovation inputs.

6.3.3.1 Raising the cap based on output criteria

In a price-based-environment, companies can generally not directly recover the costs of RD&D, but have to recover them through the cost-savings relative to the revenue cap imposed by the regulator. If a company develops and introduces an innovation, the regulator can raise this cap, thereby allowing the company to recover some of the RD&D costs through the resulting higher revenue. As opposed to cost-based approaches, under a price-based mechanism this additional revenue allowance is not directly linked to the underlying costs a company has incurred, but is a function of the actual innovation, thus assuming an average cost value. The effect for the company would be that it still carries the downside risk of RD&D, but due to a higher cap the upside truncation is less severe and there is a higher potential for the company to benefit from successful innovations, at least as long as the costs of developing these innovations are matched by the higher cap.

While input-based approaches have to be based on a sound definition of RD&D costs, the main challenge with this approach is to define what exactly should drive the cap, or in other words how innovations can be defined. Two approaches to define revenue drivers can be differentiated:

Firstly, it has been proposed that general innovation-related output criteria such as patents be used (Holt 2005: 4). While this indicator is relatively easy to measure, the question is whether it can adequately reflect RD&D efforts by regulated network operators, especially as they will mainly be involved in demonstrating and implementing innovations. Also if the patent is held by a manufacturer outside the regulated industry, but the DSO still plays an important role in the innovation process, it would not be covered by this indicator.

Secondly, the regulator can define ex-ante what counts as innovation or rewards innovations in a specific area, e.g. innovative connections of DG. This is the approach that has been applied by Ofgem in the UK under the Registered Power Zone scheme (see UK case study in chapter 8). While this approach can be more targeted, there is also a significant danger of the regulator micro-managing RD&D.

6.3.3.2 Extending regulatory periods

During regulatory periods, efficiency gains that exceed the efficiency gains foreseen by the regulator at the beginning of the regulatory period lead to higher profits. During these periods, companies can appropriate the benefits of innovation. At the beginning of 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 principle.

While the previous approach “Raising the cap” relaxes the upper-end truncation by allowing the company to increase its revenue and make a higher profit during a regulatory period, the approach discussed in this section leaves the revenue cap untouched, but gives the company more time to benefit from reducing its costs below this cap.

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; Bailey 1974). While patents protect the innovation from being imitated by competitors for a certain period of time, the regulatory period protects the benefits of innovations from being passed on to consumers.

In a theoretical study, Bailey (1974: 295) has shown for rate-of-return regulation that extending the regulatory lag does have a positive effect on RD&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”*.

Based on these arguments, Fuckso et al (2004: 38) have proposed for network regulation in Hungary to extend the regulatory period from four to five years. The period between regulatory reviews would thus be deliberately used by the regulator to influence the innovation propensity of regulated companies. Under price-based regulation with its regulatory periods that are determined ex ante, this is in principle an option that is available to the regulator. Under cost-based regulation it may be more difficult for the regulator to commit ex-ante to an extension of the lag.

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 at least three reasons. Firstly, the innovation incentive is not unambiguous. In another theoretical study of cost-based regulation, 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 due to the lag, as such a delay would also postpone the price reduction imposed by the regulator.

Secondly, as has already been indicated by the citation 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 the prices deviate from the 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.

The question arises if given this constraint the regulatory period can be long enough to stimulate innovations. Regulatory periods normally are between three and five years. 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.

Finally, 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 (2005a) has proposed to *“allow companies to retain the benefits of efficiency savings* *derived as a result of undertaking RD&D for longer than the current five-year period for ‘conventional’ efficiency savings”*. However, it is doubtful whether 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 RD&D efforts. The fact that some in-house RD&D can lead to efficiency savings by enabling a company to appropriate external RD&D results would make this process even more complicated.

In summary, extending the regulatory period to stimulate RD&D and innovation cannot provide strong enough incentives, especially given the constraints of the overall regulatory process.

6.3.3.3 Removing the cap: Regulatory holidays

Another approach that has been discussed mainly in the telecommunications sector are so-called access or regulatory holidays (Holt 2005b; Gans, King 2004). Under this approach, the cap is not just raised, but a certain part of the network is temporarily exempted from regulation, i.e. the cap is lifted altogether and the network company can in principle charge monopoly prices. Again, this is similar to patents in some ways.

This mechanism seems quite radical compared with the previous mechanisms that seek to amend tariff regulation, rather than to intermit it. So why have regulatory holidays been proposed? The reason is related to the truncation problem I have discussed earlier.

An RD&D project (or an investment in general) has a rate-of-return probability distribution, i.e. the project can fail or be successful in various degrees. Now assume an RD&D project is highly successful and generates a high RoR. In their analysis focusing on the telecommunications sector, Gans and King argue that the regulator may consider this too high and intervene to reduce it to a ‘reasonable’ level, e.g. to avoid any ‘fat cat’ claims of excessive profits from the political side or network customers.

Ex-post – i.e. once the project has turned out to be successful – the reduced rate of return may still be sufficient for the company, and leads to lower network tariffs that enable efficient use to be made of the network including the innovative facility. However, from an ex-ante point-of-view, this additional upper-end truncation of the probability distribution would have reduced the average rate of return, and may have made the project with this adjusted risk profile unprofitable. In other words, if the company expects in advance that the upper end will be truncated, it would not have invested in the first place as the regulatory risk further truncates the potential profit. The problem is, as argued by Gans and King, that the regulator cannot credibly commit ex-ante that it will not exploit the company's sunk costs ex-post. From this perspective, the only way around this problem is to introduce regulatory holidays, i.e. the regulator does not commit to adhere to a certain overall rate of return, but commits to discontinuing regulation for a certain period of time, allowing the company to fully exploit its investment.

The analysis that leads to the regulatory holiday proposal is similar to the analysis of price-based regulation I have presented in section 6.2.2. The underlying problem is the asymmetric truncation of costs and benefits: If the project fails, the company is stuck with the costs; if the project is successful, part of the benefits is passed on to consumers without taking into account the risk associated with achieving these benefits. In the analysis provided by Gans and King the asymmetry results from the fact that the regulator cannot credibly commit to not truncating the upper-end ex-post. In the analysis provided in section 6.2.2, the asymmetric truncation is due to the fact that the regulator cannot distinguish between benefits that result from normal efficiency improvements on the one hand and innovative efforts with a higher risk on the other hand. As a result, the regulator applies the truncation that is appropriate for normal business to the riskier investments, too.

In the telecommunications sector with potential infrastructure competition, the regulatory holiday approach may be applied to entirely new networks, like a cable network for pay TV, which is the example used by Gans and King, or a VDSL (Very-High-Data-Rate Digital Subscriber Line) network, which was proposed by the German government. But even in the telecommunications sector, the approach is highly controversial, both politically (the German proposal was rejected by the European Commission) and theoretically (Blankart et al. 2006).

In the electricity sector, the approach is even more problematic. Firstly, as there is no potential for infrastructure competition, it cannot be argued that network users that face monopoly prices during a regulatory holiday can switch to or build up an alternative network. Also, as innovations in this sector are typically more embedded in the existing network, it would be difficult to identify which part of the network should be exempted. Exemption of the whole network in which an innovative company operates could not be justified. I could not find any practical examples where electricity regulators have applied this approach.

6.3.4 Conclusion

The discussion in this section has shown that there are mechanisms available within the incentive regulation framework to counter the weak innovation incentives of the standard model and promote innovation. Price-based regulation as such can reduce incentives for innovation as compared to cost-based regulation. However, as an additional innovation-oriented mechanism both price-based and cost-based approaches can be designed to promote innovations. The general advantages of incentive regulation – that it can help the regulator deal with information asymmetries and can trigger efficiency gains – are relevant to the promotion of innovations, too.

In terms of the individual mechanisms discussed, both the extension of regulatory periods and regulatory holidays have been found to be inappropriate for the promotion of innovations, at least in the electricity sector. For the other mechanisms, specific incentive properties and regulatory issues have been identified. For the design of these innovation mechanisms it is important whether the objective is to trigger efficiency gains or to support additional objectives.

As I have explained in chapter 5, cost- and price-based approaches are theoretical extremes cases that can be mixed in different ways. This is not only because in the course of practical implementation the boundaries get blurred, but also because elements of both approaches are intentionally mixed to give companies certain incentives and achieve certain results. Such hybrid mechanisms have already been discussed in chapter 5 on network regulation and DG integration. Similarly, the input- and output-based mechanisms discussed in this section can be combined to promote RD&D and innovation.

6.4 Beyond the incentive regulation mechanism

The previous sections have shown that the standard model can provide insufficient incentives for innovation, but the very mechanisms of the standard model can be adapted to promote innovation. The last section on innovation specific mechanisms was mainly concerned with amending the incentive regulation mechanism itself. This final section of the innovation chapter broadens the perspective beyond the "incentive regulation formula" in two ways: firstly, it discusses whether incentive regulation is the right place to promote network innovations; secondly, it discusses the policy-regulation interface and how it is affected by innovation mechanisms.

6.4.1 Is economic regulation the right place to foster innovations?

Relying on economic regulation to pursue objectives beyond efficiency can be criticised both from the standard model perspective as well as from the evolutionary perspective put forward in chapter 2.2.

6.4.1.1 Critique from the perspective within regulatory economics

Innovation mechanisms have not been a major issue in the standard model literature, but proponents of the standard model generally tend to be reluctant to include new mechanisms in this model to pursue new objectives. This is the case although these can be based on the very mechanisms of the standard model. There are several reasons for this reluctance:

Firstly, when the standard model was introduced, it was claimed that it improves the conditions for innovations in electricity networks. It is clear that based on this claim, additional mechanisms seem unnecessary.

Secondly, there is the argument that regulatory interventions are unlikely to have the desired effect on the innovation outcomes (e.g. Gerpott 2006: 148 on the telecommunication sector).

Thirdly, additional mechanisms are assumed to weaken the core efficiency incentives of the standard model and lead to negative side effects. For example, Brunekreeft and Ehlers (2006: 82-83; cf. Pollitt 2008: xxx) are concerned about the consistency of the overall regulatory framework and potential contradictions between different elements if new mechanisms to pursue additional objectives are added.

While this is certainly a serious issue, it is largely a matter of properly designing mechanisms, but not a fundamental argument against such additional incentives. We also need to bear in mind that additional mechanisms are not necessarily added to a hitherto consistent framework. Although economic regulation itself may be consistent, there can be significant inconsistencies between ‘pure’ incentive regulation incentivising DSOs against RD&D (as shown in section 6.2), on the one hand and policies outside network regulation that require and/or promote innovations on the other hand. The same argument has been made in chapter 5 for the political objective to increase the share of DG and the regulatory incentives that undermine this objective.

A more serious argument against regulatory innovation mechanisms is the fact that additional mechanisms within incentive regulation are to be paid by network customers. Shifting the innovation costs to customers of individual networks can be problematic especially if the innovations not only benefit network customers in one network area, but also help support national policy objectives (see the discussion on internal and external objectives in chapter 5). In this case, it is clear that these objectives should be pursued through innovation instruments outside economic regulation.

For example, in Australia the former regulator for New South Wales, IPART, decided in 2004 to set up a programme to facilitate "demand-side management", including "embedded generators". In this context, the regulator decided not to include costs associated with 'learning by doing', arguing that it is "*inappropriate for customers to bear the costs of knowledge-building or experimental demand management activities – rather, this is a role for government or the distribution network services providers themselves*" (IPART 2004: 94).

If innovations are to be financed via network charges, an alternative to economic incentives for individual companies are public service obligation funded by all customers. For example, this approach has been applied in Italy and Denmark (Bauknecht et al. 2007; see also case study on Denmark).

However, even if one argues that economic regulation is not the best place to support innovations and that RD&D should be mainly supported outside regulation, e.g. through public funding, the economic incentives of network companies are still largely influenced by economic regulation. Regulation should therefore at least point into the same direction as other instruments outside regulation. This can be achieved by applying the mechanisms discussed earlier. The practical design of the instruments should take into account any support outside regulation, e.g. when determining the relevant parameters.

For example, if network companies receive part-funding for RD&D projects through research programmes outside regulation this represents a form of lower-end truncation. However, economic regulation still needs to take into account the company's own contribution to the projects funded under this programme and generally support the innovation objectives pursued by the research programme.

In summary, economic regulation should not be the main instrument for providing RD&D funding. Yet if ‘pure’ incentive regulation is applied with the innovation incentives analysed earlier, it is likely to be inconsistent with innovation instruments outside regulation. Innovation mechanisms within economic regulation are therefore still necessary and need to be consistent with innovation instruments outside regulation.

6.4.1.2 Critique from the perspective outside regulatory economics: Are revenue incentives sufficient?

In the evolutionary economics literature presented in chapter 2.2, the innovation effects of network regulation have received even less attention than in the regulatory economics literature. This supports the argument made in chapter 2 that the evolutionary and system transformation literature has neglected to link its insights to established policies, i.e. the standard model of liberalisation and regulation in the case of the electricity sector.

Applying the arguments of the literature presented in chapter 2.2, a number of shortcomings of the above discussion on amending the standard model become visible. Most importantly, the mechanisms discussed tend to assume that innovation is an optimisation process performed by individual companies. This means that the company compares known RD&D inputs with known RD&D outputs and decides to spend on RD&D projects in order to maximise its RD&D benefits. From this perspective, innovation is analysed like an investment made by the network company. With the mechanisms presented above, the regulator changes the economic parameters of this optimisation process in order to influence the innovations outputs or the efficiency of RD&D.

In contrast to this view, the evolutionary economics literature argues that innovation is not a rational optimisation with perfect foresight, but is characterised by bounded rationality and imperfect information as well as institutional factors that influence a company’s decision-making. In other words, innovation is no longer regarded as an input-output relation, with RD&D spending as the most relevant input factor and with upper- and lower-end truncation from the company’s perspective. Rather, innovation processes are put into a wider context that constrains and directs the innovation process. In the case of network innovations this can include, for example:

- the RD&D capacity of regulated companies that is a prerequisite to react to external price signals,

- the RD&D culture and routines within companies that guide the search for new solutions,

- innovation networks, e.g. the link between regulated companies and equipment suppliers which is necessary for the regulated companies to introduce innovations in their network (see section 6.1),

- general visions and expectations of future network developments, e.g. in the sector itself or in the political realm that guide innovation processes within individual companies beyond a mere input-output optimisation.

In this perspective the regulated companies can hardly be characterised as rational, optimising actors that adapt their RD&D and innovation strategy more or less instantaneously to changes in the economic incentives given by regulation. Nevertheless, economic regulation does represent a key factor influencing the decision-making processes of regulated companies, including decisions to build up internal RD&D capacities and establish links into an innovation network. Applying the terminology of the evolutionary perspective on innovations, economic regulation is an important element of the *selection environment* (see section 2.2) in which innovations develop.

Therefore, even if amending revenue incentives is not sufficient, it is still necessary – not least of all in order to ensure that economic regulation is consistent with other approaches that are based on evolutionary thinking on innovation. The conclusion from this discussion is thus in line with the outcome of the previous section. Incentive regulation is not a neutral instrument, where one can decide whether or not to use it to incentivise innovations. Rather, even in its ‘pure’ form it provides innovation-related incentives that need to be altered in line with innovation objective and instruments outside regulation.

6.4.2 Policy-Regulation Interface

The previous section has already highlighted that the discussion on promoting innovations via economic regulation cannot be limited to the incentive regulation mechanism itself. Rather, it needs to be seen in broader energy and innovation policy context. This is necessary for two reasons: firstly, economic regulation needs to be coordinated with other innovation instruments as discussed before; secondly, even if network innovations were only facilitated through network regulation, this has a political dimension, too. This is the case irrespective of whether innovations increase efficiency or support other objectives.

If the objective of innovation mechanisms is ‘merely’ to promote innovations to further increase network efficiency, the design of innovation mechanisms could be left to the regulator, provided that innovation was a well-understood optimisation process. In this case, the innovation mechanisms could be designed so that their additional costs for network customers are justified by the expected innovation benefits. The regulator could deal with this additional efficiency potential within its efficiency remit.

In the traditional regulatory economics literature innovation tends to be portrayed as an optimisation process that allows the regulated company to maximise its profits. For example, Bailey has modelled regulation based on the firm’s objective “*to select that level of innovative activity which, for any stated value of the regulatory lag T, maximizes its discounted stream of net profits*” (Bailey 1974: 286). More recent insights into the innovation process like those presented in chapter 2.2 undermine the notion that the company is able to determine an optimal level of innovation effort.

What is more, modern regulatory economics stresses the information asymmetry between the company and the regulator. As a consequence, any knowledge about the right level of RD&D the company may have is not easily accessible to the regulator. Incentive regulation aims at overcoming this information asymmetry. However, while benchmarking procedures may give the regulator an idea about efficient network provision, the benefits of RD&D are much more difficult to assess. It is therefore hardly possible for the regulator to gain an insight into the right level of RD&D, at least not in the sense that this could justify innovation specific mechanisms in the first place.

The decision to set up regulatory mechanisms for innovations will therefore not be based on a computer model or the like that identifies innovations as a way to increase efficiency. Rather, it represents a more fundamental decision to shift the regulatory agenda based on an overall judgement of the sector and its development potential: from short-term efficiency gains to long-term network development and the implementation of innovative network concepts at short-term costs. As the benefits of this shift are uncertain, it basically becomes a decision whether to err on the side of long-term innovation or short-term cost reduction. In a different context Baldwin and Cave (1999: 103-108) have discussed the issue of regulatory over- and under-inclusiveness. In the context of this discussion, this distinction could be applied to refer to the risk of spending too much or too little on innovation. This is ultimately a political decision.

If innovations are to support objectives beyond efficiency the political dimension becomes even more apparent. In this case, the decision to be made is not just about the *level* of innovation, but the additional objectives also determine the *direction* of innovation, which even more strongly calls for a political decision and needs to be coordinated with overall energy policy objectives. If there is a political decision to support DG and related network innovations, this can be the basis for the regulator to support these innovations and to err on the side of over-inclusiveness.

6.5 Conclusion

This chapter has analysed the effect of incentive regulation on innovation and regulatory mechanisms to incentivise network innovations. The results of this chapter correspond with the results of the previous chapter 5 in several ways.

Firstly, while chapter 5 has shown the tension between incentive regulation and the DG objective, this chapter has shown the tension between incentive regulation and network innovations. This analysis pertains both to innovations that increase network efficiency and those that support DG integration. It thus confirms the general argument made in chapter 2.1 for the specific case of network regulation: the standard model of electricity market liberalisation has been successful in short-term efficiency improvements, but exhibits short-comings when it comes to long-term infrastructure developments. This is the case especially when infrastructure development is required to reach objectives beyond efficiency.

Secondly, as for the potential of the standard model to integrate DG integration and network development as new objectives this chapter has confirmed the results of chapter 5 with regard to network innovations: The standard model can be amended based on its very mechanisms to pursue additional objectives beyond short-term efficiency. Based on the broader understanding of incentive regulation put forward in chapter 5, price- and cost-based mechanisms represent a powerful toolbox for providing the network company with incentives for effective and efficient innovations. As with the DG incentives discussed in chapter 5, cost- and price-based mechanisms may be combined for that purpose.

Finally, the chapter has also highlighted a number of problems that arise when the discussion is limited to the incentive regulation mechanisms: Applying the evolutionary view on innovations presented in chapter 2.2 calls into question the notion of innovation as an optimisation process by rational firms that react to price signals given by regulation. Amending the incentive formula is necessary to make economic regulation consistent with innovation strategies outside regulation, but not sufficient.

Moreover, the political dimension, which was already mentioned in chapter 5, has become visible. On the level of the incentive formula the very mechanisms of incentive regulation can be applied to reach additional objectives. But this should not obstruct acceptance of the fact that these amendments change the relationship between policy-making and regulation.

While chapters 5 and 6 have focused on amending the incentive regulation formula, the following chapters will build on these latter aspects and discuss the potential of the standard model of economic regulation more generally.

7 Beyond changes in the incentive formula

Chapters 5 and 6 analysed regulatory mechanisms for providing DSOs with financial incentives to integrate DG and to actively promote network innovations. It was shown that these mechanisms fit into the standard model of incentive regulation based on cost- and price-based tariff regulation. Although incentive regulation was initially designed to promote the efficiency of supplying electricity via the networks, it can be adapted to pursue additional objectives like the network integration of DG.

So far, this analysis supports the general view expressed in liberalisation literature, as presented in chapter 2: new objectives can be integrated into the standard model of electricity market liberalisation. Just like the standard model of market liberalisation is supposed to provide, for example, CO_2 reductions at the lowest cost via market-based emissions trading (see chapter 2.1), incentive regulation can be designed to integrate DG into the networks at the lowest cost.

In this chapter it is argued that an incentive regulation mechanism alone is not sufficient. This is the case for three reasons:

1) Network regulation by itself is not sufficient to promote DG. Regulation is important for integrating DG into networks, but is not the right place for dealing with the economics of the DG plant itself. Therefore, regulation needs to be complemented by support mechanisms that are located outside network regulation. As mentioned in chapters 3 and 5, a main driver for DG has been specific support mechanisms like feed-in tariffs or quota systems. Considering DG in network regulation should not be confused with setting up such a support scheme for DG within network regulation. Moreover, as explained in chapter 6, regulatory mechanisms for promoting innovations need to be coordinated with innovation instruments outside regulation. However, these complementary instruments will not be discussed further in this chapter since the key focus of this thesis is on network regulation.

2) Another question is whether network regulation itself should be limited to economic incentives, or whether additional instruments should be applied by the regulator. This question becomes particularly relevant when regulation is to promote not only the efficient connection of DG, but overall infrastructure transformation. For example, the European Regulators' Group for Electricity and Gas (ERGEG 2009: 7) has stressed that *"it can be argued that incentive regulation alone should ensure that new technologies and solutions are pursued by network companies, provided that there are regulatory mechanisms in place that provide for quantified evaluation of the grid's "smartness". However, there is evidence that, while this will apply for incremental innovation, it is much less effective for more radical innovation which requires more substantial regulatory treatment"*.

   Regulatory options beyond economic incentives will be further explored in section 7.1 of this chapter. Based on the research framework put forward in chapter 4, this section mainly addresses the relationship between the regulator and the regulated company, as well as other stakeholders.

3) Finally, DG and network transformation as a new objective require not only adaptations on the level of regulatory instruments, but make it necessary to rethink the overall role and objectives of regulation. This will be discussed in section 7.2 of this chapter. Based on the research framework put forward in chapter 4, this section mainly concerns the role of regulation in the wider energy policy context.

It should be noted that there is not much literature which could be used as a basis for this chapter. On the one hand, standard model literature has been more concerned with phasing out regulation than with adapting it to new challenges. On the other hand, system transformation literature has not explained exactly how its proposals can link up with the existing governance framework in the electricity sector. There are some studies that have reviewed the potential to adapt the standard model of regulation beyond the incentive formula in order to contribute to sustainability rather than short-term efficiency alone (cf. Bartle, Vass 2007; Owen 2004). The sustainability perspective is very close to the transformation perspective because it also stresses long-term system effects and because transformation has chiefly become a relevant issue due to sustainability requirements.

7.1 Governance mechanisms beyond the incentive formula

This section reviews the governance mechanisms of the standard model in the light of network transformation. It begins by explaining why governance of system transformation is a relevant issue for electricity network infrastructure. The section then goes on to present generic governance requirements in the context of system transformation, based on chapter 2.2. In the next step, these governance requirements are contrasted with the standard model and a number of adjustments to the standard model are proposed.

7.1.1 Network transformation and the standard model

The main question addressed by this thesis is how DG integration and network development can be integrated into the standard model of network regulation and whether and how the regulatory framework needs to evolve. In chapter 2, the standard model of electricity liberalisation was contrasted with system transformation literature. Relevant system transformation literature was presented to provide a theoretical basis for challenging the standard model.

While the standard model relies on the market mechanism and market-based instruments to correct market failures, system transformation literature stresses the need for additional governance mechanisms. Proponents of the standard model will reject the very argument that system transformation represents a specific challenge. Instead, they will tend to argue that the competitive market will lead to the required changes, including structural transformations if necessary. In the case of DG and network regulation, this would mean that the financial incentives presented in chapters 5 and 6 are sufficient to trigger the required adaptations.

For example, in a report for the UK regulator Ofgem discussing regulatory mechanisms for dealing with uncertainty Frontier Economics (2003) recognises that DG can cause additional uncertainty in the short term. As a new phenomenon, its network costs are more uncertain and diverse than those of ‘traditional’ generators. This can be dealt with using incentive mechanisms like those discussed in chapter 5. However, according to this report, *“DG is likely to become a more ‘normal’ part of what DNOs do”*, assuming that *"the network develops towards a transmission role, in which its function is to connect generation to load*.” This transmission role involves active balancing of supply and demand analogous to the high voltage transmission system, rather than passive distribution of power to consumers.

How this long-term transformation towards a ‘transmission role’ will come about, whether there are other development options and how these can be influenced, is not discussed. This is surprising because it would entail far-reaching changes with repercussions on the business model of distribution network operators, their network control paradigm, the relationship between distribution and transmission system operators, and the overall commercial framework.

Although within the standard model system transformation is largely ignored as a specific challenge, there are a number of reasons as to why the arguments of the system transformation literature are relevant for the electricity sector in general and the networks in particular.

Firstly, the standard model was designed to improve efficiency, rather than to provide a governance mechanism for structural transformation. It is taken for granted that the model is capable of dealing with long-term issues, too. However, chapter 2 has shown that the standard model encounters problem when the focus shifts from short-term efficiency to more long-term issues like investment and innovation. This is particularly problematic when:

- investment and innovation are not generally framed by the need to maintain and improve the current centralised structure of electricity supply based on large-scale plants, but are building blocks of a system transformation and need to be coordinated accordingly, and

- the main objective of this transformation process is not to increase network efficiency, but to provide the infrastructure to achieve other political targets, as in the case with DG integration.

Secondly, such a system transformation is a relevant issue for the electricity system, including electricity networks. In chapter 3, it was shown that the network implications of DG can go beyond individual connections or incremental adaptations in individual networks. Rather, an overall transformation of the network structure can result from DG, covering both the distribution and the transmission system.

Thirdly, due to the special characteristics of the electricity system in general and the network in particular, the system transformation drivers and barriers described in chapter 2.2 are highly relevant for this sector. The electricity system represents a prime example of an interlinked system that is prone to lock-in and path dependency (Hughes 1983; Unruh 2000). This system characteristic is particularly tangible in the case of the network infrastructure where wires and the connected elements on the generation and demand side constitute an interlinked system. As a consequence one element is difficult to change without adapting other elements, too. Applying the concept of socio-technical system, this infrastructure system also includes, for example, the network companies, their organisational set-up, strategies and planning procedures.

A further peculiarity of the network infrastructure is that investments are (WRR 2008):

- highly capital-intensive,

- lumpy, i.e. expansions often need to be carried out in big steps, rather than gradually, which reduces the flexibility to adapt to new developments,

- sunk, i.e. investments tend to be irreversible and cannot be used for other purposes; and

- characterised by a long physical life-span and long depreciation periods.

This reduces the flexibility of network development and adds to the path dependency and potential lock-in. Network companies cannot easily adapt to new objectives and requirements, even if economic signals are changed via the incentive formula.

For example, in chapter 3.1.2.3 it was explained that in some cases DG can be used to replace network investments, thus reducing rather than increasing network costs. Provided the DG plants themselves are economically viable, these plants should be installed to increase overall efficiency. However, even under incentive regulation, this may be problematic, as described in section 5.1.3, if the DSO cannot benefit from the savings. This problem may be overcome by additional incentive mechanisms, such as those set out in chapter 5.

But even if the incentive mechanisms are adapted the DSO which employs DG as a network solution may face the problem that this requires some sort of *"holistic development"* (Harrison, Wallace 2004) rather than a case-by-case decision. This is partly because on a case-by-case basis the path dependency of the existing network layout tends to favour traditional network solutions. As de Jong explains in a review of network planning approaches and their effect on using DG as an alternative to network upgrades, *"network planners need to know in which way they want to develop their grids (…). The DNO has to make a choice about the future grid layout, especially about the functionality of the medium voltage grid. Since the amount of installed DG/RES is still uncertain and the technologies change fast, it is difficult for a DNO to anticipate future changes."*

An important prerequisite for the DSO using DG as an alternative to network upgrades is that it must be able to integrate DG into network operation, i.e. control their generation. This requires development of the necessary control infrastructure. As this will generally not be carried out for single DG connections, it represents a lumpy investment that is sunk if it turns out that DG cannot be used as a network alternative as expected.

In such a situation a DSO may prefer conventional network upgrades, even if it is incentivised to promote DG-based solutions. Even if the additional incentive mechanisms cover the costs of new solutions and enable the DSO to benefit from network replacements in individual cases, they are unlikely to reflect the uncertainty resulting from changing technologies and uncertain future system developments.

This example illustrates that even for an individual network it will not be sufficient to make individual DG projects more attractive by changing the incentive formula. Rather, the decision on individual projects needs to be embedded in a general 'vision' of the future share as well as the location of DG and corresponding network developments. It is only then that the DSO can overcome the path dependency of conventional network development and justify a new investment strategy. This vision depends on the expectations placed on the development of the network at hand, but is necessarily linked to a more general sector vision.

The coordination requirements become even more important when changes are not limited to individual networks. The proposed developments may go beyond incremental innovations in some parts of the network, developed and implemented by individual network operators. Rather, they may require system innovations and lead to an overall transformation of the network structure and the way networks are operated.

This transformation involves a broad range of actors: different network companies on the distribution and transmission level, demand and generation customers, equipment suppliers as well as other stakeholders. This necessitates close coordination of different actors changing different system components.

The innovation incentives discussed in chapter 6 may give the individual DSO an incentive to invest in RD&D so that it can thereby benefit from the cost saving. However, even with such incentives in place it is difficult for the individual company to know in which direction the system may be heading and how its innovation project links up with other innovation projects and the overall system transformation dynamics. The individual projects may not add up to an overall network configuration which works and can integrate the politically desired share of DG at low cost.

For these reasons, it is not sufficient to deal only with the costs and risks of individual DG connections and how these are likely to change due to a transformed system, as is the case, for example, in the Frontier Economics report cited above. Rather, the transformation process itself constitutes a challenge for network governance.

7.1.2 Reflexive governance of system transformation

The previous section did not present a detailed analysis of the capability of the standard model to deal with network transformation. However, it did set out a number of arguments as to why the governance proposals of system transformation literature are worth considering for the specific case of network governance.

In chapter 2.2, two governance approaches were presented to illustrate how the governance of system transformation literature proposes complementing standard governance mechanisms, namely strategic niche management and foresight. In this section, a brief but more comprehensive overview on governance mechanisms for system transformation is presented, based on Voß and Kemp (2006). This will provide a template for the following section in which the standard model is contrasted with the requirements of system transformation. Voß and Kemp presented their analysis of ‘reflexive governance’ as a prerequisite for sustainable development. ‘Reflexive governance’ may be applied to small-scale problems as well as on a system level. System transformation approaches such as transition management follow the principles of ‘reflexive governance’, as explained by Kemp and Loorbach (2006).

Five governance challenges for system transformation and corresponding strategies are identified; they are summarised in Table 6. Firstly, in terms of system analysis the consequences of policy interventions are not clearly predictable as they are the result of complex interactions between various actors and system components. Secondly, a clear-cut definition of goals is problematic since these are subject to transformation themselves, and conflicts of interest are inherent to the process. To address both of these challenges it is necessary, as a first consideration, to include a broad range of different actors with diverse interests in the process of system analysis and goal definition so that subsequent governance strategies are as robust as possible. To deal with uncertainty regarding system behaviour, a portfolio of experiments to explore different approaches should be used, e.g. via strategic niche management (see chapter 2). Goals should be re-examined on a regular basis to see if they are still valid. Moreover, strategies and institutions should be designed so as to be adaptive and capable of responding to new insights or objectives. As the long-term development of the system will be shaped by today's actions, it is necessary to anticipate the long-term effects of governance mechanisms, e.g. with the help of foresight (see chapter 2). Moreover, today's experiments should be linked to the anticipation of long-term effects and overall system development (Truffer et al. 2003; Geyer, Davies 2000).

The third governance challenge is linked to the fact that central control over the steering process is unrealistic – even more so in a liberalised market. Many actors pulling in different directions influence the transformation process. Liberalisation opens the door for new actors and new kinds of actors who can influence the future development of the electricity system. As reverting to central planning is not seen as an option, it becomes necessary to coordinate and encourage the various actors to make long-term system transformation happen.

The following table provides an overview of the governance challenges and strategies.

Table 6: Appropriate strategies for reflexive governance

Aspect of Problem treating	**System analysis**			**Goal formulation**	**Strategy implementation**
Specific problem features	Co-evolution of heterogeneous elements across multiple scales (society, technology, ecology)	Uncertainty and ignorance about transformation dynamics and effects of intervention	Path-dependency of structural change, high society impact	Sustainability goals involve value trade-offs, are endogenous to transformation	Capacities to influence transformation are distributed among actors
Strategy requirement	Trans-disciplinary knowledge production	Experiments and adaptivity of strategies and institutions	Anticipation of long-term systematic effects of measures	Iterative participatory goal formulation	Interactive strategy development

Source: (Voß, Kemp 2006: 18)

7.1.3 Network regulation and governance of system transformation

What are the implications of these governance requirements for the standard model of network regulation? At first sight, the standard model seems at odds with the governance perspective presented in the previous section.

Firstly, the standard model relies on price signals as the single most important governance mechanism. The standard model was designed to increase the efficiency of the existing network. While regulation is justified based on a market failure, regulation still is to mimic the market mechanism. 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 governance mechanisms outlined above do not seem to be relevant.

Secondly, at a more fundamental level, the standard model of network regulation is based on separation whereas governance of system transformation requires integration. The standard model focuses on one particular aspect of the energy system – namely the economic efficiency of networks. In the standard model, network regulation is regarded as a mainly technical exercise that is necessary to provide a stable framework. In contrast, governance of system transformation as outlined above requires an integrated approach, coordinating diverse actors and developments in different parts of the system and consideration of long-term structural effects of today's regulatory actions.

In this perspective, network regulation fully fits into the standard model of liberalisation and seems difficult to reconcile with the governance requirements that have been outlined in chapter 2.2 and section 7.1.2 of this chapter. However, there is more to the standard model than 'simply' mimicking the market. It is market based only in that it relies on price signals for the regulated companies. However, the way these price signals function clearly deviates from the market mechanisms. As Helm (2003: 277-278) has put it, *"the RPI-X regime is not remotely similar to the way in which prices are set in a competitive market."* One reason Helm mentions for this are the fixed regulatory periods in which – unlike the situation in a competitive market – regulated companies can rely on a fixed price level.

More importantly in this context, setting the price signal involves an institutional arrangement that cannot be described in terms of markets alone. Rather, it mixes a range of different governance mechanisms, including consultation processes and negotiations between regulator and companies as well as top-down decision-making by the regulator when determining network tariffs. In this sense, it would be too simplistic to portray the standard model merely as governance mechanisms based on price signals.

This relates to the broader definition of the standard model that was introduced in section 4.1.2 as part of the research framework. While the implementation of the standard model in liberalised electricity markets is typically equated with the introduction of price- or revenue cap-mechanisms to increase efficiency, the standard model can also be understood as a broader governance arrangement that relies on incentives-based mechanisms, but also comprises other governance mechanisms.

At a more fundamental level it is important to note that both the standard model of network regulation and the thinking on governance of system transformation have some common roots. Both are based on a dynamic, process-oriented learning perspective that has been prominently expressed by the Austrian economic tradition, compared to a static perspective that assumes the possibility of rational control (Midttun 2005; Correljé 2005). The standard model stresses the limits for the regulator to influence the behaviour of the regulated companies. Moreover, it has left behind a static efficiency perspective in that it provides companies with an incentive to strive for cost reductions. The standard model aims at providing a framework for learning, and the development of regulation itself is a dynamic learning process.

There is a difference between the two approaches in that system transformation literature does not focus on efficiency and does not want to rely on markets only; rather, it calls for additional governance mechanisms that can enable system transformation. However, similarly to the standard model, it rejects the idea that this transformation can be fully designed ex-ante and the implementation be managed in a controlling sense. It thus extends the dynamic view on the market process to overall system transformation.

In general, there are tensions between the governance of system transformation and the standard model, but they are less mutually exclusive than it may first appear. In the following, the standard model will be examined in the light of two central themes in the governance of system transformation literature, namely:

- strategies for dealing with uncertainty, and
- the coordination of a broad range of actors (partly in order to deal with uncertainty)

Each section also briefly outlines options based on the governance of system transformation literature to complement the incentive mechanism in the standard model, without presenting a comprehensive model of how to redesign the standard model.

7.1.3.1 Regulation under uncertainty

A key issue in the governance of system transformation as presented in the previous section is the uncertainty about future system dynamics and hence the need to anticipate possible long-term developments and remain adaptive to these development scenarios. How does this relate to the standard model?

From information asymmetry to systemic uncertainty

Uncertainty is a key issue for the governance of system transformation and *"uncertainty is at the heart of the economics of regulation"*, too (Frontier Economics 2003: 2). Therefore, the two concepts do have some common ground, but the focus is on different levels of uncertainty.

A primary motivation for introducing incentive regulation has been to counter the information asymmetry between the regulator and the regulated company. The regulated company has a better knowledge of its costs and the potential for efficiency than the regulator. Therefore the regulator cannot simply set network tariffs at the efficient level, but needs to incentivise the regulated company to exploit its efficiency potential. Another uncertainty with which the standard model is equipped to deal is the cost uncertainty for the network companies that results from developments like DG. This leads to the regulatory mechanisms discussed in chapter 5. Essentially the discussion is about how to distribute this cost uncertainty between network companies and network users.

Thus, the standard model provides a framework that is explicitly designed to deal with uncertainty. It acknowledges the bounded rationality of regulators and the limited control they have over companies. The regulator provides an incentive for the companies to reveal their efficient costs; cost uncertainties resulting from DG can be reflected in the network tariffs.

While connecting DG to the existing system is more or less a well-defined problem (although connection costs can be uncertain and diverse), long-term innovation and transformation entails increasing uncertainty about future development paths and how these may be shaped by today's regulation and investment. With system transformation, the lack of information thus becomes a more fundamental problem: The main issue is no longer the limited information of the regulator about efficient costs, but the general uncertainty about innovation potentials and the future development of the network infrastructure. The regulator, the network companies and other stakeholders are affected by this uncertainty.

In the case of DG connection the companies face a cost risk, but know what to do once a DG plant wants to connect to the system. In the case of system transformation, all stakeholders face uncertainty as to where the system is heading and how their decisions affect and fit into this overall system development. This uncertainty cannot be dealt with via network tariffs alone. Even if the regulator allowed the DSOs to pass through any cost risk resulting from network transformation to network users, this would not guarantee that network operators would develop a system in time that is best suited to accommodating a high share of DG.

In summary, the standard model is not based on perfect information and control, but does acknowledge uncertainty and provides and explicit framework to deal with it. However this framework is limited to cost uncertainties. Uncertainties that cannot be expressed in terms of costs alone and go beyond the relationship between the regulator and the regulated company and which become more relevant with long-term system transformation are difficult to incorporate.

Anticipation: The time horizon of network regulation

Another relevant dimension is the time horizon of network regulation. The more we move from the connection of DG to system transformation the more the focus shifts from short-term operating efficiency to long-term structural change. How can a regulator that was set up to achieve the former contribute to promoting the latter?

One rationale for regulation through an independent regulator is to enable long-term commitment that goes beyond the political time horizon of election periods and is not undermined by short-term politics (see chapter 3: Sector-specific, independent regulators). Majone describes independent regulators as a reaction to the short-termism of democratic governance that "*may produce harm when the problems faced by society require long-term solutions*" (Majone 1999: 4). Such a long-term perspective is arguably particularly important in infrastructure sectors that require long-term investments.

Majone's diagnosis sounds similar to the one put forward by proponents of transition management. For example Kemp et al. (2007) describe the need to counter "*political myopia*" with a governance model that can generate long-term solutions. At first sight, the standard model seems to be in line with the long-term perspective needed in the context of system transformation.

Yet a closer analysis reveals a number of tensions. First of all, it is not definite that setting up an independent regulator by itself can provide long-term solutions. One problem is that even for an independent regulator it is not straightforward to commit itself to its regulatory contract with network operators. While Majone presents the introduction of independent agencies alone as a solution to long-term problems, there is a discussion in standard model literature as to whether and how the regulator can indeed credibly commit to an agreed rate-of-return and how this affects investment incentives (Brunekreeft, McDaniel 2005).

Secondly, even assuming that the regulator can establish the credibility that is needed to overcome the problem of time inconsistency, it does not mean that a comprehensive long-term framework is provided. The standard model establishes, at least implicitly, a long-term framework in which companies can expect efficiency improvements to be required beyond the current regulatory period. Yet apart from this general efficiency objective there are usually no medium- to long-term objectives that can guide the companies' decision making. When the standard model was developed any problems arising from long-term regulation were deliberately ignored (e.g. Scarsi, Petrov , no date: 4). Examples for a more long-term framework include: Does the regulator expect companies to innovate in order to meet the efficiency objective (which does not follow automatically from the efficiency objective, as shown in chapter 6)? How does the regulator plan to deal with DG-related investment costs? Even if the regulator can commit to not taking advantage of individual investments ex-post, such a long-term framework will be important for companies in terms of defining their overall strategy beyond individual investments, designing their network planning philosophy or developing the necessary RD&D capacity.

Thirdly, the main rationale for the regulator being independent is to overcome the problem of time inconsistency and achieve credible policy commitments. Therefore, long-term commitment does not imply that regulation takes into account potential long-term developments. Rather, it means a commitment not to change course. The long-term perspective is not based on any institutional arrangements or instruments that would enable the regulator to take into account the long-term effects of current regulation. It is there to keep politics out of the process and ensure regulated companies that their investment will not be exploited once costs are sunk. The model may therefore be well suited to providing stability and enabling long-term investments in the current system. However, it does not provide a framework for anticipating the long-term systematic effects of measures, as requested by governance of transformation literature.

There have been calls for a more long-term framework both in network regulation literature and statements from network operators. For example, Jamasb and Pollitt (2007: 6185) conclude from their review of incentive regulation in Britain that "*European electricity regulators should take into account the power and long-term effects of incentive* *schemes in influencing the features and behaviour of regulated firms"*. In a presentation on regulation and innovation Martijn Bongaerts from the Dutch network operator Continuon Netbeheer said that *"there has to be long-term vision where to go"* (Bongaerts 2006). Such a framework can be established with the help of scenarios. It should be regarded as complementary to the innovation incentives described in chapter 6.

In the face of long-term infrastructure transformation, scenario processes can help deal with three challenges:

- anticipating long-term systemic effects
- formulating iterative participatory goals and
- identifying areas where further research and development is needed, including technological and regulatory developments, e.g. in the EU Technology Platform on Smart Grids: http://www.smartgrids.eu. This can provide the basis for developing alternative options that fit into future development paths, as discussed in the next section.

Firstly, if the focus is no longer restricted to investments in the current system, potential future developments become more diverse. The longer the time period under consideration, the more diverse these potential future developments become, with the result that more external factors gain relevance, e.g. new technical options and longer term trends in supply and demand. The future interaction between network regulation and other policies, e.g. innovation policies (see chapter 6) is important, too.

Scenarios can help to anticipate and scrutinise these development options and identify bottlenecks and barriers. They can also help to identify which elements of system transformation might be common to different future pathways for energy systems and networks. On this basis regulation can take into account potential long-term effects of incentive mechanisms and improve its judgements as to whether short-term regulatory developments are robust in the face of future uncertainty and compatible with long-term visions. Thus, scenarios can also provide the basis for regulatory impact assessment that goes beyond the immediate impacts on companies and their costs.

Secondly, if the main objective is no longer to provide a stable framework for efficiency improvements and investment in the current system, an alternative vision needs to be established. This is the prerequisite for a regulatory framework that extends beyond five year regulatory periods and does not only aim at efficiency. Scenarios can help to make explicit different development options, promote a common understanding of where to go and how to get there and thus coordinate heterogeneous actors.

Multi-actor scenarios can help coordinate these actors, but can also be a tool for the regulator to deal with the increasing complexity of development options, without relying only on the biased views and interests of network operators or other single stakeholders. This can help the regulator to reduce the danger of being ‘captured’ by some stakeholders and their particular visions. In this sense, the function of scenario processes is similar to benchmarking procedures that prevent the regulator from having to rely on the costs of individual network operators.

Importantly, such a scenario process changes the role of the regulator. The innovation mechanisms discussed in chapter 6 can in principle be designed so that additional financial incentives are provided irrespective of what the development options are. However, it may not be enough for the regulator to acknowledge that network changes are required. Rather, the regulator may need to develop an understanding of future development options and their implications, just as the regulator needs to understand cost drivers to be able to increase efficiency. Otherwise, the increasing information asymmetry between principal and agents can undermine regulatory decision-making. Setting up a scenario process means that the regulator becomes more actively involved in discussing the *direction* of innovations in a system context, yet without determining this direction. This role is suitable for the regulator due to its detailed sector knowledge and the need to link long-term visions with short-term regulation.

Adaptability[8]

A further requirement that is closely related to the anticipation of long-term developments is adaptability. Anticipation only makes sense if the results can be reflected in today's institutions and actions.

As described above, the standard model is not oriented toward long-term network development. However, it is a dynamic process that can adapt itself to changing circumstances and improved knowledge. This is well expressed by Correljé (2005: 117) who describes regulation as *"dynamic learning process, evolving over time"* with the need to establish and manage a *"process of regulatory development"*. Similarly, Agrell and Bogetoft (2003: 19) present a *"modern view of regulation and operation under regulation as a learning and discovery process"*. As a result of fixed regulatory periods, there is a built-in mechanism that makes regulation adaptive, i.e. its effects and instruments are reviewed and adapted at regular intervals. This flexibility to adapt also contributes to the credibility of the regulator (Crouch 2006: 244). Detailed work on the adaptability of the regulatory framework has been carried out by the UK regulator Ofgem (2009a).

In principle this feature of network regulation is in line with the requirements set out earlier. However, as long as the focus of network regulation is on short-term efficiency as part of the overall liberalisation paradigm, this feature cannot contribute to aligning network regulation with the requirements of system transformation. Its adaptability is not coupled with any long-term framework and there is no guidance as to how to adapt to achieve certain long-term effects. Regulation is geared towards maximising short-

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8 While "adaptivity" is used in the literature cited in section 7.1.2, the term "adaptability" may be regarded as a more apt expression since it goes beyond the fact of a capacity for adaptation to incorporate more specifically the ability to adapt (or be adapted) to fit changed circumstances. It is also the term used by the UK regulator OFGEM in its communications (Ofgem 2009a).

term efficiency and adapted mainly to improve and balance allocative and productive efficiency.

By limiting its adaptability to these objectives, the standard model can partly by-pass the tension between the need for a stable framework as described earlier and the need to adapt to a dynamic environment. This is possible in a relatively stable context dominated by investments in the current system. However, the governance of system transformation approach would argue that this tension cannot be avoided, but needs to be dealt with somehow.

Besides regular reviews, having alternative options available is another precondition for adaptability. Scenarios can help to identify relevant options. In the context of network regulation, this has two dimensions: First of all, the regulator needs to enable the companies to develop such alternatives, i.e. new technological or organisational options. The incentive mechanisms presented in chapter 6 can contribute to that. Secondly, the regulator itself needs to develop regulatory mechanisms so that it can remain flexible. Just as new technological solutions do not just ‘fall out of the sky’ once they are needed, but develop within their specific context, this ‘evolutionary’ argument can be extended to regulatory instruments.

For example, the EU Technology Platform SmartGrids (European Commission 2006: 23) pointed out that *“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.”*

One approach to developing new regulatory knowledge and developing and testing new regulatory instruments in practice would be to set up “regulatory innovation zones”. While the regulatory mechanisms in chapter 6 and the innovation instruments RPZ and IFI implemented in the UK (see chapter 8) are designed to promote technical innovations, regulatory innovation zones would provide niches where the regulator can, for example, work with individual network operators to develop and test new regulatory instruments for promoting integration of distributed generation in the context of changing network architectures and control philosophies.

In Germany, the OPTAN project has developed a concept for a regulatory innovation zone and has proposed that the regulator implement it together with a municipal utility. However, the proposal was not supported by the regulator which was still in the process of establishing its regulatory regime to increase the efficiency of the existing network (Frey et al. 2008).

Even if network regulation becomes more adaptive, we need to bear in mind that it is just as important to make the networks themselves more flexible. However, this is inherently difficult due to large sunk costs and long asset life times (cf. de Vries 2004: 216-217 on different network development strategies).

7.1.3.2 Actor coordination

Another important issue in the governance of system transformation literature is the need to involve a broad range of actors for a number of reasons: to improve the common understanding of system dynamics and to deal with value trade-offs and distributed control capacities.

In the standard model, the relationship between the regulator and the regulated company is analysed in a principal-agent framework. It thus acknowledges the bounded rationality and limited control capacity of the regulator and the need to cooperate with network operators. Both the regulator and the regulated companies obviously play an important role. However, there are other actors that have a stake in network regulation and these tend to be left out of the principal-agent framework.

The limits of a narrow principal-agent framework have been explained by WRR (2008: 89-103). According to this analysis, regime change, i.e. liberalisation and corresponding developments in infrastructure sectors leads to heterogeneous actors and rivalry between them, multiple principals and splintered arenas. There are also multiple agents, i.e. network operators that the regulator needs to deal with.

This general analysis becomes even more relevant in the context of new objectives like DG that depend on the network, and especially in the case of system transformation. In a principal-agent framework regulators are used to dealing with conflicting interests and negotiations between themselves and the companies. With DG and system transformation, this process needs to be extended to a broader and more heterogeneous set of stakeholders with different perspectives and interests. For example, both equipment manufacturers which provide innovative network solutions and developers of distributed generation projects have a stake in regulation and are important actors for system transformation.

In general the focus of conflicts is no longer the distribution of efficiency gains but future system design and how this affects the position of different stakeholders. Cooperation is therefore inherently more difficult. Summerton and Bradshaw (1991: 33) have aptly 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."

The question is what kind of role regulators can play in this process. Summerton and Bradshaw see the need for them to adopt an "*active, problem-solving roles in mediating between varying organizations";* Young (2001: 26) describes their role as *"arbiters,* *negotiators and mediators"*, thus supporting the view that regulators should not only set network tariffs. More recently a similar view has been expressed by the European Regulators' Group for Electricity and Gas in their position paper on Smart Grids (ERGEG 2009: 35). The regulators argue that incentive mechanisms are necessary, but not sufficient and *"a second priority for regulators should be to have an active role in favouring cooperation among stakeholders."*

As mentioned above, the principal-agent framework represents a good starting point for regulators to take on a more active role in promoting cooperation. Regulators also have in-depth sector knowledge, so that it would difficult to justify why such a role should be left to another organisation. This is especially the case because any cooperation mechanisms should be linked to incentive regulation. Both the scenarios and innovation zone presented earlier can be a means to promote cooperation.

However, any attempts to promote cooperation can be restricted by fundamentally different interests of stakeholders and their resources to realise them as well as by the fact that they still operate in a competitive environment.

7.1.4 Conclusion

In summary, it would be too narrow to portray the standard model of regulation simply as mimicking the market mechanism. The previous section has shown that there are tensions between the standard model and the governance of system transformation, but the two approaches also have some features in common. The standard model acknowledges bounded rationality and uncertainty, the need to remain adaptive and the limited control capacity of the regulator, but is geared towards the short-term and tends to neglect long-term systematic effects and heterogeneous actor arenas.

The mechanisms presented above can complement the incentive mechanisms discussed in chapters 5 and 6. However, there is also a potential mismatch between these two approaches: The instruments discussed in this chapter support a system perspective and coordination between different actors, but can be characterised as rather soft coordination mechanisms, whereas actual funding for innovations is still provided for individual network companies within the mechanisms discussed in chapter 6. Thus, there is likely to remain a gap in terms of funding for system innovations. This supports the argument put forward in chapter 6 that economic regulation should not be the main instrument for providing RD&D funding. Nevertheless, the mechanisms discussed in this chapter can help to set the priorities of RD&D funding outside regulation.

Overall, the standard model offers the potential to evolve from economic regulation to a more comprehensive, transformation–based approach. As argued in chapter 2, the link between governance mechanisms for transformation and standard policies is often underdeveloped. Therefore, transforming the economic regulator into a 'transformation agency' can be just as attractive as setting up a new organisation which may only inadequately be connected to other mechanisms, including economic regulation. This can be one way of avoiding the problem that Kern and Smith (2008: 4098) have observed in the case of transition management in the Netherlands: *"In summary, so far most observers do not see a substantial impact of the energy transition on 'regular' energy policy. Our assessment above highlights this. Core energy policy issues like security of supply, liberalisation and affordable prices are not being reframed by the energy transition."*

Rather than setting up additional governance mechanisms, transformation approaches could build upon the standard model. It is clear that such an agency could no longer be limited to economic efficiency because the transformation is driven by other objectives. The following section explores how DG and network transformation affect the objectives of regulation and the relationship between policy and regulation.

7.2 Energy policy and regulation

Chapters 5 and 6 and the first section of this chapter have analysed how the standard model can evolve to deal with DG and network transformation, both in terms of additional incentive mechanisms and governance mechanisms beyond the incentive formula.

In both cases, the focus was on the instruments applied by network regulation. However, it also became apparent that these instruments cannot be discussed without reconsidering the overall regulatory framework. Based on these insights this section discusses the objectives of regulation and the relationship between policy-making and regulation.

7.2.1 Additional objectives beyond efficiency

The standard model involves a narrow remit for regulators. Their objective is to increase efficiency, promote competition and ensure a level playing field for all market participants. The discussion of regulation and DG has shown that it is difficult to integrate DG into the standard model without defining DG as an additional regulatory objective. In the case of DG connection, chapter 5 has discussed the limited scope of integrating DG into the efficiency and level playing field framework of regulation. Therefore, a political mandate is needed for the regulator to design DG-specific instruments.

In the case of DG-related network innovations chapter 6 has argued that innovation instruments require political backing even if network efficiency is the primary objective. Network innovations become even more political if they aim at other objectives like DG integration, and the direction of innovation becomes relevant.

Similarly, the first section of this chapter has argued that the long-term framework provided by the independent regulator in the standard model is not sufficient for dealing with system transformation. If efficiency is no longer the main objective, guidance is needed on the direction in which the system should be heading. This also constitutes an important difference between the electricity and the telecom sectors. The latter has experienced fundamental restructuring, yet the objective was not to meet any politically defined objectives beyond providing a high-quality network at low cost. If, additionally, networks are required to contribute to additional public values, defining a long-term framework is essentially a political task. However, as was explained earlier, the regulator can play an important role in this process, which affects the remit of the regulator and its relationship with policy-making.

In the standard model economic efficiency tends to be regarded as an apolitical objective that benefits customers connected to the network. DG reintroduces politically defined public objectives (see section 5.2.1.2). The DG and innovation instruments in chapters 5 and 6 are not drawn up to increase network efficiency, but to enable the integration of DG. This integration should be implemented as efficiently as possible, but efficiency is not the primary objective of DG integration.

Therefore, the objectives of network regulation need to be redefined to integrate DG and network transformation. As was shown in chapters 5 to 7, the incentive mechanisms of the standard model can accommodate new objectives and there is scope for its institutional design to incorporate governance mechanisms to support transformation. Yet beyond the level of regulatory instruments the question remains as to what this implies for the paradigm of independent regulation. DG represents one prominent example in the debate on additional objectives, which more generally includes environmental and social policy as well as broader sustainability objectives (Fitzgerald, Waddams Price 2003).

7.2.2 Multiple objectives and independence

How do the additional objectives beyond efficiency fit into the institutional context defined by the standard model? As was pointed out in chapter 3 and the first section of this chapter, the standard model of network regulation is characterised by the regulator being independent of the government. The institutional set-up proposed by the standard model is to support its objective, namely to promote the economic efficiency and a stable investment framework for electricity networks. Other than that the networks do not serve to meet any political objectives. Thus, the standard model has essentially depoliticised the networks and regulation is seen as a technical, rather than a political, task. Indeed, political interference is regarded as counterproductive to meeting the efficiency objective. For this reason, regulators are granted the right to operate with some independence from policy-making.

The concept of independent regulators can be traced back to independent central banks that have been set up to commit to an inflation target (Stern et al. 2002). However, it is worth noting the difference between central banks and utility regulation (e.g. Corry 2003: 15). Even within the economic efficiency paradigm of the standard model, there can be different objectives and trade-offs between them, notably between increasing the efficiency of network operation and investment (productive efficiency) and ensuring efficient charges for network users, i.e. avoiding monopoly rents (allocative efficiency). Moreover, it is difficult to avoid trade-offs with other policy objectives, as chapter 5 has shown for the case of DG.

The independence of the regulator is directly linked to a narrow remit since it is arguably a prerequisite for the regulator being independent of the political process. As soon as the regulator is in charge of a broader set of more political objectives, its independence can no longer be guaranteed or it leads to problems of democratic accountability (Young 2001: 150; Brunekreeft, McDaniel 2005: 124). Thus, there is a tension between the additional objectives presented earlier and the institutional principles of the standard model.

The standard model is not supposed to pursue multiple objectives and deal with trade-offs between them. However, trade-offs necessarily result from multiple objectives. For example, if DG integration is introduced as an additional regulatory objective, it is not sufficient to simply add this new objective. Rather, the costs which are acceptable for specific volumes of DG would still need to be decided. Although calibrating the incentive mechanisms presented in chapter 5 may appear to be a small detail in the regulatory process, Frontier Economics (2003: 45-46) have rightly pointed out that *"the preferred balance between the risk of DG not being connected and the risk of inefficient or "gamed" costs being reimbursed through regulated charges (…) is of course a matter of policy."* This example shows that multiple objectives render regulation more political. Even if the promotion of DG becomes a regulatory objective, this does not provide the regulator with any guidance as to how to balance the DG objective with the objective to reduce costs.

Reintroducing political objectives and trade-offs into network regulation leads to the following dilemma: On the one hand, depoliticising the regulation of networks has made it possible to create a stable framework for private investors – at the expense of pretending that networks represent a 'neutral' infrastructure, rather than a critical basis for implementing political objectives. On the other hand, political objectives can undermine the institutional arrangement of the standard model, although a stable regulatory framework is still important for enabling investments by private companies – or indeed has become even more important in an environment that is generally riskier due to technological change and fundamental restructuring. According to WRR (2008: 55), *"this is perhaps the most important challenge facing policy makers dealing with infrastructures today – how to realise broader public objectives without threatening the very sources and possibilities of new and private investment."*

There is a higher level trade-off between clear objectives and a stable, investment-friendly framework on the one hand and taking into account multiple policy objectives and trade-offs between them on the other hand. Due to its focus on economic efficiency, the standard model can neglect this trade-off. Similarly, as was pointed out in section 7.1.3.1, narrow objectives allow the standard to reduce the tension between the need for a stable framework as described earlier and the need to adapt to a dynamic environment.

7.2.3 The relationship between policy and regulation

As long as the governance of networks is predominantly about efficiency, policy-making tends to be regarded as a spanner in the works, dominated by short-term election periods and political opportunism that can erratically intervene in infrastructures, and potentially renege on the agreed rate-of-return, thus reducing economic efficiency and preventing investment.

The situation changes once efficiency is no longer the single most important objective (as discussed in the previous section) and networks become an instrument for pursuing public objectives beyond distribution of efficiency gains. Policy-making can then no longer be regarded as a disruptive factor, but becomes the very arena where the future of networks and their contribution to meeting these public objectives is negotiated.

As long as the focus is on short-term efficiency, the standard model can manage the trade-off between the instabilities of political decision-making and a stable framework for efficiency and investment by banning politics. However, new policy objectives like DG undermine this strategy. Especially network transformation reveals that the time inconsistency problem, which is the main reason for regulatory independence, does not simply result from political opportunism and political myopia dominated by short-term election periods. Rather, the time inconsistency problem can also stem from a fundamental uncertainty about future system developments, distributed control capacities as well as value trade-offs that require an iterative process of goal formulation (see section 7.1.2).

As a consequence, stability can no longer be provided by locking out policy. What is required instead is an embracing of the political challenges of trades-offs and system transformation in a transparent political process. Most importantly this requires gearing policy-making towards long-term structural change with the help of long-term objectives, underpinned by the strategies outlined in section 7.1.2 (cf. Helm 2004a: 32-33). These strategies allow for long-term political trade-offs to be dealt with and can help to constrain short-term political opportunism and ad hoc intervention. However, the mechanisms through which policy-makers can provide a framework for future infrastructure development are beyond the remit of this thesis. In terms of establishing a closer link between policy trade-offs and regulation, the social and environmental guidance to the regulator Ofgem described in the UK case study in chapter 8 provides an example. It has been designed to make policy objectives other than efficiency more ‚visible’ to the regulatory decision making process.

Importantly in this context, even when networks are re-established as a basis for policy-making, it does not render obsolete separate sector regulators, although these were originally set up to keep politics at arm’s length. Defining the future of infrastructures and dealing with political trade-offs cannot be left to the regulator, but the regulator can still play an important role in this process.

Firstly, even if the focus shifts from efficiency to politically motivated transformation, this process can still benefit from a degree of regulatory independence in terms of protection from *short-term* political interference, cf. definition of independence by Ocana (2003: 17). This can help to provide consistency over time in implementing the politically defined strategy.

Secondly, when drawing up a long-term framework, the government should rely on the sector-specific expertise of the regulator. The regulator can contribute to setting up a strategic framework and making explicit trade-offs and available options, especially by means of the governance mechanisms outlined in section 7.1 (cf. Bartle, Vass 2007: 268). For example in the Netherlands, this has been recommended by the Scientific Council for Government Policy (WRR 2008: 189). In the UK Helm (2004a: 34) has proposed the 'agency model' as an alternative to the regulatory office model on which Ofgem is based. Under this model, the relationship with policy would be more of a two-way process, with the agency both explicitly advising the government and implementing policies.

Thus, rather than making independent regulators redundant, strengthening the political dimension of network governance can entail a more active role for regulators too, both in terms of defining and implementing long-term strategies. This does not imply that the regulator turns from a neutral referee into a *"proactive and interventionist puppeteer (…) that knows better and can produce a prescriptive plot for all players"* – a dichotomy suggested, for example, by Sioshansi (2008b: 11-12). Rather, as outlined in section 7.1, the regulator should take on the role of a proactive moderator and catalyst. For example, setting up a scenario process means that the regulator becomes more actively involved in discussing the *direction* of innovations in a system context, rather than just providing economic incentives. However, it does not imply that the regulator determines the direction of innovation.

Thirdly, even if networks become more political and the role of regulators is complemented by additional tasks and instruments, incentive regulation does not become redundant (cf. WRR 2008: 42, 54). Even with additional political objectives, efficiency still plays an important role, not the least in implementing these objectives as efficiently as possible. Therefore, independent regulators should remain in place to continue applying economic instruments, as well as to establish a link between the standard model instruments and the ones outlined in this chapter.

7.3 Conclusion

This chapter has discussed the standard model from outside the box of incentive mechanisms which are only one element of the standard model. The analysis has covered both the governance mechanisms applied by the standard model and its role in a wider energy policy context.

There is more to the standard model than emulating the market mechanism with the help of economic incentives. There is scope for this model to incorporate governance mechanisms that are geared towards infrastructure transformation.

The model of independent regulators was originally introduced to depoliticise network governance. New political objectives like DG and network transformation seem to entail a dilemma between political interference that can undermine the model of independent regulators on the one hand and the need for a stable framework for private investors on the other hand.

Nevertheless this model is still valid. Regulators can contribute to setting up a strategic framework and a degree of independence is still useful when it comes to implementing this framework and applying the incentive mechanisms to enable cost-efficient network development.

Importantly, the results of this chapter complement the analysis provided in chapters 5 and 6. Regulators should not only rely on incentive mechanisms, but these are still important, as is the link between the governance mechanisms discussed in this chapter and economic incentives.

There is scope for the standard model regulators to evolve into a 'transformation agency', which combines the principles of the standard model and the governance mechanisms suggested for system transformation. More work is needed on the institutional design of such an agency.

Part III:
Case studies

8 Case study UK

This chapter presents the country case study on the UK. The chapter begins with a brief background section (8.1). It is then structured based on the connection-integration-innovation-transformation heuristic set out in chapter 4 as one element of the methodology and which was also the basis for structuring the conceptual analysis in part II. Section 8.2 analyses the governance of DG connection and integration, section 8.3 examines network innovations and section 8.4 describes developments in the regulatory regime that are not limited to the incentive formula.

8.1 Background: Liberalisation pioneer and DG policy

The UK has been a pioneer in developing and implementing the standard model in different network sectors. It could even be argued that the approach was to some extent tailored to the UK context and only afterwards was it de-contextualised and adapted into a standard model that was implemented around the world (Praetorius et al. 2009: 201-205). In the UK, electricity market liberalisation began in 1990, after other utility sectors such as telecommunications had been liberalised and privatised. For a comprehensive overview of liberalisation and the development of the governance and market structure in the UK, see Surrey (1996) and Newberry (2006).

As in most countries the standard model that was introduced in England Wales and with some differences in Scotland and Northern Ireland meant a radical shift from the previous governance structure. In the UK, this process also entailed a major change in the industry structure. Before liberalisation, the state-owned Central Electricity Generation Board owned all generation and transmission in England and Wales and distribution networks and supply were run by 12 Area Boards. There was significant political influence on the company. In principle, electricity charges were mainly cost-based. With the 1989 Electricity Act, the standard model of liberalisation that was described in chapter 2.1 was implemented as follows: the CEGB was privatised; several generation companies were set up (horizontal restructuring); vertical unbundling along the supply chain was introduced; National Grid became the independent transmission system operator for England and Wales; Offer, the Office of Electricity Regulation was set up as the independent regulator. The current regulator Ofgem was formed by the merger of the Offer and the Office of Gas Supply (Ofgas). In terms of wholesale markets, the Electricity Pool was set up. This was a compulsory day-ahead market that determined the merit order and wholesale spot prices. In 1998, wholesale competition was complemented by retail competition. The New Electricity Trading Arrangements (NETA) that were introduced in 2001 are an important step in the further evolution of the market design. NETA replaced the compulsory Pool by several voluntary markets.

Compared to Denmark, the pre-liberalisation governance of the sector is less relevant in the UK since it was mostly replaced by the standard model. As a consequence, the liberalisation process was not characterised to such a degree by the need to find ways of merging the existing governance structures with the standard model. Unlike the Danish case study, this chapter does not therefore elaborate on previous industry structures and the liberalisation process.

As the IEA has pointed out, *“the UK is among those countries that most rely on market actors, responses to price signals and private participation”* (IEA 2007b: 9). Although the UK has been a champion of the standard model, there have also been significant shifts in UK energy policy, from the beginning of the millennium onwards. An important milestone was the 2003 Energy White Paper (DTI 2003), which did not focus on competition only, but placed a strong emphasis on long-term climate targets (MacKerron 2009: 79-83). This is important for understanding the developments within the standard model of network regulation analysed in this chapter.

The UK electricity network is operated by one TSO and nine DSOs running 14 distribution networks with separate licenses. All network operators are privately owned, profit-orientated companies. The UK energy regulator Ofgem (and its predecessor Offer, as well as other regulators in the UK) has been a forerunner in developing and implementing incentive regulation mechanisms. During the 1990s, the focus of network regulation was very much short-term. Its objective was to increase the operating efficiency of network operators and to bring down network tariffs. This has largely been successful (NAO 2002). Network regulation has thus been part of the overall liberalisation paradigm to improve the efficiency of the existing centralised system.

Riechmann (2002) distinguishes the following three phases of the development of electricity network regulation in the UK:

- 1990-1998: the "fat cat" years with high profits for the regulated companies,
- 1998-2002: new Labour government, redistribution of regulatory gains,
- Since 2002: reform of regulatory approach: balancing incentives, balancing productive and allocative efficiency, trying to better anticipate how regulated companies react.

In contrast to the development of the standard model, the UK has not been a pioneer in DG deployment (see chapter 4.2) although both CHP and renewables have more than doubled their output between 1995 and 2005. The installed capacity of distributed generation was estimated at 13.3 GW at the end of 2005 (Econnect 2006), compared to a total installed capacity of 81.7 GW. DG plants provided less than 10 % of UK electricity generation (DTI 2006; see chapter 4). DG plants are wind and hydro plants and mainly gas-driven CHP plants.

The new market arrangements NETA mentioned above increased the risk for small-scale and intermittent renewable generators and triggered a debate on the role of these plants in the competitive market and the extent to which NETA was and should have been cost reflective (Bauknecht, Colella 2002; Mitchell, Connor 2002). While the UK government asked Ofgem to take into account this issue in the development of the market arrangements, according to Woodman (2002: 181), "*it was widely felt by generators* *and commentators that throughout the development of NETA, Ofgem ignored the impact of the new trading arrangements on renewables and CHP, thereby threatening their increased deployment"*. Ofgem maintained its view that renewables and CHP should be treated like any other generators in the market and policy objectives to increase their share should be pursued outside of the competitive market. In a similar vein, before the introduction of the incentive mechanisms described below Ofgem argued that connection charges for DG should be cost-reflective and include all the network extension costs triggered by DG beyond the point of connection (deep connection charges, see below), although these were prohibitively high in some cases and gave the DSOs the opportunity to include network costs into the connection charges that were not primarily caused by new DG connections (Mitchell, Connor 2002).

This is important to understand that the DG incentive mechanisms within network regulation that are described in the following sections are rather different from Ofgem's previous approach to regulation and market design, although in conceptual terms they neatly fit into the standard model. Following the introduction of NETA, there were increasing concerns in the government about the role of renewables and CHP. According to White (interview) Ofgem realised that it could not maintain its position that it was up to the government to support DG, if DG cannot connect to the network.

In many other countries including Denmark, DG has not been defined as a separate policy objective. There is often no explicit DG policy, but rather policies for renewables and CHP plants. In the UK DG has been explicitly put on the political agenda. Since about 2000, it has been an issue for both the UK's Department of Trade and Industry (DTI) and Ofgem. DG was also one of the main issues addressed by the 2006 Energy Review, where it is officially seen as a *"long-term alternative or supplement to our current highly centralised system"* (Cabinet Office 2006: 61). According to this review, "*a 'distributed' system could fundamentally change the way we meet our energy needs, contributing to emissions reduction, the reliability of our energy supplies and potentially to more competitive energy markets"* (Cabinet Office 2006: 62).

This statement indicates that DG is not only discussed in terms of connecting a new technology to the existing system, but also in terms of system transformation. However, the UK is less advanced than Denmark in terms of developing and implementing new network concepts in the system, partly because the share of DG has traditionally not been that significant.

When DG emerged as a policy issue, the standard model that was implemented in the UK already set the scene for the UK approach to dealing with it. The established role of Ofgem and the standard model of regulation are important to understanding why the UK debate on small-scale renewables and CHP was framed to a large extent in terms of amending the standard model, despite the fact that there are other and arguably more important issues for DG developers, e.g. the quota-based support mechanism (Mitchell et al. 2006).

In its 2003 Energy White Paper the government emphasised the important role which network regulation could play for the development of DG (DTI 2003: paras 4.21-22): *"Under the present price control rules there is no financial incentive for the DSOs to connect distributed generation to their networks. We therefore believe that the regulatory framework needs to be amended so that the DSOs connect and use higher levels of distributed generation"*. In the same year, Ofgem began working on the 2005 Distribution Price Control Review and explicitly included DG in this process to integrate DG and network innovation into its incentive regulation framework. Ofgem (2004c: 54) sees it as its task *"to encourage DSOs to undertake the investment required to facilitate distributed generation connections (and generally be proactive and positive in responding to connection requests)."*

As a result, Ofgem introduced both the so-called DG hybrid incentive to promote DG connections and two instruments to foster network innovations in 2005, namely Registered Power Zones (RPZ) and Innovation Funding Incentive (IFI) (Ofgem 2004a; 2004b; 2004d). These will be presented and analysed in more detail in the following two sections.

8.2 Incentive regulation and DG connection

The UK energy regulator explicitly takes into account network costs of DG connections in the design of network regulation. The revenue cap formula has been adapted to incentivise DSOs to pursue these objectives. The UK is indeed the first country in the EU and probably worldwide to include DG in its incentive regulation framework (Skytte, Ropenus 2005). As part of the 2005 Distribution Price Control Review, Ofgem introduced the so-called DG hybrid incentive to promote DG connections (Ofgem 2004a; 2004d).

The analysis of the hybrid incentive includes a description of the incentive mechanism which compares it with the regulatory approaches in chapter 5. It also encompasses an evaluation of the regulation-policy interface and repercussions for DG developers.

8.2.1 How does the hybrid incentive work?

'Hybrid' refers in this context to the combination of a partial cost pass-through and a volume-related revenue driver, based on the connected DG capacity. The main elements of the hybrid incentive are as follows:

- Shallow connection charges: Together with the introduction of the hybrid incentive, deep connection charges were replaced by shallow connection charges. This means that in the connection process individual DG developers no longer pay for all the costs of network extensions that become necessary as a result of the DG connection. Rather, they are charged only for direct connection costs. All the network costs beyond the point of connection are in the first instance borne by the DSO.

- Generator-use-of-system charge: DSOs can recover the difference between their costs and the shallow connection charge via the generator-use-of-system charge. This means that the difference between deep and shallow charges is distributed among all generators in a network area. This needs to be paid by generators connected to the network after 1 April 2005 when the new system came into force. While the shallow connection charge is a one-off payment, generators have to pay the use-of-system charge as long as they are connected. This combination of shallow connection charges and a generator-use-of-system charge is also called “shallowish” charge.

- Cost pass-through: Via the ‘generator use-of-system charge’ network operators can directly pass through 80% of their DG-related costs for network expansions beyond the connection costs borne by the individual generator.

- Supplementary revenue driver: For each kW of DG capacity connected the revenue cap is increased by £ 1.5 per year for the duration of 15 years.

- There is an additional £ 1 per year per kW for operation and maintenance.

- Cap and floor: There is a cap on the overall return on DG-related investments that is set at twice the cost of capital as well as a floor based on the cost of debt.

- Incremental unit costs above £ 200/kW are paid by the plant operator through connection charges.

The UK hybrid incentive provides a practical example of the mechanisms analysed in chapter 5. In the case of the UK, the mechanism is made up of a combination of cost-based elements (the 80% cost pass-through) and price-based elements (the kW-based revenue driver) to provide both connection and efficiency incentives.

In terms of the price-based elements, Ofgem has opted for a standardised revenue driver instead of including DG in the comparative efficiency analysis. The revenue driver is rather simple and only takes into account the capacity of DG connected, leaving out other factors that may also influence network costs such as the type, size or generation of DG.

The pass-through rate and the additional revenue driver is the same across all DG technologies and network areas. All network operators and all technologies are measured against the same benchmark, irrespective of cost differences.

The hybrid incentive fits into the standard model for the regulation of electricity networks. The DG scheme relies on the standard model mechanisms to enable an efficient integration of DG into the network. In conceptual terms, it can be argued that network regulation remains unchanged in principle, but takes into account DG as a new phenomenon. Nevertheless, in the context of the UK the inclusion of these mechanisms geared towards DG represents a significant departure from Ofgem's previous approach to regulation, which involved the promotion of competition and a level playing-field rather than supporting individual technologies.

The effectiveness and efficiency of the mechanism crucially depends on how the parameters are set. The instrument needs to be calibrated so as to balance connection and efficiency incentives. The pass-through level and the value of the revenue driver need to be set in such a way that they give network operators a strong enough incentive without opening the door to excessive profits chapter 5.3.

The UK hybrid incentive has been calibrated so that even DSOs with average costs for DG connections can earn a rate-of-return that is one percentage point above the normal regulated rate-of-return (7.5 % instead of 6.5 %). This indicates a relatively strong connection incentive that not only incentivises efficiency improvements, but also rewards DG connections that are 'just' average. In addition, DSOs can further increase the rate-of-return up to the limit of twice the cost of capital if they can reduce the network costs of DG below the average.

Before introducing the new instrument, Ofgem carried out a 'regulatory impact assessment' (Ofgem 2004e). This mainly contained rather general statements. What is interesting is that the document quantifies how the additional revenue that network operators can earn increases the overall costs to customers, i.e. newly connected generators, as compared to a ‘normal’ regulatory treatment of network costs triggered by DG.

Table 7: Assumed costs of the DG hybrid incentives

New DG capacity MW	Costs if included in RAV at 6.5% cost of capital (£m/year)	Costs under DG incentive scheme at 7.5% return (£m/year)	Total difference (£m/year)	Difference per kW (£/kW/year)
200	10.6	11.3	0.7	0.35
5000	26.6	28.3	1.7	0.35
10000	53.2	56.6	3.5	0.35

Source: Ofgem 2004b

8.2.2 Generator-use-of-system charges and the policy-regulation interface

In chapter 5.2.1.1 it was argued that it is difficult to integrate DG into the standard model if DG is only regarded as an additional way to reach the efficiency objective, rather than an additional objective in itself. This is because DG requires a different network infrastructure in many cases and therefore leads to additional costs, rather than cost reductions. As a consequence, the integration of DG in the incentive regulation framework requires political backing to broaden the regulatory objectives.

However, as described in chapter 5.2.1.2, this can lead to a conflict between these policy objectives and the efficiency objective of regulation. More precisely, the potential societal benefits of DG in such a regime can entail increasing network tariffs for consumers in network areas with a particularly high share of DG to pay for the additional incentive schemes. In the UK, this is a relevant issue as there is already a significant variance in the amount of DG connecting in each region (Econnect 2006: 38).

As explained above, DG is a policy objective in the UK. The regulatory instruments described in this section are justified by Ofgem based on this objective. Moreover, the hybrid incentive is designed to dampen the cost of DG integration, but does not only incentivise DG that can lead to overall cost reductions, thereby entailing additional costs. Therefore, the question arises of how the UK regime deals with the conflict outlined above.

As was explained earlier, the costs of the hybrid incentive are not borne by electricity consumers or all network customers in the UK, but only by the DG developers via the generator-use-of-system charge. This means that the DG developers themselves have to incentivise the network operators to connect DG.

Connection costs below the level defined by the revenue driver element – either due to increased efficiency or the cherry-picking of low-cost connections – can lead to a lower generator-use-of-system charge for the DG operators. However, they also entail additional profits for the DSO, especially due to the calibration of the hybrid incentive explained above. These additional profits for the DSO represent a financial transfer from the DG developers to the DSOs. This is the price the former have to pay for incentivising the DSOs to facilitate grid access and potentially benefit from lower charges. This is in line with the general logic of incentive regulation, according to which consumers forego some of the benefits of cost reductions to enable these reductions in the first place.

The risk that the hybrid incentive may not lead to higher efficiency is carried by the DG operators. Ofgem (2004e: 8) argues in its regulatory impact assessment that this risk is small since *"evidence suggests that DSOs do cut costs significantly when provided with incentives to do so."* A further point made by the regulator is that the additional costs of the incentive mechanism are small compared to the value of the UK Renewables Obligation Certificate which renewable generators can sell.

In the light of the plant operators being charged with the costs of the hybrid incentive, the rationale for introducing this scheme becomes unclear. On the one hand, the incentivisation of network operators to connect DG can support the political objective to increase the share of DG. The official rationale of the DG incentive mechanism is clearly to increase the share of generation connected to the distribution network, rather than ‘simply’ providing a level playing field and then letting ‘the market’ decide which options to choose.

On the other hand, given that DG developers themselves have to pay for the incentive mechanism, the hybrid incentive can be interpreted as a scheme that is not directly linked to energy policy objectives, but rather located within the regulator’s efficiency and competition remit. In this case, the main objective of the hybrid incentive would not be to increase the share of DG, but to increase the efficiency of network access for new market actors. Although this can also contribute to reaching political DG targets, DG developers rather than society as a whole are regarded as the main beneficiaries, and therefore have to bear the costs of the hybrid incentive.

With this cost allocation Ofgem avoids the dilemma between promoting DG on the one hand and the objective to reduce costs for consumers on the other hand, or in other words between its secondary duty to pursue environmental objectives and its primary duty to promote the interests of consumers (see section 8.4.1). However, burdening the DG operators with the generator-use-of-system charge that also entails an additional profit incentive for DSOs can represent an obstacle for DG deployment. As a consequence, a new potential dilemma arises: between setting up a DG incentive mechanism on the one hand and promoting DG deployment on the other hand. DG deployment may be constrained by burdening DG with the very costs of the DG incentive mechanism.

The DG community was quite critical about the generator-use-of-system charge that is used to recover the hybrid incentive (interview Hartnell). One reason was that paying for the network costs beyond the point of connection represents an additional economic burden for DG developers. In the UK, switching from the previous deep charging regime to "shallowish" charges at least reduces the upfront costs of connection for the DG developer. Nevertheless, the mechanism does not look very attractive to DG developers, especially as it not only includes actual costs for network extensions, but also additional profits for the DSOs to incentivise them to do what they are obliged to do anyway: connecting generators to their network.

Another problem in the UK context has been that moving from deep charges paid by each project individually to a general generator-use-of-system charge means that all DG plants in one network pay the same charge. Therefore low connection charges in good network locations can no longer be used as a competitive advantage by some DG project developers (interview Hartnell). This issue is directly linked to the UK support scheme for renewables based on a quota system and therefore leads to competition between DG developers.

8.3 Incentive regulation and network innovation

On top of the DG hybrid incentive Ofgem set up two mechanisms to promote innovations in the network. I have not found any similar mechanisms geared towards network innovation in other EU countries and have not encountered any such schemes outside Europe, either.

8.3.1 Background

Chapters 3 and 6 have already discussed the main reasons for why network innovations are becoming an issue in the regulatory debate. On the one hand, there is a lot of potential and need for innovations in electricity networks, partly as a result of the increasing generation capacity connected to the distribution network. On the other hand, 'pure' incentive regulation arguably has a number of shortcomings with regard to long-term issues and additional risk that can result from innovative activities. As shown in chapter 2 for market liberalisation in general and in chapter 6 for incentive regulation in particular, there is evidence that the introduction of the standard model tends to coincide with a decline in RD&D activities.

In the UK, this decline can be observed across the utility sectors, the only exception being telecommunications (Holt 2005a: 2). As for the distribution networks, there is evidence that RD&D expenditure by DSOs declined significantly after liberalisation (Scott, Evans 2007: 42-43) and that it is significantly below the level of RD&D of other sectors. In 2001-2003, the average RD&D intensity of DSOs, defined as the ratio of RD&D expenditure to company turnover, was only 0.1 %, which was significantly below the UK average of 2.5% according to Ofgem (2004b: 5).

At the same time, DG is regarded as a significant new technical challenge for the DSOs (Ofgem 2004b). Moreover, according to the UK's Electricity Networks Association, two thirds of network assets are nearing the end of their lifetime, meaning that significant investments will be required soon (SDC 2007: 54). This represents a window of opportunity for the introduction of innovative network concepts.

Innovation incentives do need to fit with Ofgem's primary duty, yet at the same time the political objective to increase DG penetration is an important driver for judging the need for innovations. The regulatory debate on innovation indeed originated from the need to integrate DG into networks. Ofgem then looked at RD&D activities by network operators more generally and found that the lack of RD&D was a broader problem (Interview Evans).

On the one hand, Ofgem (2004b) presents its primary duty – the benefits of consumers – as the rationale for introducing innovation mechanisms. On the other hand, the regulator argues that the main purpose of the new instruments and especially the RPZ is *"to help meet the government's targets for renewables and CHP"* (Ofgem 2003: 2). This ambiguous foundation of the innovation mechanisms is reminiscent of the analysis in chapter 5.2.1 in terms of the potential tension between the efficiency objective and politically-defined objectives as well as the blurred rationale for the DG hybrid incentive explained in the previous section.

The political justification for introducing innovation mechanisms in the UK supports the argument made in chapter 6.4.2. It is very difficult to identify an ‘optimal’ level of RD&D. Therefore analysis of whether there was too much RD&D before liberalisation which has now been reduced to an efficient level or whether RD&D spending and investment in innovation has fallen below an adequate level is not straightforward. Against this background, innovation mechanisms essentially need to be based on a judgement that more RD&D and innovation is needed and erring on the side of innovation is justified. In the UK, this judgement is based on the political DG objective.

Although it identified a lack of RD&D, the UK regulator only partly subscribes to the analysis in chapter 6.2 of the shortcomings of the standard model with regard to RD&D. Ofgem argues that it has not prohibited RD&D (Ofgem 2004b: 7), but concedes that *“it is possible that the regulatory system is perceived to be such that it undermines the commercial incentive to RD&D”*, although this is not clear cut in its opinion (2004a: 48). Nevertheless, Ofgem introduced the following innovation mechanisms to rectify the problems resulting from ‘pure’ incentive regulation.

8.3.2 How do the innovation mechanisms work?

Ofgem set up two mechanisms within the 2005 Distribution Price Control Review (Ofgem 2004b; Ofgem 2004d; Ofgem 2004a):

- the Innovation Funding Incentive (IFI)
- and Registered Power Zones (RPZ).

The IFI and RPZ are designed to be complementary, addressing different stages of the innovation process. 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 specifically addresses demonstration projects that employ new, more cost effective ways of connecting and integrating DG into network operation.

The Innovation Funding Incentive gives network operators an allowance to spend 0.5 % of their regulated revenue on innovation projects on a use-it-or-lose-it basis. Within this limit, there has been an average 80 % cost pass-through over five years with the following profile. The higher pass-through rate at the beginning is supposed to incentivise first-movers.

Table 8: 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 second mechanism, Registered Power Zones, is based on the hybrid incentive for DG connection that gives DSOs a £/kW incentive for new DG connection. If the connection is carried out in a RPZ with the help of new solutions, the £/kW incentive is increased. While 'normal' DG connections are rewarded with a £/kW 1.5 incentive rate for a 15-year period, the RPZ incentive is increased to £/kW 4.5 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.

The two mechanisms provide a practical example of the instruments analysed in chapter 6.3. Both mechanisms are designed to balance the incentive to develop and try out new approaches with the incentive to do this efficiently. DSOs do not get rewarded for RD&D, but only for useful RD&D outcomes.

Both mechanisms reduce the downside risk for companies through a partial cost pass-through (lower-end truncation). The IFI is only based on this input- or cost-based mechanism. DSOs are incentivised to control the costs of RD&D via the 80 % cap, rather than through an explicit price-based element. The remaining 20 % can only be recovered via cost savings resulting from the innovation. As there is no price-based element, the IFI does not need to include a definition of innovation outcomes that would need to underlie the price-based element.

The RPZ explicitly combines input- and output-based elements. The price-based element in the RPZ scheme allows the DSO to directly recover 100 % of its costs or even more than that, provided that the costs do not exceed or are below the cost level defined by the revenue driver (£/kW 4.5 for 20 % of the costs). There is a predefined area of innovation to which the price-based element is linked (DG connection).

Compared to the IFI, the RPZ is more attractive for DSOs due to the additional price-based element on top of the 80 % cost recovery. While the IFI mechanism protects DSOs against part of the innovation risk, the RPZ gives them an additional positive incentive for the innovative connection of DG plants in demonstration projects, similar to the hybrid incentive.

Taking into account that Ofgem generally assumes RPZ demonstration projects to have a lower risk than IFI development projects it may seem surprising that the RPZ includes an additional revenue driver, while the IFI does not. However, IFI projects include innovations that can help the DSO to reduce the costs of its core business, delivering electricity via the network. RPZ projects do not contribute to this core business. This refers to the discussion in chapter 6.1 on externalities which can justify an additional incentive. RPZs support the DG objective of energy policy and from the DSO perspective they may help to reduce the costs of DG connections, but not connecting DG may even be more attractive to meet the regulator’s efficiency target.

The following example illustrates how the IFI mechanism redistributes risk between DSOs and network customers and how this is supposed to stimulate additional RD&D. In this example, the investment is profitable from an overall economic point of view, but without the innovation mechanisms would not be carried by the DSO as its customers would see most of the benefits, making the investment uneconomical for the DSO (upper-end truncation). With the IFI, which shifts costs to customers, the investment becomes profitable for the DSO, but customers still benefit.

Table 9: Redistribution of costs and benefits through the IFI

RD&D investment	£ 5 m	
Over what period?	5 years	
Savings per year as a result of the innovation	£ 1 m	
Over what period?	20 years	
Discount rate	6.5 %	
Net present value	£ 3.7 m	
Distribution of costs and benefits	Without IFI	With IFI
Costs	DSO 100 %	DSO 20 %, network customers 80 %
Savings for the DSO (over 5 years)	£ 5 m	£ 5 m
Savings for network customers (over 15 years)	£ 15 m	£ 15 m
Net present value for the DSO	£ -1.1 m	£ 2.1 m
Net present value for network customers	£ 4.8 m	£ 1.6 m

Source: Based on Ofgem 2004c

As the IFI aims at general cost reductions that benefit demand customers, it is paid for by the latter. The costs of the RPZ scheme are treated like the costs of the DG hybrid incentive and are added to the use-of-system charge for generators, leading to the same problems as the hybrid incentive: the mechanism is introduced to support DG, but DG operators have to pay for it and carry a significant part of the risk. Although it may be argued that the RPZ scheme does not significantly increase the level of the generator-use-of-system charge (interview Brook), this can also indicate that the incentive for DSO is not very strong. In any case, increasing the incentive for the DSOs under this model of cost allocation increases the charges for the DG operators.

8.3.3 The incentive mechanisms under discussion

As discussed in chapter 6, reliance on economic regulation to pursue objectives beyond efficiency can be criticised both from the regulatory economics perspective of the standard model as well as from the evolutionary perspective put forward in chapter 2.2. This is confirmed by the empirical analysis of the developments in the UK. Although both the hybrid incentive and the innovation mechanisms confirm the conceptual analysis that the incentive mechanisms can be adapted to pursue new objectives, the process of introducing these instruments in the UK was less straightforward.

Scepticism from the regulatory economics perspective was most prominently expressed by Ofgem itself. Although the additional mechanisms fit into the incentive framework and can be justified based on Ofgem's duties, they did not fit as easily into the framework provided by Ofgem as an organisation. A general attitude within Ofgem was that it should not become involved in intervention in the area of network innovations. According to the Sustainable Development Commission (SDC 2007: 35), when the innovation mechanisms were *"first suggested within the organisation* [Ofgem] *it was rejected on the basis that innovation spending does not always lead to increased value to the consumer as many innovative projects fail and there was reluctance to micro-manage network operators' activities."*

At the same, the innovation mechanisms can be criticised for neglecting a number of important features of the innovation process. As argued in chapters 2.2 and 6.4, innovation is – from an evolutionary perspective – not simply an optimisation process whereby companies increase or decrease the innovation output depending on price signals such as the ones provided by the IFI and RPZ. Rather, the innovation process depends on a number of institutional factors such as the companies RD&D capacity and culture.

In principle, the mechanisms represent a signal to network operators that long-term issues and innovation become more relevant and that they should not only focus on short-term efficiency. However, the fact that the two mechanisms were initially only set up for one regulatory period running until 2010 and the lack of certainty as to whether they would continue beyond that date arguably made it difficult for DSOs to build up RD&D capacity that they had lost after liberalisation (interview Brook).

Moreover, the IFI puts a cap on how much the DSOs can spend in-house (15 % of the overall IFI budget). Although the regulator recognises that DSOs need to spend some resources internally to pursue IFI projects, according to Ofgem (2004a: 49), *"it is not the intention of the IFI to encourage DSOs to re-establish in-house RD&D facilities"*. However, this may prevent DSOs from increasing RD&D capacity which may produce effective RD&D and may be necessary for the DSOs to appropriate and translate the results of external projects that they have funded via the IFI. Thus, the cap represents an example of micro-management that Ofgem wanted to avoid.

Another interesting point has been made by Woodman (2007) who criticised the restrictions imposed on the possibility of replicating the demonstration of a new technology in more than one RPZ. This may hamper its commercialisation and wide-spread adoption.

While the principal design of the innovation mechanisms as such represents an elaborate approach to providing incentives for efficient RD&D, a critical question is how the parameters are set and how strong the incentives actually are. Against the background of the above arguments, it is not surprising that the incentive mechanisms have been considered to be too weak (e.g. SDC 2007: 35), especially given the fact that DSO are generally not particularly innovative organisation, but are used to operate in a low risk environment (interview Brook).

The level of incentives can be explained both by Ofgem's reluctance to introduce the instruments in the first place as well as the innovation model applied, which seems to neglect institutional factors that are necessary for DSOs to engage in RD&D. The relatively weak innovation incentives must be judged against the risk for the DSOs that new approaches may cause network problems and endanger network quality, for example if the connection of DG leads to voltage problems, which would lead to them incurring penalties (interview Botting).

Finally, the UK example also shows that the additional incentive mechanisms may provide some incentive for the DSOs, but are not necessarily attractive for the DG developers. As explained in the previous section, DG operators are charged both for the hybrid incentive and the RPZ scheme. Besides the additional costs which these entail for DG developers, RPZs may be unattractive even if the demonstration may lead to new insights that can contribute to system transformation. Individual DG projects that are connected in a RPZ are not included in the incentive scheme. They do not necessarily benefit from the innovative approaches, and may even be disadvantaged due to the uncertainties and delays in the connection process. While network innovation and system transformation are arguably important to accommodate a changing generation structure, the UK case shows that these issues are less relevant from the perspective of DG developers that 'simply' want to get connected to the network (interview Hartnell).

8.3.4 Innovation outcome and further developments

The practical outcome of the innovation mechanisms is difficult to measure, especially in terms of useful innovations. Nevertheless, it is fair to say that in the UK the effects do not live up to the expectations, especially in the case of RPZ. This has led Ofgem to review and revise its approach.

Before the mechanisms were introduced, Ofgem carried out a regulatory impact assessment and estimated the net benefits of the mechanisms. The following table shows that significant benefits were expected.

Table 10: Expected net benefits of IFI and RPZ, present value (£m)

	RPZ	**IFI**
Potential savings	121	443
Cost to customers of initiative	29	57
Net benefit	92	386

Source: Ofgem (2004b)

As for the IFI, there has been an increase in RD&D spending by the DSOs (Ofgem 2009b: 5). However, according to their annual IFI/RPZ reports for the first year running until March 2006, all DSOs stayed significantly below the 0.5 % cap introduced by Ofgem, with EdF Energy reaching the highest level (0.39 %). The higher pass-through rate in the first years did not lead to the expected ‘early action’.

This can be interpreted as a lack of the DSOs’ capacity to initiate, manage and make use of RD&D projects and confirms that DSOs have difficulty building up this capacity in a short period of time.

The majority of IFI projects are found in the area of lifetime extension of the existing network infrastructure rather than innovative network concepts that could replace existing networks and facilitate the integration of DG (Woodman 2007).

As for the RPZ mechanism, this has had limited practical impact on the demonstration of innovative concepts and DG connections. By March 2008 when the review for the next regulatory period began (DPCR5), only four RPZs were registered (Ofgem 2008: 20). Moreover, after registering the RPZ, there have been significant delays in actually connecting the DG plants, which is one reason why RPZs have proved unattractive for

DG developers. It is therefore justified when the RPZ scheme is described as *"less successful than hoped"* (Ofgem 2008: 20) or even when described as a failure (e.g. Pollitt 2009).

As a reaction to the relatively limited effects of the two mechanisms and especially the RPZ, Ofgem carried out a detailed review of the two mechanisms in late 2006, i.e. in the middle of the regulatory period. The main points that emerged from this review are:

- All respondents have in principle supported the mechanisms.

- Many respondents have asked Ofgem to extend the mechanisms beyond the current regulatory period and provide more long-term stability.

- It has been proposed that the RPZ scheme be extended beyond DG connections to include other decentralised resources such as demand-side measures and storages.

- DSOs should be allowed to replicate innovative approaches in different RPZs to promote the diffusion of innovations.

- A major problem identified with the RPZ mechanism is the relationship between DSOs and DG developers. The RPZ mainly addresses DSOs. However, in order for RPZs to work they require the cooperation of DSO and DG developer.

As a result of the review, the regulator took the unusual step of announcing in the middle of the regulatory period that the two instruments will be extended beyond the current regulatory period to enable more long-term planning and certainty (interview Evans). This indicates that it is difficult to deal with innovation within the limited length of regulatory periods that have been set up to increase short-term efficiency.

The instruments have been reviewed again as part of the next distribution price control review, which began in 2008. While it was decided that the IFI be continued, the RPZ was replaced by a new funding mechanism, the Low Carbon Network Fund (LCN). An important change provided by this new mechanism is that innovation funding is no longer based on network tariffs in individual networks, but will rather be recovered from all DSOs (Ofgem 2010).

8.4 Beyond changes in the incentive formula

The DG and innovation mechanisms introduced by Ofgem fit into the standard procedure of incentive regulation based on revenue incentives and regulatory periods. They are designed to promote network connection and innovation.

However, as I argued in the conceptual part of the thesis and especially in chapter 7 based on system transformation literature, it is not sufficient to add additional economic incentive mechanisms, especially when addressing system transformation. Rather, the overall regulatory framework itself may need to evolve, both in terms of additional governance mechanisms and the role of the regulator.

As explained in the previous section, the DG hybrid and innovation incentives were designed so that they can be justified within the Ofgem efficiency remit rather than as an instrument to pursue political objectives: they can facilitate DG connections at lower costs and demand customers do not have to bear any additional costs.

Nevertheless, the evolution of the regulatory framework in the UK is not confined to adaptations in the incentive formula. Rather, there are a number of developments – not all of them driven by DG – that go beyond changes in the incentive mechanisms and change the overall design of network regulation. This includes both the objectives of regulation and its instruments. In principle, this confirms the analysis conducted in the conceptual part. The following two sections analyse these developments.

8.4.1 The role and objectives of Ofgem

Initially the UK electricity regulator Offer (which was later to become Ofgem) had mainly economic duties and focused on promoting and maintaining competition. Over recent years, the role of Ofgem has changed to include a broader set of objectives and a more long-term perspective.

The Labour government that came to power in 1997 marked the beginning of a new regulatory phase in the UK. When the network industries were first privatised by the Conservatives, the government did not put any effort into developing a regulatory concept that placed network regulation into a wider energy policy context. In line with the standard model which was to a large extent developed in the UK, regulation was put in place mainly as a means to implement liberalisation and privatisation and as a surrogate for competition. There was no detailed regulatory 'philosophy', except that regulation should be independent based on the economic theory that provided the foundation for the 'incentive regulation' framework (chapter 3.2). As a consequence, as Helm (2003: 273) has pointed out, *"the regulatory regime for both gas and electricity was designed without much thought to its wider role in energy policy"*.

When still in opposition, Labour, on the other hand, did not initially show much interest in regulation since it was opposed to the whole liberalisation agenda (Corry 2003: 6). Regulation thus fell into a political void. Regulation has therefore been developed to a large extent bottom-up by the regulators themselves, based on the overall liberalisation paradigm and the incentive regulation concept developed by economists.

Once it had remodelled itself as New Labour and was preparing to assume power, renationalisation was no longer an option and Labour had to reconcile itself to the new regime. This made it necessary for a 'Labour' approach to regulation to be developed. Thus, it was only in the late 1990s that a regulatory 'philosophy' underwent development, which was to be more than a continuation of competition by other means. This philosophy puts regulation into a broader political context and rejects the notion that regulation can be neutral and value-free. In this perspective regulation is not just about efficiency, but also about public policy and public values (Corry 2003: 4-5)

The most obvious in-road for Labour's regulatory reform agenda was to tackle the distributional effects of network regulation. Firstly, this refers to the monetary distribution between network operators and consumers and the trade-off between productive and allocative efficiency. Labour sought to rectify the results of regulation under the Conservative government – a time that is often referred to as the "fat cat" years when network operators increased efficiency and were able keep most of the gains for themselves. Secondly, there were concerns about certain groups of consumers, e.g. low income customers threatened by 'fuel poverty'.

When the new Labour government started to amend the standard model, it was chiefly concerned with improving equity issues in the beginning. Later on, the reworking of regulation that was set off by the UK Utilities Act linked up with the environmental and long-term issues such as DG integration and network transformation which were moving up the agenda (MacKerron 2003; Helm 2005). With regard to social policy objectives, Ofgem argued that these are best served by competitive markets, whereas in environmental policy there is more recognition that market mechanisms need to be complemented by other instruments (Green, Trotter 2003: 79).

The government first amended the objective of regulation with the 2000 Utilities Act (Owen 2004: 18). The interests of consumers became the new principal objective, which should be pursued "*wherever appropriate, by promoting competition*". This was implemented despite concerns that downgrading the competition objective may *"weaken the ability or resolve of the authority to pursue what has surely been the main instrument for progress in the industry"* (Littlechild 2003: 44). A further interesting aspect is that according to the Utilities Act "consumers" includes both existing and future consumers, thus adding a more long-term perspective to regulation (Utilities Act 2000, Section 13(6)).

Moreover, the new primary duty was complemented by so-called secondary duties, including both social and environmental ones. According to the OECD (2002: 26), broadening Ofgem's remit beyond economic objectives represents *"an interesting institutional innovation"* and *"compared with arrangements in other jurisdictions Ofgem's role (…) represents a ' quasi-policy' function.*

This raises the question of how the regulator's broader remit affects the relationship between Ofgem and the government. The discussion in chapter 7.2 showed that multiple objectives render regulation more political. With a more encompassing role for the regulator it becomes more urgent to properly define the interface between regulation and policy and ensure political control of the regulator (Helm 2004a).

Broadening the regulatory remit tells the regulator which objectives to pursue, but not which to choose in the case of trade-offs between them. In the UK, the hierarchy of primary and secondary objectives provides some guidance on how to deal with trade-offs between these objectives. Moreover, the new law enabled the UK energy minister to issue guidance to Ofgem as to how to take environmental and social objectives into account.

On the one hand, the guidance is described as a *"mechanism to resolve the issue of blurred responsibilities between the government and Ofgem"* (OECD 2002: 26). On the other hand, it was criticised in the Energy Review initiated by the government that the guidance given to Ofgem was not *"sufficiently specific about the outcomes Government wishes to achieve and when it wishes to achieve them"* (PIU 2002: 146-147).

In addition to social and environmental duties, the introduction of a more comprehensive sustainability duty was also discussed. The England and Wales water regulator Ofwat provided an example for a more explicit consideration of sustainability objectives in the regulatory framework (Owen 2004: 27). One explanation for the differences in water and energy regulation in the UK can be found in different institutional responsibilities: while Ofgem belongs to the DTI's remit, the water regulator Ofwat is overseen by

DEFRA, the the UK's Department for Environment, Food, and Rural Affairs (Owen 2006b: 213). This shows how the standard model can be interpreted differently within one and the same government.

A sustainability duty was not introduced in the UK Utility Act. However, the discussion to amend Ofgem’s duties continued, and the 2004 Energy Act eventually added a new secondary duty for Ofgem to contribute to sustainable development (Owen 2006b). The 2004 Energy Act (section 83) stipulates that that the regulator should carry out its duties in a manner *“best calculated to contribute to the achievement of sustainable development”* subject to the principal objective, the protection of the interests consumers.

The new duties were to some extent also reflected in Ofgem’s internal structure following the UK Energy Act (SDC 2007: 32). A new European Strategy and Environment Directorate was introduced, Ofgem set up a sustainable development sub-committee and started producing a sustainable development report.

There have been further debates about improving the alignment of Ofgem’s duties to broader government policy and further extending its duties and putting sustainability on the same level as economic objectives (SDC 2007: 29-32). The 2008 Energy Act further strengthened the sustainability duty.

It is certainly debatable whether and how these new duties have affected the actual performance of Ofgem and whether Ofgem possesses the necessary capacities to implement the new duties (Owen 2006b; Bartle, Vass 2006; SDC 2007). According to a survey carried out by Bartle and Vass (2006: 37) which focused on the effects of the sustainable development duty, *“there is little evidence of a substantial and significant change in the actions of the regulators which can be directly connected to the duty”*. Even with the new duties in place, Ofgem is still described as an institution concentrating on incremental change, rather than long-term system transformation (interview Strbac). Economic issues remain Ofgem’s main objective. The regulator has been rather reluctant to implement the new duties. As Helm (2004a: 34) has pointed out, the government unofficially wanted Ofgem to go beyond its primary duties and implement the 2003 Energy White Paper (DTI 2004b). Yet there was a struggle between neo-liberal economists at Ofgem who see its environment-related objectives as political interference and those in government who envisage a wider role for Ofgem (Green 2004: 7).

It is therefore not surprising that there have also been more far-reaching proposals for revising the institutional set-up, rather than merely amending the objectives within the standard model. For example, Owen (2004: 30) put forward the idea of giving the UK Environment Agency a role in network regulation to ensure that various objectives are balanced. As mentioned in chapter 7.2, Helm (2004a: 34) proposed the “agency model” as an alternative to the regulatory office model on which Ofgem is based. In this model, the agency would explicitly cover the entire sector, including all the policy objectives related to it, rather than adding additional objectives to the economic regulator. In the UK context, this may require a merger between Ofgem and other bodies, including the Energy Savings Trust and the Carbon Trust.

Although the effect in practice of the new objectives should not be overrated and must be evaluated in the specific institutional and political context, the UK example shows that the clear-cut economic objective of regulation has been increasingly called into question and the standard model of economic regulation has become a subject of political debate. These developments in the UK support the point made throughout the conceptual part of this thesis: due to political objectives such as DG which depend on the network and the far-reaching changes that networks may experience, it is difficult to maintain the standard model as a depoliticised approach and only adapt it on the level of the incentive formula.

8.4.2 Regulatory instruments beyond economic incentives

So far the UK case study has analysed how incentive regulation has been amended to take into account DG and network innovation and how the objectives of regulation have been expanded beyond economic efficiency.

This section briefly describes the development of regulatory instruments that go beyond changes in the incentives given to the regulated companies, but establish additional co-ordination mechanisms. This is based on the conceptual analysis in chapter 7.1 that has argued that economic incentives are not sufficient to manage network transformation and that transformation mechanisms can build on the standard model.

8.4.2.1 Coordination beyond economic incentives

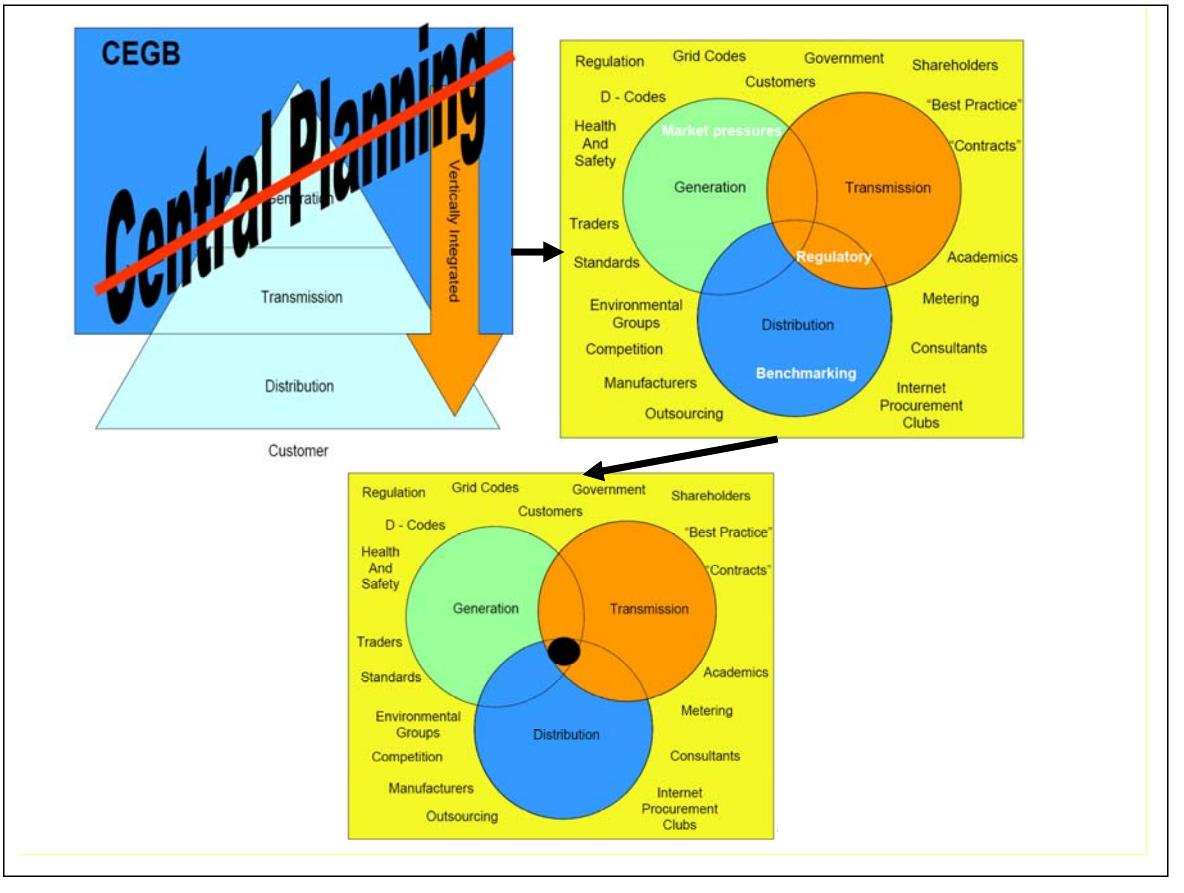
In chapter 7.1 it was argued that system transformation poses a number of governance challenges that cannot be met by the market, but require specific governance arrangements, including strategies for dealing with systemic uncertainty, the anticipation of long-term system development, measures to increase adaptability, and the coordination of a broad range of actors. Although the UK has been a champion of the market, this generic analysis of the need to apply non market-based coordination mechanisms is to some extent reflected in the development of the regulatory regime in the UK.

In 2005 the Distributed Generation Coordination Group, chaired by the DTI and Ofgem, commissioned the so-called Technical Architecture Report. It addresses issues of system transformation and identifies the need that *"a single entity is given responsibility to be the focal point for developing future technical architectures"* (DGCG 2005, 8). Joint thinking would be necessary because *"the largest identified barrier to Distributed Generation (DG) being adopted in large scale was the 'lack of joined up thinking' in the industry"*. In a similar vein, John Scott, who was then Ofgem's Technical Director in charge of the DG and innovation incentives, emphasised the importance of the new incentive mechanisms presented above, but at the same time questioned whether *"this is sufficient to energise the 'supply chain' of parties across the wider sector that will be needed?"* (Scott 2004).

The Technical Architecture Report comes to the conclusion that the transformation from central planning to a liberalised market has led to a lack of coordination. While central planning by the state-owned and vertically integrated Central Electricity Generation

Board (CEGB) was the main governance mechanism before liberalisation, it was replaced by unbundling and a heterogeneous actor arena that is supposed to be coordinated through the market. While this market structure is not called into question, the argument is made that an additional 'focal point' is necessary for improving coordination in the liberalised market environment and for developing a new system architecture. This is illustrated in the following figure.

Figure 15: From central planning to a new focal point in the liberalised market?



Source: Adapted from Botting (2006a)

Although it remains rather vague what this focal point is and what it should do, it becomes clear that it should complement the market and provide a coordination mechanism that is located somewhere between central planning and coordination through the competitive market. It is a central coordination mechanism in a heterogeneous arena, rather than a decentralised coordination through prices. The notion of such a focal point resembles the proposals made by the governance of system transformation literature. For example, both the foresight and strategic niche management approaches presented in chapter 2.2 and the coordination of actors discussed in chapter 7.1 can be regarded as such focal points.

In the UK, Ofgem and the DTI set up and co-chaired three consecutive groups that comprise a range of stakeholders to analyse the barriers for DG and propose ways to overcome them. In 2000, the Embedded Generation Working Group (EGWG) was established to identify barriers for the further deployment of DG. A key conclusion of the group was that DSOs play a key role for DG and a lack of incentives on their side, resulting from the regulation of network tariffs, represents a key barrier for DG (Botting 2006b). This led to the DG hybrid incentive. In 2001, the EGWG was followed by the Distributed Generation Coordinating Group (DGCG), which was to implement the recommendations of the EGWG. This was followed by the Electricity Network Strategy Group.

8.4.2.2 The Electricity Network Strategy Group

Following the Technical Architecture Report the Electricity Network Strategy Group (ENSG) was set up in 2005 by the DTI and Ofgem to replace the DGCG. The ENSG can be interpreted as an attempt to establish the ‘focal point’ proposed by the Technical Architecture Report in order to tackle long-term network transformation.

Besides the DTI and Ofgem its members include representatives from the Scottish Executive, the Welsh Assembly, DEFRA, network operators, generators, consultants and other industry participants. Thus, the group brings together different market players, policy-makers and the regulator. Network governance is no longer restricted to the principal-agent relationship between the regulator and the network operators.

The task of 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"* (ENSG 2006: 2) and it wants to formulate *"a holistic view of the strategic development of transmission and distribution networks"* (ENSG 2006, 3).

While the earlier industry groups described in the previous section focused on connection of DG to the distribution network, the ENSG has a broader scope and analyses both transmission and distribution issues. This indicates a shift to a more systemic perspective, rather than looking at innovations in individual networks. Also, network transformation is seen in the wider context of the transformation of the energy system to a low carbon economy. The group also takes a long-term perspective and analyses potential future development paths and upcoming options. This is supported by the development of long-term scenarios that analyse possible future network developments (Ault, Hughes 2008).

It is chaired jointly by the DTI and Ofgem, indicating that the clear distinction between policy formulation and delivery has been blurred to some extent and that there is more of a two-way exchange. Ofgem's role in this group goes beyond implementing objectives defined in the energy policy realm; it has an important role in moderating the process of defining the future development of the network. In this context, it is important to note that Ofgem not only has a role as a financial tariff regulator, but also on a technical level: there is a technical group through which Ofgem becomes involved in the debate on potential future system architectures in the ENSG (interview Evans).

The ENSG is not based on any explicit concept of how to deal with system transformation, as for example Transition Management in the Netherlands (see chapter 2.2), although Ofgem has considered how such a process needs to be designed (Scott, Evans

2007: 51-52). In any case, the ENSG exhibits a number of governance features similar to those discussed in chapter 7.1 for dealing with long-term network transformation: the regulator takes a long-term perspective rather than looking only at the next five-year regulatory period; the group explores different options; a broad range of stakeholders from different parts of the electricity sector is involved in contributing to this long-term perspective; the ENSG pursues not just economic efficiency, but broader policy objectives; networks are discussed in the context of overall electricity system development; the relationship between policy and regulation becomes more interactive.

According to the regulator, the ENSG is to make explicit and analyse different potential developments so that DSOs can prepare and adapt to them (interview Evans). The multi-stakeholder approach is not only aimed at providing coordination between the different actor groups. Rather, the ENSG also has a role in advising Ofgem on the different scenarios and options available. As the regulator wants to avoid being captured by vested interests, it expects to benefit from a broader and more balanced perspective that can be elaborated in such a group (interview Botting).

The ENSG represents an institutional innovation in the regulatory regime of the UK context. It complements the market mechanism and can help to coordinate the innovation activities of different actors to contribute to system transformation. However, many in the UK have been rather critical about the ENSG and its performance, including those who see the need to address system transformation. Although in principle it is regarded as a good idea to involve a broad range of stakeholders, it is regarded as problematic that the ENSG only has an advisory role and is seen as suffering from a lack of power (interview White). It has therefore also been called a ‘talking shop’ (interview Strbac).

One main problem of the various groups and especially the ENSG is that the rather theoretical work has not been sufficiently translated into actual experiments or changes in the regulatory framework. The long-term perspective which the group takes is not adequately linked to short-term regulatory actions (interview ENA, Mitchell). The RPZs were expected by Ofgem to provide a tool to try out various options that emerge from the horizon-scanning (interview Evans), but in practice they could not live up to this expectation (see section 8.3.4).

In terms of actor coordination, the ENSG also highlights the problem that these kinds of processes require additional resources that many stakeholders do not have. Especially in the case of DG developers and associations of new generation technologies, they have realised the importance of regulation, but lack the resources to fully participate in the regulatory process, including the various groups that have been set up such as the ENSG (interview Hartnell).

This chapter does not provide a detailed analysis of the way in which the ENSG works and its practical effects. However, the above-mentioned problems are rather typical of such long-term and transformation-orientated governance mechanisms that often lack resources and power and are not properly linked to short-term decision-making processes (e.g. Kern, Smith 2008 for the case of Dutch transition management; Hendriks, Grin 2007).

Although the practical effects of the ENSG may have been limited to date, the principal design of the ENSG and the grounds on which it has been justified potentially marks a departure from the standard model of economic regulation. What is most interesting in the context of this thesis is that such a governance mechanism has been established in the homeland of the standard model. Moreover, the ENSG is not a separate process, but is directly based on the standard model, with the regulator Ofgem playing an important role in this process. Although Ofgem and the ENSG are far from the transformation agency suggested in chapter 7.1 and despite the potential for improving the design and performance of the ENSG, it represents a practical example of a governance mechanism that can establish a link between the liberalisation and the transformation discourse as discussed in chapter 2.

9 Case study Denmark

This chapter presents the second country case study on Denmark. Although both the Danish and UK case studies seek to answer the same questions and examine the issues laid out in chapter 4, the structure of the Danish case study differs in some respects from the UK one. This reflects the differences between the two cases: While in the UK the focus is on the standard model and how it is being adapted, the Danish case study has revealed other mechanisms beyond the standard model that govern the transformation of the Danish network infrastructure.

As a consequence the outline of this chapter revolves less around the standard model and how it evolves; rather it is structured so as to present both the role of the standard model as well as these additional mechanisms. It also places more emphasis on innovation and transformation, because this has become the key issue in Denmark. The chapter first presents the background (section 9.1) that is necessary to analyse the governance of DG connection (9.2) as well as the governance of innovation and transformation (9.3) in more detail.

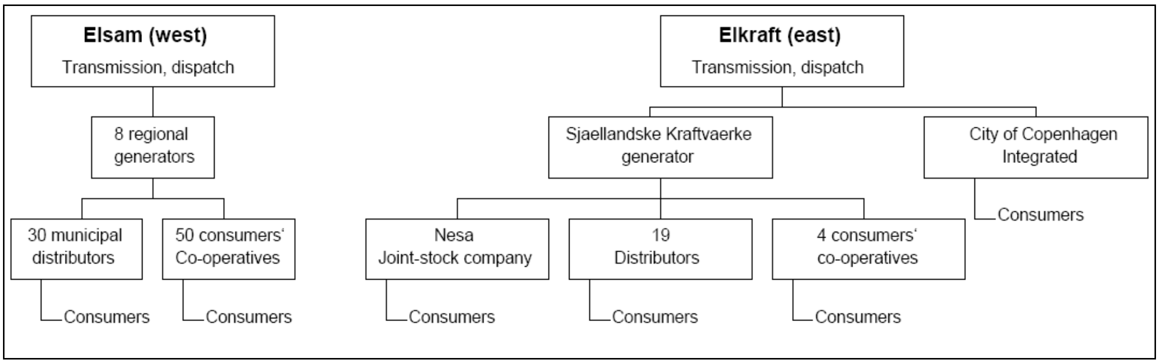
9.1 Background: Liberalisation, DG and system transformation

9.1.1 The traditional structure of the electricity industry in Denmark

The Danish electricity system is divided into two systems: an Eastern system in Zealand and a Western system covering Jutland and Funen. There is no synchronous interconnection between the two systems. Until recently, there were also different companies operating in the two regions, including two separate system operators. Most DG is situated in the West and most issues surrounding DG therefore emerged in this part of the country. Therefore, the focus of this study is on western Denmark. Although the eastern and western parts of the country are still separate from an electrical point of view, they have started to converge since the national system operator Energinet.dk formed in 2004.

The following figure shows the ownership structure of the Danish electricity supply industry in 1995, just before liberalisation started to transform the sector. Besides the separation into “east” and “west”, the figure shows another important feature, too: the bottom-up ownership structure.

Figure 16: The organisation of the Danish electricity supply industry in 1995



Source: Grohnheit, Olsen (2001: 130)

As in other countries electricity supply was initially characterised by decentralised generation and distribution, which in Denmark was run by municipalities as well as farming cooperatives and consumer-owned companies. Over time the system became technically more and more centralised, with large-scale plants and a transmission system across different regions and interconnectors to other countries. However, in contrast to many other countries, the technical integration did not overthrow decentralised ownership, but the local cooperatives managed to maintain control over the centralised supply structure. This led to a bottom-up ownership structure where a large number of local companies jointly controlled the larger generation companies, which in turn used to be the owners of the two transmission system operators.

This traditional set-up of the Danish electricity supply industry is rooted more broadly in the peculiarities of the Danish socio-political system, which is characterised by cooperatism and decentralised governance (Christiansen et al. 2001).

Importantly, the ownership structure also entailed a strong public service obligation and an orientation of the companies towards the requirements of their local owners. Besides the consumer ownership system, there was a “consumer profit” system in place until 2000, too. This meant that the electricity companies had to re-invest any profits into the electricity system; otherwise any surplus had to be paid back to the consumers through lower prices (Lucha 2006). This has become a major issue in the transformation towards a liberalised market: it has led to the nationalisation of the system operator (see section 9.3.3.1) and has influenced the implementation of the standard model of network regulation in Denmark.

Another consequence of the bottom-up ownership was that Danish electricity companies have traditionally not been controlled by the state and the direct involvement of the state in operation of the electricity system was rather minimal (Hadjilambrinos 1999). Energy policy did play an important role, defining ambitious targets and seeking to guide the development of the sector. However, energy policy did not rely on ownership, but rather on command-and-control instruments and to a large extent also on joint planning and agreements between the government and the companies (see section 9.3.4.1) These agreements were "*the means by which many public service obligations, which would otherwise not be economic, are carried out*" (OECD 1999: 25). Many of these measures were to do with environmental objectives that were a primary objective of Danish energy policy before liberalisation (OECD 1999: 10).

Overall, in the Danish electricity industry governance through cooperation has traditionally played an important role, both between the government and the industry, and between companies themselves. As the large companies were owned by the smaller ones and eventually by consumers and municipalities, they could not unilaterally decide on the development of the electricity system, but had to seek the agreement of their local owners (interview Styrbro).

9.1.2 Overview of electricity market liberalisation

Unlike the UK, Denmark has not been a pioneer of electricity market liberalisation, but it has not been a 'laggard' either. Liberalisation in Denmark was mainly triggered by liberalisation efforts outside the country, namely other Scandinavian countries and the European Union (IEA 2002b; Grohnheit 2002). Due to its proximity to the Scandinavian liberalisation pioneers, Denmark came under early pressure to open up its market. The first steps of electricity market liberalisation in Denmark were taken with the 1996 amendment of the Danish Electricity Supply Act – just before the European Union made liberalisation mandatory in its 1996 internal electricity market directive.

Market liberalisation went hand in hand with new environmental targets for the energy sector: in the same year, the Energi 21 plan was adopted, setting targets for CO_2 reductions for 2005 and 2030 and the further promotion of renewables and CHP.

The first amendment in Denmark was soon to be followed by a more encompassing reform that led to the 1999 Danish Energy Supply Act. The aim of this act was to implement the European directive, but also to combine Danish environmental and energy policies and the requirements of the energy market directive. Denmark went beyond some of the requirements of the EU directive; the Energy Act provides for a faster opening of the electricity market than required and introduced full opening of the retail market in 2003.

Overall, it can be said that Denmark has implemented the main elements of the standard model, including an independent economic regulator. In this process, many peculiarities of the Danish system were abolished, while others were kept, at least initially. Electricity companies became more commercial enterprises that were allowed to make a profit, breaking with the traditional Danish non-profit principle. At the same time, the strong role of local authorities and consumers continued after market liberalisation, although in the meantime the government has made it easier for them to sell their companies (Owen 2006a: 49; IEA 2002).

A major challenge in the transformation towards a liberalised market with ‘normal’ commercial companies was the so-called “capital issue”, i.e. the question of how to deal with the money the companies had accumulated and which was regarded as belonging to the consumers. This eventually led to the nationalisation of the transmission system operator Energinet.dk. This will be analysed in more detail in section 9.3.3.1.

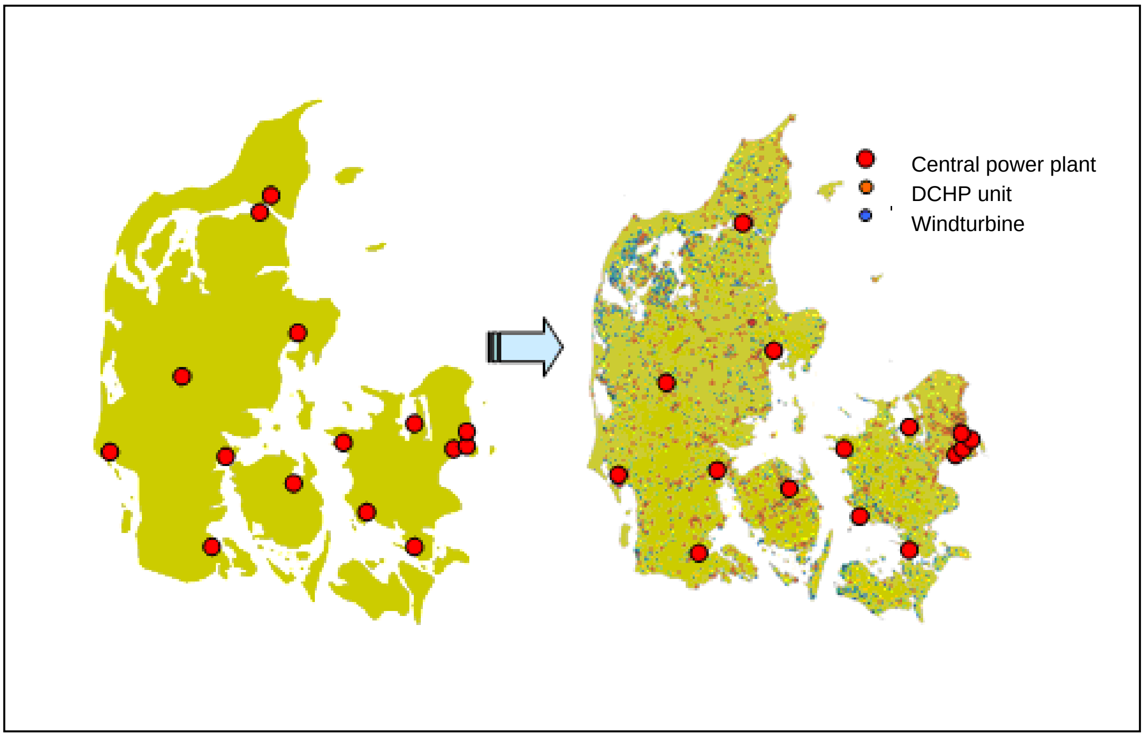
One important reason why Denmark and especially the former Western system operator Eltra became more enthusiastic about liberalisation after showing some initial reluctance was its high share of intermittent and distributed generation. An open European market with more cross-border exchange of electricity should help to maintain system security even with a high share of intermittent generation (interview Bach).

9.1.3 DG Policy

Denmark has, at least in the industrialised world, the highest share of DG capacity. Both wind and CHP plants have a major share in generation capacity. More than 50% of the total production capacity is dispersed throughout local distribution grids of 60 kV or less. Several distribution companies have an installed DG capacity several times higher than their total load and therefore need to export power (Lund et al. 2006).

Only twenty years ago the generation structure of Denmark looked similar to other countries, with most electricity generated in large-scale plants. The following figure illustrates the transition of a centralised to a decentralised electricity generation system from 1980 to 2000.

Figure 17: Decentralisation of electricity generation in Denmark from 1980 to 2000



Source: provided to the author by Eltra

This development is mainly due to political support for renewables and CHP that has provided a stable environment for DG since the 1970s (van der Vleuten, Raven 2006b):

- Since the oil crisis of the 1970s, Danish energy policy has sought to reduce dependency on oil imports by promoting renewables and CHP. In the 1980s, environmental objectives became the main driver of this policy. Decentralisation was also seen as an alternative to nuclear plants.

- Long-term objectives, plans and instruments were set up that have been consistently applied over time.

- As the state was not involved in the electricity industry in terms of ownership it did not have strong economic interests in the centralised system, which made it easier for it to pursue these objectives.

- The Danish Energy Agency was set up as a central actor and managed to develop a long-term and coordinated energy policy.

- While the government and the energy agency provided a strategic and long-term policy framework, the decentralised ownership structure of the industry was amenable to developing a decentralised generation structure.

- For both CHP and renewables, effective policy instruments have been put in place.

For CHP “heat planning” as well as an obligation for new and old buildings to connect to district heating was crucial. The 1979 Danish heat supply law made the local authorities responsible for identifying the potential for public heating in their areas. In 1988, electric heating was banned (Lorentzen 2005; IEA 2009a).

For renewables, support was provided through fixed feed-in tariffs, together with an obligation to connect these plants to the network. With the 1999 Energy Act which liberalised the market, there was to be a shift from the feed-in model to a quota system with a green certificate market, similar to the UK system *(Agnolucci 2005; Meyer, Koefoed 2003).* This was supposed to be a more market-based instrument. After several postponements, the scheme was eventually shelved and a premium system was introduced, whereby renewable operators receive the market price plus a premium payment. The feed-in law thus became a *"victim of its own success"* (Agnolucci 2005: 959). The shift from a fixed feed-in payment to a premium payment also confirms that with an increasing share of DG the emphasis shifts from connection to integration, in this case market integration as opposed to network integration.

Almost ironically, the attempts to replace the feed-in system have led to a surge of wind projects, the realisation of which was intended to occur prior to the implementation of the new systems, which arguably provides less favourable conditions for wind plants. This sudden increase in wind capacity was a main reason for the system operator to consider the system implications of this changing generation structure (interview Bach).

9.1.4 From individual plants to system transformation

Denmark has attracted a lot of interest for the policies that have been sketched out in the previous section and the resulting development of renewables and CHP. In contrast to the majority of previous studies, this analysis is not concerned with the deployment of individual plants, but with the governance of system integration and transformation. Very little research has been conducted on how this has operated in Denmark.

Denmark is an interesting case in this respect, too. From around 2000 onwards it has been increasingly recognised that the large increase in distributed and intermittent generation requires adaptations in the overall system. Over the last decade Denmark has become a *"real-life laboratory"* (Nielsen 2007) for electricity infrastructure transformation and a pioneer not just for DG deployment, but also for system change. This shift towards a system view has been summarised well by Nielsen: *“It’s about systems, not technologies: we don’t know yet how the system as a whole could operate”* (interview Nielsen).

The argument elaborated in chapter 3 and which helped to structure this study – that with an increasing share of DG the focus needs to shift from connection and network integration to innovation and system transformation – is thus confirmed by the Danish case. This section briefly describes the main projects and developments aiming at system change.

On the one hand, the Danish case indicates that a 50% DG share is not necessarily impossible to operate even in a conventional power system (Bach et al. 2003). In terms of market integration, the strong interconnections with Germany and the hydro-based systems in Scandinavia have certainly contributed to balancing the system despite a high share of intermittent generation (Jäntti 2003: 46; interview Strbac). In terms of network integration and additional network costs, the fact that most DG was connected before the market was liberalised and a special cost-sharing mechanism for distribution companies (section 9.2.2.1) have contributed to dampening the system consequences of DG.

On the other hand, the Danish example shows that large shares of DG do not easily fit into today’s centralised power systems. As in other countries the Danish electricity infrastructure was aligned to the centralised generation of electricity which characterised the electricity system and the increase of intermittent DG has made this system less stable. The increase of less controllable DG has made network expansions and network redesign necessary and has resulted in problems with balancing supply and demand and several times the system was close to breakdown (Jensen 2002). In January 2004, there was a large-scale black-out. According to Tech-Wise (2002: 43), *“the electricity system has been turned upside down without any actions being taken until recently. The consequences have been that the stability of the system is put into jeopardy and that increasing funds have had to be utilised to maintain the stability”.*

Several interviewees and especially those from the system operator Eltra and Energinet.dk have confirmed that system issues were almost entirely neglected when the objectives to increase renewables and CHP were drawn up and implemented:

- *"There was no planned development; the DG plants simply appeared, and nobody had foreseen the problems in advance; it was only in the late 1990s that the people in the industry realised in earnest the mounting problems"* (interview Lund.)

- And similarly: *"We started to realise too late that a system change is required. (…) No one was thinking about the infrastructure"* (interview Bach).

Having been neglected for two decades of DG development, infrastructure transformation has been a major topic on the Danish electricity agenda since around 2000. In contrast to the UK, this new issue has been triggered by the high level of DG which has been reached and which requires infrastructure transformation to ensure an efficient and secure supply and to enable the system to efficiently integrate even larger amounts of DG.

In around 2000, the problem became more apparent for two reasons, both of which indirectly involve the liberalisation of the electricity market. First, in the second half of the 1990s most resources, especially those of the transmission system operator were absorbed by designing the liberalised market. It was only after much of this work had been accomplished that enough resources could be made available to turn attention towards infrastructure issues. Secondly, as described in the previous section, in the wake of market liberalisation, the support system for renewables became less favourable, which led to a surge of new projects that wanted to benefit from the old system. This significantly exacerbated the system problems.

There have been three key programmes or projects. They all concentrate on transforming the overall system architecture rather than changes in individual networks, even though these changes are still in a pilot phase. The general philosophy is that the system cannot be rebuilt from scratch and what is therefore required is incremental system change adapted from the existing infrastructure. As a consequence, a focus is on intelligent control, to enhance the performance of the existing system (interview Lund).

System 21

The first attempt to tackle the system challenges resulting from a changing generation structure was made by the then Western transmission system operator Eltra with the so called ‘System 21’ programme, in the course of which various projects were coordinated to develop a new conceptual framework for a more decentralised system (Eltra 2003: 19-20; interviews Nielsen, Bach).

The set-up of System 21 was very much influenced by the way the system operator Eltra had implemented liberalisation, for which it could rely on the standard model and experiences in other countries. As for system transformation, however it turned out that this was more complicated because there were no blueprints and it was less clear what would work and what would not. It was therefore decided that System 21 should be halted and a pilot project initiated.

Cell Controller Pilot Project

This led to the cell controller pilot project, which was initiated by Eltra, the former transmission system operator in western Denmark and is now run by its successor Energinet.dk, in cooperation with the distribution system operator Syd Energi, where the pilot project is being implemented (Lund et al. 2006). While System 21 was mainly conceptual, the cell project acknowledges that new concepts need to be developed and tested in practice, i.e. in a real distribution network (interview Bach). Besides providing a system that can accommodate more DG, an important objective for Energinet.dk is to break the monopoly of the big generators in the ancillary service market by enabling DG to provide such services through the cell controller (interview Lund)

The Cell project is about developing a new system and control architecture based on distribution network cells. Cells are distribution networks that are enabled to operate independently from the overall system. Starting in 2006, the Cell Controller hardware and software have been installed and tested in a full 60/10 kV distribution system. The system comprises 49 wind turbines totalling 39 MW, 5 CHP plants totalling 38 MW and has a maximum observed load of 60 MW. According to Energinet.dk this distribution system is the first utility scale Smart Grid in operation world wide (interview Lund). The final full scale test trials will be conducted in fall 2010 and spring 2011.

With this concept, the DSOs are to have a greater opportunity to monitor and actively control their network and will take over responsibilities from the transmission system. Decentralisation of generation thus leads to a partial decentralisation of control. A key driver of the cell concept is to enable the cells to disconnect from the transmission system and run in fully automated island operation if an imminent system black-out is detected. Furthermore the new control infrastructure will also enable the cell to fulfil a number of control and operational functions in normal operation by utilising a novel system design (interview Lund).

EcoGrid

Finally, another crucial project is the EcoGrid project, which started in 2007[9] with a pre-study. The full-scale project will most likely commence in January 2011 as an EU-funded project. This project aims at providing the system which can handle the energy policy objective to cover 50% of demand with wind power in 2025. The objective is more encompassing compared to the Cell Controller Pilot Project which is a pure technical project to prove the concept. EcoGrid is expected to explore a number of different

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9 http://www.Energinet.dk/en/menu/R+and+D/EcoGrid/EcoGrid.dk.htm, last accessed on 18 February 2009

system solutions, including the full Cell Controller concept (Energinet.dk 2007b: 46-47). Moreover, it is planned that EcoGrid does not just look at the technical options, but also explores how the transactions between the generation and demand in the cell can be optimised. To this end the project aims at establishing near real-time markets within the cell, including new markets for different ancillary services.

9.2 Governance of DG connection

Having looked at the structure of the electricity industry in Denmark and liberalisation as well as the innovation and system transformation that has been triggered by the high share of DG, the analysis now continues by examining the *governance* of DG connection and system transformation. This section investigates how DG *connection* has been dealt with in Denmark and what the role of the standard model of network regulation was in this process. The governance mechanisms to deal with system innovation and transformation, which is now the dominant issue in Denmark, are presented in section 9.3.

9.2.1 The standard model of network regulation in Denmark

As described in the previous section, the standard model of liberalisation has not left out Denmark on its way around the world. This includes the standard model of economic regulation of the network monopolies. Denmark has set up both an independent regulator (section 9.2.1.1) and has been shifting from cost-based to price-based regulation (section 9.2.1.2). At least in terms of the general regulatory model, Denmark has taken into account the UK example (interview Aarberg).

Nevertheless, looking at the role of the standard model with regard to DG (section 9.2.1.3), the situation is very different from the one found in the UK. It is not that the standard model of network regulation does not have any impact on DG. However, while in the UK the regulator plays a central role in the DG arena, the regulator in Denmark is almost invisible when it comes to dealing with the infrastructure challenges of DG. The main factors explaining the Danish situation are presented in section 9.2.2.

9.2.1.1 The role and objectives of regulators

While in the UK Ofgem is responsible for both the economic regulation of networks as well as the implementation of some other energy policies, these tasks are clearly split between two agencies in Denmark, namely DEA, the Danish Energy Agency (Energistyrelsen) and DERA, the Danish Regulatory Agency (Energitilsynet). As will be explained in section 9.3.3.4, the Danish transmission system operator has a regulatory function, too. This was the case to some extent even before the state-owned TSO Energinet.dk was set up, as the cost-socialisation mechanism described in section 9.2.2.1 shows.

Danish Energy Agency

In 1976 the Danish Energy Agency (DEA) was set up to implement Denmark's first energy plan, i.e. well before liberalisation was introduced. It *"continues to be the key institution for development and implementation of energy legislation and policy"* (IEA 2002b: 25; IEA 2002b). It is an agency within the energy department and is responsible for energy policy formulation and implementation. It administers Danish energy legislation, including the Energy Supply Act. An important instrument of policy implementation has been agreements with the industry, notably with the system operators (OECD 1999: 25). The agency carries out functions that in other countries are often split between different departments and agencies. Importantly, the agency is in charge of a number of functions which in other countries often lie within the remit of the independent energy regulator, including licensing, setting rules on environmentally benign electricity production and defining public service obligations. This means that key regulatory powers with regard to renewables and CHP and their network integration are not delegated to the independent regulator DERA (OECD 1999: 39; Owen 2007: 74).

Danish Energy Regulatory Agency

While the DEA is an organisation that was set up well before liberalisation, the Danish Energy Regulatory Agency is a much more recent institution that began its activities in 2000 as part of the Danish effort to introduce the standard model of electricity liberalisation. It is set up as an independent body not subject to direct intervention by the energy department (DERA 2002b: 11) – a criterion that could not have been fulfilled by the DEA. Its main task is to regulate the monopoly companies in the energy sector, including electricity transmission and distribution, gas and district heating.

As explained above, the DEA has kept responsibility for a broad range of issues and consequently DERA's task is very much confined to economic regulation of monopolistic activities, whereas *"key decisions – e.g. on connection rules and transmission issues for offshore wind tend to be taken by the DEA"*, according to Owen (2006a: 74). The OECD (1999: 39), in its effort to reduce political intervention in liberalised electricity markets, even diagnosed that the scope of independent regulation is too narrow and that a *"greater reliance on independent regulation could help reduce regulatory barriers, promote entry and accelerate the development of competition in the Danish electricity supply industry"*. DERA has also very limited staff resources and hence less capacity to understand technical issues (interviews Ackermann, Styrbro).

9.2.1.2 From cost-based to price-based regulation

As in most countries, the Danish pre-liberalisation regulatory model, implemented by a Price Commission, was cost-based and applied to the overall end-user price (Grohnheit, Olsen 2001: 148). The allowed rate-of return was very restricted in this system (Groenli 2001).

In 2000, when the economic regulator DERA was set up, network operators became separate companies and cost-based regulation was to be replaced by price-based regulation to give network companies an efficiency incentive – *"in line with "best practices" for network regulation increasingly applied around the world"* (OECD 1999: 37). The transmission system operators – Elkraft System in the east and Eltra in the west of the country, now merged into Energinet.dk – who are responsible for security of supply and the coordination of the overall electricity system continue to be subject to a cost-based regime (DERA 2002b: 24; DERA 2002a: 15). DERA started to regulate the network tariffs through a revenue cap model with four year regulatory periods (Abildgaard et al. 2003: 15; Kinnunen 2003). The revenue cap was supposed to be based on a benchmarking of network companies.

However, the implementation of price-based regulation that was planned for all network companies except for the transmission system operators proved more difficult than expected and they were significant teething problems that delayed the process. A main reason for this has been the “capital issue” mentioned above (section 9.1.2). It has been a major task for DERA to determine the companies’ capital base (DERA 2005b).

The agreement that led to the nationalisation of Energinet.dk also stipulated that the network tariffs would be frozen at 2004 levels until 2008 (DERA 2005a; interview Aaberg). This meant that companies could not increase their tariffs, but at the same time there was no requirement for them to cut their costs. Network companies were effectively given time to become normal profit-oriented companies and increase their return on capital from the previously ‘sub-normal’ levels. This is a prerequisite for incentive regulation to work – and for including DG incentives into this framework (Abildgaard et al. 2003). While tariffs were frozen, DERA started preparing for a new system with a benchmarking exercise carried out in 2007 which reintroduced efficiency requirements in the setting of the revenue cap.

9.2.1.3 Network regulation and DG

Against the background of the general development of network regulation in Denmark, a key question for this analysis is the role of DG in this framework. First of all, this concerns any impacts of incentive regulation on DG connections, and second any attempts to explicitly integrate DG into this framework.

In terms of the effects of network regulation on DG, this does not seem to be an important issue in Denmark, certainly not compared to the UK. I have hardly found any publications, be it scientific or documents in the policy or regulatory debate, that mention any negative impacts of regulation on DG. According to Abildgaard et al. (2003: 27), *"a first assessment of the impact suggests that the revenue cap will be of very little importance in relation to DG and other network operation"*.

A number of issues have received some attention, including the relatively low rate of return that provides a disincentive for grid extensions (Tech-wise 2002: 27), the administrative costs resulting from prioritised feed-in from DG and renewables that were not included in the revenue cap (Abildgaard et al. 2003: 27) as well as the fact that the costs for communication systems needed to control DG are not considered as an investment, but as operating costs, which make 'investments' less attractive (interview Bach). Overall, however, network regulation is not considered as an important impediment to DG development. In the interviews with the DERA, this was not considered to be an important issue, either (interviews Aaberg, Ulrichsen).

In line with this observation and in contrast to the UK, there are no specific mechanisms for DG connection within network regulation. This is the case in spite of there having been separate mechanisms geared towards specific objectives in other areas of Danish regulation, e.g. direct cost pass-throughs that have been applied for losses and costs resulting from energy saving measures (Abildgaard et al. 2003: 27). As for the 2007-2008 benchmarking process that is to reintroduce efficiency requirements the interview with regulator has confirmed that *"DG has not been mentioned at all"* (interview Ulrichsen) and DERA *"seems to have only a marginal role in this area"* (interview Hoffmann).

9.2.2 Explaining the marginal role of the standard model

Looking at the Danish case, it is striking that the share of DG is much higher than in the UK, but at the same the UK discussion about how to integrate DG into the standard model of network regulation, which has led to the UK hybrid incentive, has not occurred in Denmark. The standard model has been introduced, but has not been adapted to DG. How can this be explained?

Firstly, the Danish regulator DERA has a relatively narrow role and limited resources, partly because it has not replaced the previous regulatory structure, but has been "*slotted into a long established framework for sustainable energy*" (Owen 2006a: 74), including DEA and the bottom-up ownership structure that has led to a degree of self-governance within the sector. While DEA is in charge of general energy policy development and implementation, DERA focuses on the economic regulation of networks. Due to this limited remit, it is not an obvious task for DERA to take on the regulation of DG connection and network transformation and deal with these issues within the standard model.

Secondly, this has been further complicated by the fact that the introduction of the standard model proved more difficult than expected due to the so-called "capital issue". As a consequence, the fully-fledged introduction of the standard model, including benchmarking between companies, has been delayed. In the further process, DG related network costs may well re-emerge as a regulatory issue.

Thirdly, while DG emerged as an issue in the UK when the standard model of network regulation was well established, it occurred the other way round in Denmark. When the liberalisation process began, Denmark already had a very large share of DG. It is not that the network companies' obligation to connect DG did not cause any conflicts or did not have to face the resistance of network companies (interview Bach). But these problems and additional costs of DG were dealt with before the standard model was introduced. It certainly helped that distribution companies were not profit-oriented and were owned by consumer and farming cooperatives that also had a stake in wind energy development themselves. However, a decisive factor has been the cost socialisation mechanism, which will be analysed in more detail in the following section.

9.2.2.1 Cost-sharing mechanism

The key instrument in Denmark for dealing with the costs of DG connections has been the cost sharing or socialisation of the network costs of DG, which this section analyses (Nielsen 2003: 49-55; Panzer 2008: 50-54; interviews Nielsen, Jensen, Ackermann, Bach).

Description

With this mechanism, the network costs that result from DG, including renewables and CHP plants, are not borne by the individual network company that connects DG to its network, but companies get reimbursed for these costs and the costs are then distributed among all consumers via the network companies. Network companies are not reimbursed for their real costs, but get paid the costs calculated on the basis of a cost model.

Cost socialisation was first introduced back in the 1980s, when the network costs of DG started to become relevant. The main rationale was that it was considered unfair to burden some network companies and their customers with high costs that happen to be located in areas with high potential for renewables. Many of the network companies were also very small and would not have been able to carry these additional costs that go beyond their initial task to supply customers with electricity. It was clear that such an uneven distribution of the costs of national objectives to promote environmental-friendly electricity generation would not have been acceptable for the affected regions (interview Jensen).

Initially the mechanism was started voluntarily by the companies themselves together with ELFOR, the former Danish association of electricity distributors. The administration was taken over by the transmission system operator, which is now Energinet.dk, subject to public auditing. A socialisation committee was set up, whereby the transmission system operator and delegates from the distribution companies jointly develop and adjust the model. According to Energinet.dk, this cooperative approach between Energinet.dk and the distribution companies is essential for the scheme to function and is also a reason for why the scheme was not taken over by the regulator. This has also been confirmed by DERA (interview Aaberg).

What is indeed remarkable is that the regulatory authority is not involved in operating this mechanism. It was started well before the regulator was set up, and even now the regulator DERA is only informed by Energinet.dk of any changes in the socialisation model and is given the opportunity to comment on it. This is necessary not the least to make sure that this scheme does not interfere with its own regulation of network costs and the treatment of costs outside the 'normal' regulatory mechanism is not misused, e.g. to charge certain costs twice.

According to both Energinet.dk and DERA, there have not been any major issues so far. As the cost socialisation mechanism is essentially price-based it can easily co-exist with the general price-based regulation, because otherwise companies would have an incentive to shift as many costs as possible into the socialisation mechanism.

When the mechanism was first set up, the real project costs were refunded and socialised, similar to cost-based regulation. The administration of this system was cumbersome and led to high costs (Nielsen 2003: 17). It was also difficult to separate the grid costs induced by renewables and CHP and other costs resulting from the 'normal' supply function of distribution network (interview Jensen).

In the late 1990s it was therefore decided, again by the companies involved, to change the socialisation scheme from refunding the actual costs to estimating the costs based on a cost model. At around the same time, the voluntary mechanism was turned into a legally defined public service obligation for the system operator (§ 8,1 and § 28,2 of the Danish Act on Electricity Supply). This was done without changing the way it works.

With the introduction of the cost model, there was no longer any need to survey the real costs for each individual project. Besides reducing the administrative costs, another reason for introducing the cost model was to enable network companies to plan their grid in a more flexible and forward-looking way, as they are not constrained by the requirements of any costs statements to be made to Energinet.dk. At the same time, however, this change increases their risk.

The model was initially calibrated with the help of 156 real cases. At first, the model was rather simple and was only based on the capacity connected, similar to the UK hybrid incentive. Over time, it has become more elaborate, taking into account a larger number of cost drivers. Increasing the number of cost drivers tends to make the cost model more accurate and reduces the risk again for the companies where DG is connected, thereby reducing the need for cost-based elements (see section 5.3). According to Energinet.dk, the real costs are “close to the model” (interview Jensen); according to Nielsen (2003:17) the accuracy of this model is +/- 20%.

When costs are exceptionally high, this can be treated outside the cost model as a special case, but unlike in the UK, where costs above a certain level have to be borne by the plant developer, these exceptionally high costs are still socialised.

Analysis

The Danish cost socialisation approach was introduced well before liberalisation, but has now become part of the Danish electricity market regime. It seems unlikely that this approach ‘outside the standard model’ will be replaced by a mechanism inside the standard model, similar to the UK hybrid incentive.

The Danish cost sharing mechanisms and the standard model of network regulation exhibit both similarities as well as highly relevant differences. In terms of similarities, the fact that the network companies are reimbursed not for their real costs, but only for the costs calculated by a model makes the model very similar to price-based regulation and companies in principle get an incentive to become more efficient.

However, although the shift to this approach coincides with electricity market liberalisation, it was not set up to provide efficiency incentive to companies, but to make the operation of the cost-socialisation mechanism itself more efficient and workable. Although in practice it does give companies an efficiency incentive, especially now that Danish companies have generally become more profit-oriented, it would be misleading to associate the development from a cost-based approach to a generic cost model with the overall shift from cost-based to price-based regulation, as proposed by the standard model. The Danish approach is clearly a mechanism outside the standard model.

This is due to important differences between incentive regulation and the Danish model. Firstly, as the costs of DG are dealt with outside the standard model, there is a clear distinction between making the system and individual companies more efficient on the one hand (which is DERA's task) and dealing with the additional costs of DG and increasing the efficiency of this additional task on the other hand. This distinction is reinforced by the fact that the Danish approach was not developed by the network regulator. And even now that DERA has been established to carry out the economic regulation of networks, cost socialisation is still a separate mechanism run by the system operator Energinet.dk.

Secondly, and this is strongly related to the first point, the standard model and the discussion between cost- and price-based regulation are mainly about the distribution of costs between a single network company and its customers. In Denmark, however, distributed generation is not seen as a property of an individual distribution network, but rather as a property of the system as a whole, driven by national policy targets. From this point of view it would seem inappropriate to increase the efficiency of an individual network by not connecting DG to that specific network. Thus, the Danish approach takes into account the different target groups as described in section 5.2.1.2.

The socialisation of network costs goes a long way to explain why – unlike in the UK – the network costs of DG have not been a major issue in Denmark and according to Tech-wise (2002: 32; 2002: 32) *"the incentive [for the network companies] to avoid grid connections of distributed generation is thereby dampened"*. As this mechanism was introduced before liberalisation and network regulation were introduced, there was no need to implement mechanisms to deal with DG connection within the standard model of liberalisation and regulation.

9.3 Governance of Innovation and System Transformation

The previous section has shown that the network regulator and the standard model of network regulation have only been a supporting actor in the governance of DG connection. This represents a stark difference to the results of the UK case study. Against this background, this section analyses the governance of innovation and transformation, which has become a pressing issue in Denmark due to the high share of DG.

9.3.1 The role of network regulation

The initial effects of liberalisation on R&D in Denmark are similar to those in the UK and in line with the generic analysis in chapter 2. There has been a decline in R&D spending and a stronger focus on near-term commercial and operational issues (IEA 2002b: 121). How has it been possible in this context to undertake the R&D efforts presented in section 9.1.4?

Unlike the UK regulator, the Danish regulator is not active in the process of DG integration and network transformation and seems rather invisible for many stakeholders (interviews Ackermann, Nielsen, Holstroem). For example Ackermann who contributes to the cell controller project and is well aware of regulatory issues (Ackermann 2004) stated that he had not noticed any involvement of the regulator during his work on the cell project – a statement that is difficult to imagine with regard to the UK regulator OFGEM.

The interviews with the regulator have confirmed that there are no specific innovation mechanisms within the standard model (interviews Aaberg, Ulrichsen), similar to those discussed chapter 6 and implemented in the UK, nor does the regulator play a moderating role in the transformation process. The comparison with the UK is all the more interesting as network transformation in Denmark is already happening 'on the ground' while in the UK it is still mainly 'paperwork'.

Again, this can partly be explained by the fact that the standard model is in an early development phase and its introduction has been impeded by attempts to solve the 'capital issue' (see section 9.2). Although the regulator officially should also support the structural development in the energy sector (DERA 2005b: 2), it has been occupied with it task to resolve the 'capital issue', which has involved long negotiations with the companies. DERA itself seems to have been unsatisfied with its role and pointed out the need to clarify its management basis (DERA 2005b: 6).

Moreover, the projects outlined above represent pilot projects in selected networks, rather than innovation mechanisms across all distribution networks. Once these pilot projects are completed and the results need to be implemented in different networks, regulatory support will become more relevant.

Nevertheless, as with the governance of DG connection analysed above, the weak involvement of the regulator in the innovation and transformation process poses the question of which governance mechanisms are relevant for the developments described in section 9.1.4.

9.3.2 Public Service obligation and the governance of innovation

In Denmark there are no instruments within the standard model that are specifically geared towards promoting innovation. Instead, there are separate funding mechanisms for RD&D that are financed by electricity consumers and network users. They complement tax-financed government RD&D programmes, like those funded by Danish Council for Strategic Research. Although there was an initial decline in RD&D as mentioned in the previous section, according to the IEA (2006: 167) Denmark has successfully countered the problem that liberalisation tends to entail a reduction in utility RD&D.

The Danish Electricity Supply Act introduces public service obligations (PSO), especially for the transmission system operator Energinet.dk. A PSO is a compulsory service for companies to satisfy public interests (cf. article 3 of the EU Directive 2003/54/EC). § 8 of the Electricity Supply Act stipulates that *“every electricity consumer in Denmark shall bear a relative proportion of the collective electricity-supply enterprises' necessary costs incurred in carrying out the latter’s public service obligations”*. Similar to the cost-sharing for connection costs described in 9.2.2.1, RD&D costs are thus distributed between all electricity consumers, rather than paid for by consumers in individual networks as is the case in the UK.

The Danish PSOs cover a broad range of issues. This includes funding for electricity generation from renewables as well as support for energy efficiency measures. PSOs are also a key funding mechanism for RD&D and there are several PSO-based research programmes.

The system operator Energinet.dk is in charge of providing PSO-based funding for third-party RD&D projects. According to § 29 of the Danish Electricity Supply Act, *“the system operator shall ensure that any research, development and demonstration projects necessary for using environmentally friendly electricity-producing technologies are carried out, including development of an environmentally friendly and secure electricity system.”* One important programme administered by Energinet.dk is the ForskEL programme, which is to support energy policy objectives. The focus areas need to be approved by the Danish Minister for Climate and Energy, yet it is Energinet.dk’s task to make a proposal (Energinet.dk 2009: 5). The programme has focused on RD&D in environmentally-friendly electricity generation technologies. According to Energinet.dk’s Strategy 2010+ for the ForskEL programme, a new focus area is smart grids and thus the development of the electricity system, rather than individual generation technologies (ibid.: 12).

In addition to the PSO-based RD&D programmes that are administered by Energinet.dk, the system operator itself is obliged to carry out RD&D activities that are considered necessary to enable the electricity transmission and distribution system to accommodate the changing generation structure (§ 28 of the above Electricity Supply Act). For this purpose it uses its internal RD&D programme ForskIN. For example, the cell project (see section 9.1.4) has been funded under this programme (Energinet.dk 2009: 11).

Although ForskEL and ForskIN have a different status, there is a close link between them. The way in which the EcoGrid project presented in section 9.1.4 has been set up is a case in point (Energinet.dk 2007a: 23). Based on the new focus of ForskEL, Energinet provided funding for projects dealing with electricity system control in the 2007 ForskEL call. Rather than selecting individual projects for funding, the system operator decided to *"unite forces"* (interview Bach), i.e. to combine various project applications and to set up a more long-term, large scale RD&D project.

According to Bach (interview), who led Energinet.dk's System 21 project (see section 9.1.4) one of the results of this project was that system transformation was not just a question of implementing established concepts. Rather, RD&D was required, using the capacities of both research institutes and industry. This is what led to setting up the comprehensive EcoGrid project.

The first phase of EcoGrid that was mainly exploratory was funded under ForskEL. It produced among other things a list of research priorities. For the second phase it was originally planned to make use of Energinet.dk's internal ForskIN resources, but EcoGrid has now been turned into an EU-funded project. With this combination of different research programmes and project proposals, it became possible for Energinet.dk together with a broad range of research partners to launch a programme that can link up different RD&D proposals and innovation activities to tackle issues of system innovation and transformation.

EcoGrid is not just about funding or incentives for individual innovations. Rather, it resembles the coordination of research activities discussed in chapter 7 and the strategic niche management approach presented in section 2.2, although there are no such explicit concepts in the Danish context to justify the approach to research funding. In the case of EcoGrid, the Danish research programmes do not just provide funding, but the funding framework is capable of setting up a purpose-built niche that combines different actors as well as technical and market aspects. Furthermore, it is based on a joint screening of options (EcoGrid Phase I) and links up different individual research proposals in different areas of research to develop a new 'configuration that works' (see chapter 2.2). It is difficult to imagine such a process in a regime where research funding is mainly provided via the standard model.

The Danish approach is important in the context of this thesis as it shows that real systems do not just rely on the mechanisms proposed by the standard model, but also apply mechanisms that are similar to the transformation mechanisms discussed in chapter 2.2, especially to tackle issues of system innovation and transformation. The example also demonstrates the central role of Energinet.dk in RD&D in coordinating various research activities. It can be regarded as the 'focal point' that has also come to be seen as important in the UK (see section 8.4.2).

In summary, the Danish research funding is not just located outside the standard model, but exhibits a number of differences to the regulatory innovation incentives discussed in chapter 6:

- Funding is provided through the PSO tariff paid for by all electricity consumers, rather than network customers connected to the DSO that happen to be particularly active in RD&D.

- Research priorities are coordinated with energy policy objectives. Under the standard model, this is possible too, but more difficult to achieve.

- One of the peculiarities of innovation funding in Denmark is that the system operator Energinet.dk plays a central role. Energinet.dk has a legal obligation to ensure that RD&D is carried out to enable the system to accommodate DG and renewables. It administers the research programme ForskEL and carries out its own research through the ForskIN programme.

- The EcoGrid example shows that Energinet.dk uses these resources to strategically select and design RD&D projects to carry out research on system innovation and transformation together with other stakeholders. This contributes to the coordination of individual research activities that was discussed in chapter 7 and that is difficult to achieve with economic incentives for individual companies only.

The central role of Energinet.dk is not restricted to research funding. Therefore this actor will be analysed in more detail in the following section.

9.3.3 The role of Energinet.dk

As the Danish case study has shown so far, the standard model was introduced, but does not play a significant role in DG integration and network innovation. Moreover, the presentation of two key mechanisms – the cost-sharing for connection costs and the PSO-based research funding – as well as the system transformation projects presented in section 9.1.4 have indicated the key role of the system operator Energinet.dk. This has been confirmed by interviews both inside and outside of the system operator (interviews Bach, Holstroem). This section analyses this key actor in some detail: how it was set up as a state-owned company, its relationship with the government and the regulator and its own ‘regulatory powers’.

9.3.3.1 How Energinet.dk was set up

In 2005 the Act on Energinet Danmark established Energinet.dk as a public corporation. The legislation was based on an agreement of March 29 2004 between all major political parties as well as the government and the electricity association Elfor. Energinet.dk was founded by merging Eltra, Elkraft System, Elkraft Transmission and Gastra. The new company is both owner of the 400 kV grid and system operator of the Danish power and gas transmission system. While the previous transmission system operators were owned by regional grid companies which in turn were owned by local authorities and consumer co-operatives (see section 9.1.1), the new transmission system operator has been transferred into direct state-ownership. It is completely unbundled from generation and supply.

Nationalisation is the opposite of what the standard model proposes, namely privatisation of energy companies that used to be state-owned. The role of the state should be limited to regulatory functions. While other countries, including the UK, have privatised their electricity industry, Denmark has nationalised an important part of the industry that was not controlled by the state before liberalisation, or only partly and indirectly via the municipalities.

It is tempting to interpret the nationalisation of the system operator as an attempt to gain direct influence on the development of the sector, not the least in order to guide the transformation of the electricity system. In its 2004 energy policy statement (DEA 2004: 5), the Danish Minister for Economic and Business Affairs states that "*the objective [of nationalisation] is to secure efficient operation and expansion of the overall infrastructure*".

However, the evidence suggests that the decision to turn the system operator into a state-owned company was not primarily influenced by future energy policy goals in general and objectives to develop the infrastructure that is run by Energinet.dk in particular. The government had initially no active interest in taking over the system operator, let alone using it as an active instrument of energy policy-making. Rather, nationalisation was triggered by the remnants of the pre-liberalisation structure that had hampered liberalisation. The main interest of the state was not to gain control over the system operator, but to disentangle the traditional sector structure in order to enable sector liberalisation. According to Styrbro (interview) the government would have preferred a completely independent company that is not owned by the state either.

Nationalisation was a means to solve the so-called "capital issue" mentioned in section 9.1.2. (DERA 2005b: 5). The fact that the state ended up owning the system operator is more of a by-product of this process. The problem that the government tried to solve resulted from the traditional consumer profit system according to which companies had to pay back any profits that were not re-invested to consumers. After liberalisation, when the regulator started evaluating the companies' capital base and some companies were to be sold, this essentially led to a conflict as to how much of the distribution companies' capital base was owned by consumers and had to be transferred to them ("tied-up capital"), and how much the companies could dispose of themselves ("free capital"). Given the tight linkages between energy companies and consumers on the one hand and between the companies themselves, nationalisation of the system operator came to be seen as a prerequisite for a liberalised market and further restructuring of the industry.

Nationalisation is described as the result of a 'horse trade' to solve the capital problem (interviews Styrbro, Hanghøj), The distribution companies gave up their ownership in the transmission system operator and transferred it to the state. In return, a number of obligations were lifted from them and they got unrestricted access to their capital, including 20 to 25 billion DKK (ca. three billion Euros) of capital that was previously tied up. However, as a consequence the electricity consumers lost out, because there was no longer an option for profit-sharing between consumers and the companies (interview Styrbro). Before the nationalisation agreement was struck, the government regarded the tied-up capital in the companies that result from the previous cost-plus regime as a loan to the companies that should be paid back to consumers through reductions in grid tariffs (DEA 2003: 7).

9.3.3.2 Relationship with energy policy

As described in the previous section, the main driver for the nationalisation of Energinet.dk was not to use the company as an instrument for implementing energy policy objectives. Nevertheless, the question remains of the extent to which the company is now used by the government as such an instrument.

Energinet.dk is not an ordinary company where the state happens to be the only shareholder. It is owned by the Ministry of Climate and Energy on behalf of the Danish state. According to the regulator DERA (2008: 55), Energinet.dk's system planning is guided by political goals, especially integrating wind energy of up to 50% of electricity consumption. All investment plans must be reported to the minister and projects of a certain size require the minister's approval. As explained in the section on RD&D, the government also needs to approve the focus areas of the RD&D funding programmes.

Importantly, section 13 of the Act on Energinet.dk stipulates that *"Energinet Danmark's profits may be carried back to the respective consumer groups"*, but *"Energinet Danmark shall not be entitled to distribute any profit or equity through dividend distribution or in any other way to the State"*. As the government cannot use Energinet.dk to generate income for the state budget, it is not faced with the trade-off between increasing the profitability of Energinet.dk and using it to support its energy policy objectives with additional costs for Energinet.dk.

Energinet.dk's statutory obligations are an important driver for its activities. It has an obligation to promote environmentally-friendly electricity generation (Energinet.dk 2010: 3). Moreover, the company is in charge of maintaining overall security of supply, developing the transmission infrastructure and carrying out coherent and holistic planning. As the new generation structure has potentially a major impact on security of supply, this is regarded as a main reason for Energinet.dk's activites in the area of system transformation (interviews Holstroem, Bach, Nielsen).

According to Scott (2007: 22), *"political influence on the TSO is strong and policy finds its way into the objectives and obligations of the TSO in developing and operating the transmission system to promote RE [renewables], and in funding research and development of RE through the Public Service Obligation"*.

However, within this general energy policy framework, Energinet.dk is a main driver for the work on system transformation taking place. This means that the government sets ambitious political targets, but leaves it up to the system operator to provide the necessary system. System transformation emerged as an issue within Energinet.dk and its predecessor Eltra, rather than within the government. This is the picture that emerges from the interviews with Energinet.dk and other stakeholders, as well as the fact that it was not possible to arrange an interview for this thesis with the government or its energy agency DEA on system transformation. For example, Bach pointed out in his interview that the Danish government set an ambitious renewables target (see 9.3.4.1), but did not seem to address the infrastructure requirements this entails. According to Ackermann (interview), the system operator's central role in this process has been strengthened through its more proactive, forward-looking corporate culture that has resulted from the creation of Energinet.dk.

9.3.3.3 Regulation of Energinet.dk

The tariffs of state-owned Energinet.dk are regulated by DERA. When Energinet.dk was set up, it was initially planned to regulate the company's tariffs based on a price-based revenue-cap scheme (Ministry of Economic and Business Affairs 2004), similar to other network operators. However, as mentioned in section 9.2.1.2, this has not been implemented. In contrast to the other network operators, the system operator is still not subject to price-based regulation, but continues to be regulated under a cost-based regime.

Maintaining a cost-plus regime for Energinet.dk rather than switching to a price-based regime as proposed by the standard model is related to its status as a not-for-profit company. Price-based regulation is based on the companies' objective to maximise their profits and provides an efficiency incentive by allowing them to keep a share of the additional profit resulting from efficiency gains. While the regulator can still set an upper price limit for Energinet.dk, the resulting incentives for the Danish system operator would be weaker. This is because Energinet.dk can only maintain the value of its assets in 2005 when it was set up as the state owned TSO (DERA 2008: 17). It cannot transfer any profits to the state, either.

What does this cost-based regulatory framework imply for DG integration and network innovation? First of all, it is important to remember that many costs are dealt with outside normal regulation, partly applying mechanisms with price-based elements (DG connection costs, see section 9.2.2.1, partly using mechanisms that are essentially cost-based (RD&D costs, see section 9.3.2).

As for other infrastructure development costs that Energinet.dk has to cover to react to the rising share of DG and renewables, a cost-based regime is generally amenable to these additional objectives in that it removes any cost risk from the DSO. As was shown in chapters 5 and 6, DG can indeed be a driver for the regulator to revert to cost-based elements, both to promote DG integration and network innovation.

The interviews have confirmed that cost-based regulation of the Danish system operator has had the effect that those within the company dealing with system innovation have not been confronted with any significant regulatory restrictions (interview Bach). The effects of cost-based regulation in the Danish context are also well expressed by the following quote by the former CEO of Eltra (interview Styrbro),

"We think it [wind power] is madness from our experience and from an engineering point of view, but we do not have any disincentives to deal with it. It costs more money, but if they want that, we can do it. The regulator has to accept the costs. Of course he does accept it. It is in the framework of what we are set up to do. (…) The regulator is not the one who is to look into it, he doesn't understand it technically. If I buy some cement factory in America, he probably says you cannot spend on that. But if we spend money on what we need to run the system and solve the problems we are charged to solve. There is therefore much more dynamism as compared to profit-oriented systems with incentive regulation."

This quote illustrates how cost-based regulation facilitates the integration of DG. A guarantee for the company that it can recover its costs is not sufficient for it to tackle new problems such as system transformation, as is illustrated by the relatively late start of this process in Denmark (see section 9.1.4). However, it does provide a solid basis. The quote also shows the importance of Energinet.dk's obligations that set the framework for Energinet.dk's activities (*"the framework of what we are set up to do"*). Usually even under a cost-based regime not all costs are eligible. Therefore, the effects of a cost-based regime critically depend on which costs the regulator actually accepts. It is therefore important to note that cost-based regulation and especially the acceptance of costs in Denmark is strongly related to overall energy policy objectives, rather than absolute efficiency objectives.

Thus, these obligations are an important driver for Energinet.dk, but they are also important in that they influence the acceptance of costs by the regulator. Energinet.dk's obligations thus represent an important interface between general energy policy objectives and the effects of network regulation on the company and help ensure consistency between energy policy and network regulation. This is also influenced by a moderate public pressure for aggressive, cost-reducing regulation and the high visibility of environmental issues on the public political agenda (Nemesys 2005: 18).

However, what is not addressed in the above quote is the efficiency of DG integration. The statement is based on a dichotomy between cost- and price-based regulation. It is clear that cost-based regulation removes any cost risk for the network operator that may result from DG connection and innovation, but it does not give any efficiency incentives and shifts all the risk to the network customers. However, chapters 5 and 6 have shown that specific mechanisms can be drawn up that mix price- and cost-based elements and which can thereby balance these different objectives and provide incentives for the efficient integration of DG.

Price-based regulation as an incentive for efficiency improvement by profit-oriented companies may not work quite as well for state-owned not-for-profit companies. However, the regulator still needs to deal with the question of acceptable cost levels. According to DERA (2008: 17), this has not been addressed yet in detail. The regulator considers applying an international benchmarking between Energinet.dk and TSOs in other countries. Based on the results, the regulator may not accept costs incurred by Energinet.dk, so that price-based elements come into play, even though DERA may not switch to 'incentive regulation' of Energinet.dk.

If benchmarking is applied, a critical question will be how the additional costs of Energinet.dk that result from the high share of DG and renewables are taken into account, especially given the lower share of these generators in other countries. This leads directly to the mechanisms discussed in chapter 5. However, this debate has not yet commenced in Denmark. In contrast to the typical standard model discussion, where cost-based elements are re-introduced into a system that has previously switched to price-based regulation, the Danish development starts from a cost-based regime and adds price-based elements to take into account the 'necessity of costs'.

9.3.3.4 The regulatory role of Energinet.dk

On the one hand, Energinet.dk's tariffs are regulated by DERA as described above. On the other hand, the company itself carries out regulatory tasks which in other countries are within the remit of the regulatory authority (DERA 2006: 5). In the interview with DERA (interview Aaberg), Energinet.dk's regulatory function is acknowledged as follows: "*As a speciality – and I don't think you will find that in so many places – the competence to make (…) further regulations (…) is delegated to Energinet.dk in Denmark"*.

This was the case before the company was nationalised, and as a state-owned company it has taken on further regulatory duties. Arguably, Energinet.dk is therefore more than a system operator owned by the state; it is part of the regulatory regime, together with DEA and DERA that have divided regulatory tasks between them. These regulatory functions are an important instrument for Energinet.dk to fulfil its obligations and shape the transformation of the electricity infrastructure.

Energinet.dk's tasks[10] include market regulations and it is supposed to contribute to organising the competitive energy market. The company is also in charge of the regulations pertaining to grid companies' public obligations and can require transmission grid operators to make specific investments and maintain the electricity grid (DERA 2006: 16). The mechanism to socialise the network costs of DG that was analysed in section 9.2.2.1 as well as the Public Service Obligation Mechanism described in section 9.3.2 are under the auspices of Energinet.dk, too.

9.3.3.5 Summary

Energinet.dk plays a key role in the governance of the Danish network infrastructure and its transformation to meet energy policy objectives. This is based on its role in RD&D funding, the way the company is regulated as well as its own regulatory powers. Thus, in Denmark governance of system transformation is not merely left to the standard model and the market, but there is also a strong element of top-down coordination. However, in an environment that is largely based on the standard model and in the face of system transformation, this top-down coordination cannot simply be based on vertical integration or hierarchical control, but is faced with a systemic uncertainty and a distributed control over system development. Therefore, the next section shows how long-term planning and actor coordination play an important role, too.

9.3.4 Governance mechanisms beyond economic incentives

The key research question of this thesis is whether the standard model of network regulation based on economic incentives can deal with DG integration and network transformation and how it can be complemented by additional governance mechanisms. The

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[10] http://www.Energinet.dk/en/menu/Market/Rules+and+regulations/Rules+and+regulations.htm, last

Danish case study has revealed that the standard model only plays a minor role in terms of network integration and system transformation. The regulator DERA has not been significantly involved, but the system operator is a key actor. Both DG connection and RD&D funding are managed outside network regulation.

Nevertheless, the question remains in the Danish context of whether other governance mechanisms can be observed on top of these external funding instruments, as proposed by the system transformation literature (see chapters 2.2 and 7.1). This final section provides a brief overview of long-term planning and approaches to improve anticipation of long-term system development (section 9.3.4.1) and actor cooperation (section 9.3.4.2) – two of the central themes of the system transformation literature. Similar to the UK case study, this does not represent a detailed analysis of these instruments and how they work in practice, but the objective is to show that such mechanisms are important in Denmark, too.

9.3.4.1 Long-term planning

Danish energy policy has a long-running tradition of policy-making based on long-term plans. According to Owen (2006a: 49) *"Denmark has been willing to undertake a degree of planning and imposition of rules in its energy sector that would seem unusual in many other countries"*.

accessed on 27 February 2009.

Already in the 1970s, the government invited a broad range of stakeholders to jointly draw up the “Energy Plan”. Negotiating these plans became a central arena for discussing energy policy visions. In the first plan issued in 1976 the main objective was the transition from oil to coal, nuclear power and renewables. In the following years this was replaced by a stronger focus on renewables; the second Energy Plan drawn up in 1981 set the target to build 60,000 wind turbines by 2000. Later plans put a stronger emphasis on creating a liberalised market, but still included environmental targets, too (van der Vleuten, Raven 2006b: 3745). In 2007 the government published *“A visionary Danish energy policy 2025”*. It set the target to double the share of renewables to cover 50 % of demand by 2025 (van der Vleuten, Raven 2006a).

While long-term plans have been used for some time to define political targets, due to the increasing system implications of these political targets long-term system planning has also become increasingly important for the system operator. For example, the Copenhagen Strategy on offshore wind power issued by the Danish Energy Authority (DEA) has called for overall energy policy planning to be complemented by long-term grid planning and has emphasised that *“any short-term solution should fit into a long term strategic vision”* (DEA 2005, 6). The Act on Energinet.dk (section 2) requires the company to base its activities on *“coherent and holistic planning”*. The quotations given in section 9.1.4 (no planned development, the industry started to realise too late that a system change is required, no one was thinking about the infrastructure) show that this was not done before.

After Energinet.dk was set up, the new company started building up the capacity to deal with the uncertainties of future system developments and established a separate department for planning and scenarios (interview Nielsen). According to the head of this department the objective is to convert the government energy strategy into concrete analysis (Vinther 2007). One way to achieve this is to move away from simply using cost-benefit analysis based on single forecasts, rely more on multiple scenario analysis and develop a common understanding of future development options (ibid.; Energinet.dk 2006: 9). This reflects some of the core features of the system transformation literature.

9.3.4.2 Actor cooperation

Energinet.dk has a central role in the Danish electricity sector, both as a system operator and due to its regulatory functions. Nevertheless, the situation is very different from a structure with a vertically integrated monopoly as the dominant actor that characterised many countries before liberalisation. Rather, Energinet.dk is a vertically unbundled transmission system operator and a large number of companies are active in the Danish electricity sector and the capacities to influence transformation are distributed among these actors (cf. section 7.1.) Besides Energinet.dk which is the overall system operator and runs the 400 kV network, there are a further nine regional transmission network operators running networks from 60 to 150 kV and some 90 companies operating local distribution networks (DERA 2009: 10-11).

Moreover, one of the main features of the network transformation taking place is that different network levels are to operate in a more integrated mode. The local distribution companies are to be included in the technical regulation of the system and take on system responsibilities from the transmission system operator. Thus, the transmission system operator has launched concepts that need to be implemented on the distribution level. However, Energinet.dk is not in a position to force any solutions or demonstration projects on the distribution companies, but requires their consent and trust (interview Ackermann).

Therefore, in order to implement these concepts, Energinet.dk needs to cooperate with these companies – which it has declared is a high priority (Energinet.dk 2006: 2). On the one hand, this fits the cooperative culture outlined in section 9.1 that has been emphasised as a key success factor (interview Nielsen). On the other hand, the interviews have revealed that historically, transmission and distribution systems tended to be operated separately. Distribution companies were quite independent and initially sceptical about any interference from the transmission company (interview Nielsen).

To facilitate cooperation between the transmission system operator and the distribution companies, a grid committee was established by Eltra, one of the predecessors of Energinet.dk. It is a joint committee between the transmission system operator and the distribution companies. Energinet.dk chairs the committee and provides a secretariat. According to Energinet.dk its task is to *"ensure economic operation and development of the entire power system, including coordination of the planning of the transmission grids and the distribution grids together with ensuring the implementation of the initiatives that are part of the overall development of the whole power system"* [11].

The first committee was started in 1980s. The then transmission system operator Eltra cooperated with the distribution companies on energy efficiency (interview Bach). There is also a socialisation committee to coordinate the cost-sharing mechanisms for DG-related network costs (see section 9.2.2.1). In terms of cooperation on grid issues there was initially a transmission committee made up of members from Eltra and the regional transmission companies.

A distribution committee was set up after 2002 when Eltra began to realise that the new generation structure necessitated corresponding infrastructure development (interview Nielsen, who was the chairman of the distribution committee; interview Bach). Again, this committee was chaired by Energinet.dk. The members from the distribution companies are appointed through DanskEnergi, the Danish association of energy companies. In the wake of the creation of Energinet.dk, there was a debate between Energinet.dk and DanskEnergi about their future roles. For Energinet.dk it was very important in this process to keep its coordinating role and remain in direct dialogue with the DSOs (interview Bach).

[11] www.Energinet.dk/en/menu/About+us/Cooperation/Grid+Committee+-+Electricity/Grid+Committee+electricity.htm, last accessed on 29 July 2010.

The grid committee has a variety of functions: agreeing on connection rules, discussion of future system concepts and coordination of demonstration projects. The grid committee confirms the strong role of Energinet.dk in the system transformation process, but also demonstrates the cooperative mechanisms that are used to promote system development.

On top of cooperation through the committee, demonstration projects like the Cell Controller project are a further cooperation mechanism which Energinet.dk uses to work with particularly progressive companies that are also interested in innovative network equipment paid for by Energinet.dk (interviews Lund, Ackermann). As explained in section 9.3.2, cooperation is also supported by the RD&D funding mechanism.

In summary, this brief analysis of governance mechanisms beyond economic incentives confirms the central role of Energinet.dk. Despite this, the company needs to cooperate with other actors in the system. In doing so, it cannot merely rely on economic mechanisms. The developments in Denmark show that economic mechanisms are complemented by instruments that support long-term planning and actor cooperation. While complementary mechanisms can partly build on established Danish policy approaches and cultural traditions, it is also interesting to observe that both long-term planning and cooperative mechanisms have become more explicitly institutionalised after system transformation has become an issue.

10 Comparative evaluation of the case studies

Following analysis of the governance of DG integration in the UK and Denmark, this final chapter of part III provides a comparative evaluation and summary of the two country case studies.

The UK has been a pioneer of the standard model with a relatively low share of DG. Denmark implemented the standard model only following the international wave of liberalisation, but is a leading country in terms of DG development and system transformation. Despite these different starting points, in both countries governance mechanisms for dealing with an increasing share of DG and the resulting network challenges have been elaborated.

One important difference between the two countries is that in the UK these governance mechanisms have been developed mainly within the standard model of network regulation, whereas in Denmark the standard model has only played a marginal role in the governance of DG integration. Although Denmark has followed the international liberalisation process and implemented the standard model in its national context, the infrastructure implications of DG have been managed mainly outside of the standard model. The key actor in Denmark is not the regulator, but the transmission system operator Energinet.dk, a state-owned company that fulfils a number of regulatory functions. This contrasts with the strong role which the UK regulator Ofgem has in this field.

A further difference between the two countries is the link between the DG mechanisms and the energy policy framework. In Denmark, the design of the DG mechanisms takes into account that DG is a political objective and the costs should therefore not be dealt with in individual networks where DG happens to be connected. In the UK, DG is also driven by energy policy objectives, but the regulatory mechanisms drawn up for DG follow the logic of the standard model, i.e. access of individual actors to the network and cost allocation within individual networks.

While the UK confirms the flexibility of the standard model in accommodating new objectives as analysed in the conceptual section, the Danish case indicates that new objectives do not need to be addressed via the standard model. Rather, the governance of DG can be established alongside the standard model. The interactions between the two regimes require further attention, especially as the Danish version of the standard model becomes fully implemented and tested over a longer time period.

In both countries, there are also non-economic mechanisms to coordinate the activities of different actors in the system and facilitate long-term system planning. This confirms the general argument made by the system transformation literature in general and the specific analysis for infrastructure governance carried out in chapter 7 in particular that such additional mechanisms are required. Again, in the UK these mechanisms emerged in the context of the standard model and can be interpreted as a process of redefining this model, whereas Denmark relies on other governance regimes.

In the following sections, the results of the two case studies will be compared in more detail based on the connection-integration-innovation-transformation heuristic that was introduced in section 4.1.5.

10.1 DG connection and integration

In the UK the additional network costs that result from DG are included in the incentive mechanism of the standard model via the DG hybrid incentive. The hybrid incentive combines cost- and price-based elements and seeks to combine connection incentives and incentives for cost reduction, based on the mechanisms outlined in chapter 5. The mechanism has been developed and implemented by the regulator.

The cost socialisation mechanism is the Danish equivalent to the UK hybrid incentive. This approach was introduced prior to liberalisation and goes a long way to explaining why – unlike in the UK – the network costs of DG have not been a major issue in the development of network regulation in Denmark. While the UK hybrid incentive has developed in the framework of the standard model, in Denmark network costs of DG are dealt with outside of network regulation. In contrast to the UK, the Danish instrument is not administered by the regulator, but by Energinet.dk in cooperation with the network companies.

In terms of the cost- and price-based mechanisms presented in chapter 5, the Danish solution can be characterised as a price-based approach in that companies are reimbursed according to a generic cost model. Rather than including an explicit cost-based element, the Danish model contains a differentiated set of cost drivers. This can be seen as an equivalent to an explicit cost-based element as explained in chapter 5.3.2.

As a consequence, there are no major differences between the two countries in terms of determining the costs to be reimbursed. However, in Denmark the rationale for introducing a price-based approach was mainly to simplify the implementation of the model, rather than to provide efficiency incentives in a competitive market environment. Nevertheless, the Danish example shows how incentive regulation mechanisms that are at the heart of the standard model can be applied outside of this model, too.

A key difference between the two approaches is not primarily the way in which the DSOs are reimbursed for their network costs. Rather, the two countries allocate the costs differently. In the UK, the DG developers in each network area have to pay for the incentive mechanism, whereas in Denmark these costs are socialised between all network customers across the country. While such a cost socialisation is not impossible within the standard model, it constitutes a less obvious approach since the standard model tends to focus on the regulation of individual networks. Moreover, in the UK cost socialisation would have been a significant departure from the regime that was in place before the hybrid incentive was introduced and that was based on deep connection charges that were supposed to reflect the network costs caused by DG connections.

As a consequence of these different methods, the mismatch set out in chapter 5 between internal objectives (increasing the efficiency of the individual network and reducing network tariffs) and external objectives (connecting more DG and providing the necessary network infrastructure) is resolved in different ways in the two countries. The Danish approach acknowledges that the infrastructure required to reach the political DG objective should not be paid for by network customers in areas with high DG potential. Rather, it should be financed by all consumers. The UK avoids burdening demand customers unequally with these costs, too. However, the cost allocation does not primarily reflect the political DG objective, but rather passes most of the costs to individual DG developers.

10.2 Network innovation

In terms of network innovation, the comparison between the two countries yields results similar to the previous section. In the UK, the regulator Ofgem has designed incentive mechanisms within its incentive regulation framework to promote network innovation. In line with the conceptual analysis, the UK approach mixes price-based and costs-based elements. The UK example demonstrates that innovation incentives can be included in the incentive mechanism, but also indicates that in practice these may be too weak to lead to a significant increase in RD&D by network companies.

In Denmark, innovations are funded through a PSO scheme that is separate from the standard model and the costs of which are added to the electricity tariffs for all electricity consumers. Thus, similar to the socialisation of DG connection costs, RD&D costs do not have to be paid for by network customers in one network area. While the UK partly applies price-based elements to innovation funding, the Danish approach relies on cost-based funding outside of the standard model.

The two approaches differ both in terms of how funding is raised and how the money is spent. While in the UK, each network company is incentivised individually to spend on RD&D, the Danish PSO funding mechanism administered by Energinet.dk together with the transmission system operator's own role in RD&D contains some of the elements suggested by system transformation literature. It enables the strategic selection of research projects and the setting up of niches that develop new system configurations; and it provides for a degree of coordination between different RD&D activities. This makes it possible to tackle issues of system innovation and transformation.

10.3 System Transformation

Finally, the case studies have confirmed that DG is not only about network connections or innovations in individual networks. In both countries a more comprehensive system transformation has moved onto the agenda; Denmark also has a leading role in developing a new infrastructure.

Once the focus shifts from connecting DG to the current system to transforming that system, it can be observed that non-market-based governance mechanisms become more important in both cases. This is despite significant differences between the governance regimes in the two countries. As with DG connection and network innovation, the UK discussion on system transformation has been dominated by the regulator Ofgem within the framework of the standard model. In Denmark, the standard model does not feature prominently in the governance of system transformation. Rather, the transmission system operator Energinet.dk is the single most important actor in promoting system transformation.

These non-market-based mechanisms are not limited to economic incentives to allocate the network costs of individual DG connections or innovations in individual networks, but address system transformation and the challenges identified by the system transformation literature, such as uncertainty about future system developments, the need to anticipate long-term effects and to coordinate different actors and their innovation activities.

These mechanisms go beyond the governance regime proposed by standard model. The proposals put forward by system transformation literature (see chapters 9.3 and 8.4) provided a useful template for analysing them. Neither of the countries has explicitly established a comprehensive system transformation regime such as, for example, the transition management approach in the Netherlands (see chapter 2.2). Nevertheless, in both countries individual mechanisms can be found. In both countries governance of transformation mechanisms emerge from existing governance regimes, i.e. the standard model regulator in the UK and the state-owned transmission system operator in Denmark.

In Denmark, transformation mechanisms include the coordination of RD&D funding and the strategic selection and design of projects to carry out research on system innovation and transformation, the institutionalisation of long-term planning by the system operator that complements long-term planning on a policy level as well as coordination of network operators on different network levels via the grid committees.

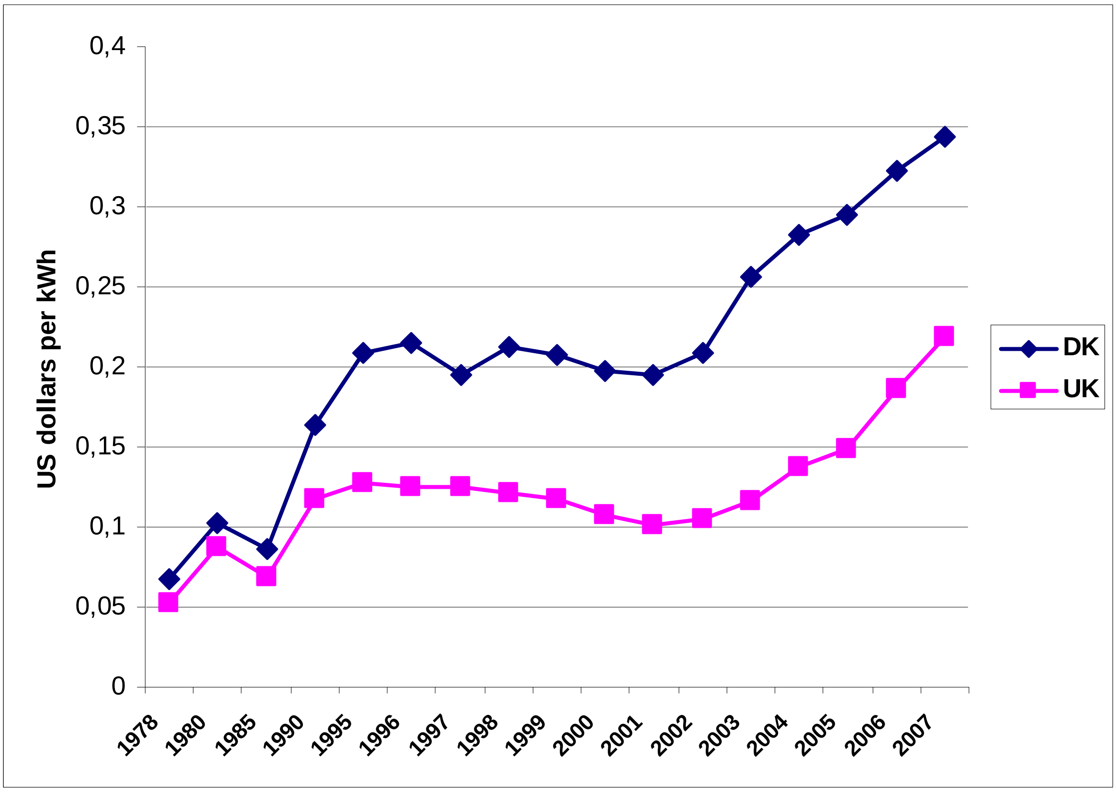
Even in the UK, where incentive mechanisms within the standard model to promote network connection and innovations have received much attention, new approaches are emerging. The Electricity Network Strategy Group in particular is an attempt to provide a new coordination mechanism to address network transformation with the help of long-term scenarios and 'horizon-scanning' of potential development options. There are also developments which extend the objectives of regulation beyond short-term efficiency and competition and can open the door for a broader understanding of network regulation.

10.4 Cost implications

The two country case studies have compared the governance regimes for network integration of DG in Denmark and the UK. One question that arises when comparing the two countries is how the two regimes have affected electricity prices.

The following graph shows the development of electricity prices for household customers in the two countries. It shows that Denmark has significantly higher prices than the UK.

Figure 18: Electricity prices for household customers in the UK and Denmark



Source: (IEA 2001a; IEA 2007a; IEA 2009b). Data are in US dollars at the time of publication. The data for the years 1978-1999 was published in 2001, the data for 2000 in 2009, for 2001 to 2005 in 2007 and for 2009

A first potential explanation for this price difference that comes to mind is the liberalisation of electricity markets that started earlier in the UK. However, the prices started to diverge already before the effects of the 1990 electricity liberalisation in the UK could become visible. Moreover, the price difference results from a price increase in Denmark rather than a decrease in the UK. Finally, the liberalisation in Denmark in the late 1990s has not led to a re-convergence of prices. A more plausible explanation is that the price increase in Denmark in the second half of the the 1980s was caused by the development of DG and especially CHP in Denmark in the 1980s (van der Vleuten, Raven 2006b).

Although there is no conclusive evidence, the comparison of electricity prices may indicate that the higher share of DG (renewables and CHP) in Denmark compared to the UK has led to higher electricity prices. This is in line with the analysis presented in section 3.1.2.3. Such an analyis is highly relevant for the evaluation of politcal objectives to increase the share of this type of electricity generation.

Assuming that the lower share of DG in the UK is one explanation for the lower prices, this can support the argument that DG should not be promoted as it increases costs and consequently electricity prices. Making this argument may neglect additional benefits of DG, like environmental ones, as well as the potential trade-off between short-term and long-term costs: Denmark may have higher costs in the short-term, but this may lead to lower electricity system costs in the long-term.

However, these arguments are less relevant for the comparison carried out in this thesis. This is because the thesis has taken the political objective to increase the share of DG that has been set in both countries as a starting point. Against this background it has analysed the potential of the standard model to adapt to this objective and has analysed the governance regimes in place in the two countries to deal with DG integration.

A price comparison that complements the analysis in this thesis should compare the costs of integrating DG based on the UK approach with the costs resulting from the Danish approach to DG integration – rather than comparing the costs of a system with a high share of DG with a system that has less DG. Such a comparison however is difficult based on empirical data, for the very reason that the DG share in the two countries differs significantly.

The thesis has shown that the standard model can provide the instruments for reaching objectives in an efficient way. Therefore, the UK approach may be more effective in reaching DG targets at low costs. However, the UK case study has also shown that the very focus on efficiency has made it difficult to pursue DG as an additional objective that leads to higher costs. Therefore, the focus on efficiency may enable a low-cost integration of DG, but may also lead to avoiding DG that increases overall costs. At the same time, the Danish case study has shown that mechanisms that provide efficiency incentives have been implememted outside of the standard model.

Part IV:
Conclusions

11 Conclusions and questions for further research

This final chapter presents the overall conclusions and indicates the limits of the thesis, which can form the basis for further research.

11.1 Conclusions

Against the background of electricity market liberalisation and the literature on governance of system transformation, the main question of the thesis was how DG integration and network development can be integrated as a new objective into the standard model of network regulation and whether and how the regulatory framework needs to evolve. A broad definition of the standard model was applied, i.e. the standard model is not restricted to price- or revenue cap mechanisms to increase efficiency and there is more to the standard model than economic incentives to mimick the market mechanism. Rather, regulation is an institutional arrangement based on 'independent regulators' that can for example also comprise command-and-control mechanisms.

Based on the literature review on liberalisation and transformation as well as distributed generation and network regulation in part one, the research question was analysed from two perspectives: the conceptual analysis in part two and the two country case studies in part three. Part two asked how the standard *model* could be adapted in principle based on the connection-integration-innovation-transformation heuristic introduced in chapter 4.1. Part three analysed two empirical cases to find out how the standard model is applied and adapted in practice and how these empirical developments relate to the conceptual analysis.

The conceptual part and the case studies complement each other and their combination renders their respective weakness less severe. The case study results themselves based on only two cases make it difficult to draw conclusions about the standard model or even the potential development of network regulation in other countries. Yet together with the conceptual part they can contribute to the evaluation of the standard model and its development. The conceptual part does not take into account 'real-life' settings. It is therefore useful to check its findings in the case studies, even though the number of cases is only limited to two and more cases could provide a broader picture of the governance mechanisms that emerge in the face of DG integration.

The conceptual analysis shows how incentive regulation can accommodate the efficient integration of DG as an additional objective. Beyond the incentive mechanism, there are tensions between the standard model and the governance of system transformation, but the two approaches also have some features in common. There is scope for this model to incorporate governance mechanisms that are geared towards infrastructure transformation.

In terms of the case studies, the UK has been a pioneer of the standard model with a relatively low share of DG that has tried to adapt the standard model to rectify this. Denmark implemented the standard model only following the international wave of liberalisation, but is a leading country in terms of DG development and system transformation. Despite these different starting points, in both countries governance mechanisms for dealing with an increasing share of DG and the resulting network challenges have been elaborated.

The UK case study provides a practical example of the development of the standard model that was analysed in the conceptual part, both in terms of incentive schemes geared towards DG and additional mechanisms. As for Denmark the standard model plays a marginal role and economic issues of DG integration are mainly dealt with outside regulation. The same is true for mechanisms beyond economic incentives. The Danish case study adds a perspective 'outside of the standard model' that could not be captured by the conceptual analysis of the standard mode. Both case studies show that governance of DG integration is not limited to economic incentives and governance mechanisms similar to those proposed by the governance of transformation literature play a role. The results of the two case studies cannot be generalised to other countries, but they effectively complement the conceptual analysis.

The thesis shows the potential of the standard model to pursue new objectives as well as the need to broaden the scope beyond governance based on economic incentives both in terms of additional governance mechanisms and the regulation-policy interface. However, even if network decision-making becomes more influenced by political objectives and the role of regulators is complemented by additional tasks and instruments, incentive regulation does not become redundant. Regulators should not rely on incentive mechanisms alone, but they are still important.

The following sections summarise the results on three different levels:

- the incentive mechanisms that are at the heart of the standard model and the relationship between the regulator and the regulated company,
- developments beyond the incentive formula, both in terms of new regulatory instruments and a changing role of the regulator in the political context, and
- more general conclusions about the standard model of liberalisation.

11.1.1 Applying incentive mechanisms to new objectives

In terms of the incentives for network operators to integrate DG, the analysis has shown that the standard model can make it difficult for the DSO to connect DG and become involved in RD&D due to the tension between the short-term efficiency objective and additional costs and risks of DG connections and network innovations. In the case of network innovations this is particularly problematic if network innovations are required to promote new objectives like DG integration. A simple level playing field approach that ensures network access for all market participants to the current network is therefore not sufficient.

At the same time, in the conceptual section and the UK case study it was shown how DG connection and integration as well as network innovation can be integrated into the standard model by extending the very mechanisms of the standard model to pursue these new objectives in an efficient way. The standard model provides a sophisticated toolbox for mixing cost-based and price-based mechanisms to balance different incentives and pursue the efficient implementation of different objectives.

This requires a broader understanding of incentive regulation. It should not merely be regarded as a regulatory concept based on price-based mechanisms that has replaced cost-based regulation in the wake of market liberalisation in order to mimic the market in the network monopoly and increase the efficiency of networks. Rather, incentive regulation should be interpreted as a regulatory framework in which incentives for the regulated company are explicitly designed to pursue specific objectives. These objectives can be broader than just efficiency and the menu of regulatory options becomes broader, too, including cost- and price-based elements.

While the UK case study provides an example of the practical implementation of additional mechanisms, the Danish case study provides an alternative perspective. Firstly, it shows that the costs of DG can successfully be dealt with outside of the standard model, even based on a price-based mechanism. Secondly, the Danish model distributes the costs differently. While the standard model focuses on individual networks, the Danish approach more explicitly regards DG as a political objective, rather than a property of individual networks. As a consequence, network costs of DG are not borne by the customers or the DG developers in each network, but are distributed among all consumers across the country.

11.1.2 Beyond the incentive formula

While the thesis has demonstrated the potential of incentive regulation to accommodate new objectives, it has also shown the limits of relying entirely on this mechanism. This has been confirmed both by the conceptual analysis and the two case studies. Both case studies have shown that it would be too short-sighted to only examine economic mechanisms within the standard model that allocate the network costs of DG. Rather, in both countries additional governance mechanisms are in place alongside economic mechanisms. In Denmark, these are not even strongly connected to the standard model of independent regulation.

The conceptual analysis has shown that there is not only a tension between the cost reduction objective and the standard model and the additional costs of DG integration, but also between the narrow technical approach of the standard model and the governance of system transformation. However, it has also revealed common ground between the two approaches. The standard model is not only about price signals and mimicking the market, but involves an institutional arrangement which cannot be described in terms of markets only. This provides an inroad for the governance mechanisms proposed by the system transformation literature. Overall, the standard model offers the potential to evolve from economic regulation to a more comprehensive, transformation-based approach. Such a development cannot be observed yet in the two countries, although in the UK an open-ended process of redefining the standard model has begun.

Finally, the analysis has confirmed the need for network regulation to be examined in its specific political context. DG is more than a new market actor that needs to establish access to the network and can therefore be dealt with in the regulatory level playing-field framework, but DG is an energy policy objective and requires a different kind of infrastructure. Therefore, the amendments of the incentive formula to accommodate DG-related costs as well as mechanisms geared towards system transformation re-introduce political objectives and thus change the relationship between policy-making and regulation.

11.1.3 General conclusions about the standard model of liberalisation

The research question was embedded in the more general context presented in chapter 2. DG and network development were used as an example to analyse the capability of the standard model of electricity market liberalisation to deal with new objectives beyond efficiency and developments that may transform the system. More specifically, the following question was asked: To what extent can insights from the system transformation literature be integrated into the standard model?

The analysis has confirmed the value of adding the governance of system transformation perspective to the standard model perspective, both in the conceptual section and the case studies. The connection-integration-innovation-transformation heuristic on which the study was based enables a differentiated view on the standard model and the need for additional governance mechanisms. While the economic incentive mechanisms of the standard model can make a significant contribution to accommodating DG connection and integration, network innovation and especially transformation entail additional governance requirements, such as the anticipation of long-term effects on a system level and the strategic coordination of innovation activities in an heterogeneous actor arena.

The analysis showed that there is more to the standard model of regulation than mimicking price signals. Extending this argument to liberalisation in general, the standard model of liberalisation should not only be discussed in terms of markets, but rather in terms of broader governance arrangements, whereby the market can be complemented by a combination of different governance mechanisms, including those proposed by the system transformation literature.

11.2 Limits of the thesis and further research

This thesis necessarily has a number of limitations that can provide the basis for further research in different directions.

Firstly, for the case of network integration of DG the thesis has contributed a comprehensive analysis of the potential of the standard model to adapt to new issues and objectives. However, for each of the dimensions analysed in the conceptual part in chapters 5 to 7 (connection-integration-innovation-transformation) there is scope for a more in-depth analysis of how the standard model can be adapted. In terms of the incentive mechanisms discussed, more work is needed on the practical design of these instruments. This could benefit from a more detailed analysis of the specific design features and their practical effects in the case studies. For that purpose, it would also be helpful to carry out additional case studies on a country level.

The same applies to the proposals made in chapter 7 and the potential role of network regulation in system transformation. Conceptually, more research is needed on how the system transformation mechanisms can be linked up with the standard model, how the advantages of a regulatory authority with a narrow and well-defined remit can be reconciled with the requirements to take into account a broad range of sustainability repercussions and how the regulator could potentially be turned into a 'transformation agency'. Moreover, further research is needed to investigate how governance of network transformation can and should be located outside of the standard model.

In terms of the case studies, while this thesis has identified a number of empirical governance mechanisms that go beyond economic incentives to deal with long-term structural change and uncertainty, a more detailed analysis would be required of the extent to which these are in line with and could benefit from the governance approaches proposed by system transformation literature.

Secondly, in terms of the standard model of liberalisation and the potential to adapt it to the new objectives, the thesis has provided a case study for the case of DG integration and network regulation. However there are other elements of the electricity sector, the standard model and sector transformation which could be analysed to find out whether and how market liberalisation which has been designed so as to increase efficiency can accommodate new objectives and system transformation. Examples include the governance of *market* integration of DG and the increasing role of demand-side load-management to balance the intermittent generation from renewables.

Finally, the two country case studies enabled analysis of two different governance patterns and have provided some insights into how they have developed. However, the case studies continued the focus on the governance mechanism itself, rather than the dynamic process through which they have emerged in their respective context. A more detailed analysis of the development dynamics of the standard model and the governance of networks as outlined by Praetorius et al. (2009: 191-225) can contribute to the development of policy recommendations for how the development of the standard model can be influenced.

References

Abildgaard, J., Hindsberger, M. and Lilledahl, E.B. (2003), *Regulatory Road Map For Denmark*, Sustelnet project report.

Ackermann, T. (2004): *Distributed Resources in a Re-Regulated Market Environment*. Thesis, Stockholm.

Ackermann, T. (2007), 'Distributed resources and re-regulated electricity markets', *Electric Power Systems Research*, 77 (9), 1148-1159.

Ackermann, T., Andersson, G. and Söder, L. (2001), 'Distributed generation: a definition', *Electricity Power Systems Research*, 57 (3), 195-204.

Agnolucci, P. (2005), 'Wind Electricity in Denmark: A survey of policies, their effectivness and factors motivating their introduction', *Renewable and Sustainable Energy Reviews*, 11 (5), 951-963.

Agrell, P. and Bogetoft, P. (2003), *Dynamic Regulation*, SUMICSID, Draft Report.

Agrell, P. and Bogetoft, P. (2004), *Evolutionary Regulation: From CPI-X towards contestability*, SUMICSID.

Ai, C. and Sappington, D. (2002), 'The Impact of State Incentive Regulation on the U.S. Telecommunications Industry', *Journal of Regulatory Economics*, 22 (2), 133-160.

Ajodhia, V. and Hakvoort, R. (2005), 'Economic regulation of quality in electricity distribution networks', *Utilities Policy*, 13 (3), 211-221.

Alanne, K. and Saari, A. (2006), 'Distributed energy generation and sustainable develpement', *Renewable and Sustainable Energy Reviews* (10), 539-558.

Armstrong, C.M., Cowan, S., Vickers, J. (1994), *Regulatory Reform, Economic Analysis and British Experience*, Cambridge, MA: MIT Press.

Arthur D.Little Inc. (ed) (1999), *Distributed Generation: Understanding the economics*, Cambridge, MA.

Ault, G. and Hughes, N. (2008), *Electricity Network Scenarios for Great Britain in 2050*, Ofgem.

Averch, H. and Johnson, L.L. (1962), 'Behaviour of the Firm under Regulatory Constraint', *American Economic Review*, 52 (5), 1052-1069.

Bach, P.-F., Nielsen, J.E., Hindsberger, M., Varming, S., Gaardestrup, C. (2003): Active Networks as a tool to integrate large amounts of distributed generation. Presented at the conference *"Energy Technologies for post Kyoto Targets in the Medium Term"*, Risø, Denmark.

Bailey, E.E. (1974), 'Innovation and Regulation', *Journal of Public Economics*, 3 (3), 285-295.

Baldick, R. and Kahn, E. (1993), 'Network Costs and the Regulation of Wholesale Competition In Electric Power', *Journal of Regulatory Economics*, 5, 367-384.

Baldwin, R., Cave, M. (1999), *Understanding Regulation - Theory, Strategy and Practice,* Oxford: Oxford University Press.

Bartle, I. and Vass, P. (2006), *Economic regulation and sustainable development - Promoting good governance,* CRI, Research Report 18, Bath.

Bartle, I. and Vass, P. (2007), 'Independent economic regulation: A reassessment of its role in sustainable development', *Utilities Policy*, 15 (4), 261-269.

Bauknecht, D., Brunekreeft, G. (2008), 'Distributed Generation and Network Regulation', in Sioshansi, F.P. (ed), *Competitive Electricity Markets: Design, implementation and performance,* Oxford: Elsevier, pp. 469-497.

Bauknecht, D. and Colella, W. (2002), 'NETA und die Folgen für erneuerbare Energien und KWK-Anlagen', *Energiewirtschaftliche Tagesfragen*, 52. Jg. (Heft 6), 446-448.

Bauknecht, D., Leprich, U., Späth, P., Skytte, K. and Esnault, B. (2007), *Regulating Innovation and Innovating Regulation,* DG-GRID project report.

Bayod-Rújula, A.A. (2009), 'Future development of the electricity systems with distributed generation', *Energy*, 34 (3), 377-383.

Beesley, M.E. and Littlechild, S.C. (1989), 'The regulation of privatized monopolies in the United Kingdom', *Rand Journal of Economics*, 20 (3), 454-472.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. and Rickne, A. (2008), 'Energy System Transformation: The Evolution of Technological Systems in Renewable Energy Technology', *Industrial and Corporate Change*, 37 (3), 407-429.

Berkhout, F. (2002), 'Technological regimes, path dependency and the environment', *Global Environmental Change*, 12 (1), 1-4.

BERR (Department for Business, Enterprise & Regulatory Reform) (ed) (2007), *Future Network Architectures*, London.

Bijker, W.E., Hughes, T.P., Pinch, T.J. (1987), *The Social Construction of Technological Systems,* Cambridge: MIT Press.

Blankart, C.B., Knieps, G. and Zenhäusern, P. (2006), *Regulation of New Markets in Telecommunications? - Market dynamics and shrinking monopolistic bottlenecks*, Institut für Verkehrswissenschaft und Regionalpolitik, Discussion Paper, Freiburg.

Boltz, W. (2005): Das neue Regulierungssystem - Rückblick und Ausblick auf die Regulierungstätigkeit der E-Control. Presented at the conference *"Enquete "Anreizregulierung Strom""*.

Bongaerts, M. (2006): Continuon Netbeheer & DG. Presented at the conference *"DG-GRID Workshop"*, Berlin.

Botting, D. (2006a): Collaborative Innovation in a Regulatory Environment. Presented at the conference *"Distribution Europe 2006"*, Barcelona.

Botting, D. (2006b): Collaborative Innovation in a Regulatory Environment. Presented at the conference *"Distribution Europe 2006"*, Barcelona.

Bourreau, M. and Dogan, P. (2001), 'Regulation and innovation in the telecommunications industry', *Telecommunications Policy*, 25 (3), 167-184.

Brunekreeft, G. (2003), *Regulation and Competition Policy in the Electricity Market: economic analysis and German experience*, Baden-Baden: Nomos Verlagsgesellschaft.

Brunekreeft, G. (2005), *Supply Adequacy: From regulatory uncertainty to consistency*, TILEC report, Tilburg.

Brunekreeft, G. and Ehlers, E. (2006), 'Ownership unbundling of electricity distribution networks and distributed generation', *Competition and Regulation in Network Industries*, 1 (1), 63-86.

Brunekreeft, G. and McDaniel, T. (2005), 'Policy uncertainty and supply adequacy in electric power markets', *Oxford Review of Economic Policy*, 21 (1), 111-127.

Bundesnetzagentur (ed) (2006), *Bericht der Bundesnetzagentur nach § 112a EnWG zur Einführung der Anreizregulierung nach § 21a EnWG*, Bonn.

Burges, K., Twele, J. (2005): *Power systems operation with high penetration of renewable energy - the German case*, Amsterdam.

Cabinet Office (ed) (2006), *The Energy Review Report 2006. The Energy Challenge.*

Cao, D.M., Pudjianto, D., Grenard, S., Martikainen, A. and Strbac, G. (2006), *Costs and Benefits of DG Connections to Grid System*, DG-GRID project report.

Cardell, J. and Tabors, R. (1997), 'Operation and Control in a Competitive Market: Distributed Generation in a Restructured Industry', *The energy journal* (Distributed Resoruces Special Issue), 187-210.

Casten, T.R. (1990), 'Whither electric generation? A different view', *The Energy Daily*.

Christiansen, P.M., Norgaard, A.S., Sidenius, N.C. (2001), 'Verbände und Korporatismus auf Dänisch', in Reutter, W. (ed), *Verbände und Verbandssysteme in Westeuropa*, Opladen: Leske und Budrich, pp. 51-74.

Clemenz, G. (1991), 'Optimal price-cap regulation', *The Journal of Industrial Economics*, 39 (4), 391-408.

Coll-Mayor, D., Paget, M. and Lightner, E. (2006), 'Future intelligent power grids: Analysis of the vision in the European Union and the United States', *Energy Policy*, 35 (4), 2453-2465.

Competition Commission (ed) (2002), *The supply of banking services by clearing banks to small and medium-sized enterprises,* London.

Connor, P. and Mitchell, C. (2002), *A Review of Four European Regulatory Systems and their Impacts on the Deployment of Distributes Generation,* Sustelnet project report.

Correljé, A.F., de Vries, L.J. (2008), 'Hybrid Electricity Markets: The Problem of Explaining Different Patterns of Restructuring', in Künneke, R.W., Correlje, A.F. and Groenewegen, J.P.M. (eds), *Competitive Electricity Markets: Design, Implementation, and Performance*: Elsevier, pp. 65-94.

Correljé, A.F. (2005), 'Dilemmas in Network Regulation: The Dutch Gas Industry', in Künnecke, R.W., Correljé, A.F. and Groenewegen, J.P.M. (eds), *Institutional Reform, Regulation and Privatization. Process and Outcomes in Infrastructure Industries*, Cheltenham: Edward Elgar, pp. 115-150.

Corry, D. (2003), *The Regulatory State: Labour and the Utilities 1997-2002*, London: IPPR.

Cossent, R., Gomez, T. and Frías, P. (2008), 'Towards a future with large penetration of distributed generation: Is the current regulation of electricity distribution ready? Regulatory recommendations under a European perspective', *Energy Policy*, 37 (3), 1145-1155.

Coutard, O. (2003), 'Economics of Grid Systems in Reconfiguration: Competition in the Electricity Supply Industry', in Summerton, J. (ed), *Changing Large Technical Systems*, Boulder, San Francisco, Oxford: Westview Press, pp. 163-189.

Crouch, M. (2006), 'Investment under RPI-X: Practical experience with an incentive compatible approach in the GB electricity distribution sector', *Utilities Policy*, 14 (4), 240-244.

Damodaran, A., *Research and Development Expenses: Implications for Profitability Measurement and Valuation*, Stern School of Business, New York.

Davies, A. (1995), *Innovation in Large Technical Systems: The Case of Telecommunications*, CoPS Publication 1.

de Vries, L.J. (2004): *Securing the public interest in electricity generation markets; The myths of the invisible hand and the copper plate*. Thesis, Delft.

DEA (Danish Energy Authority) (ed) (2003), *Energy Policy Statement 2003*.

DEA (Danish Energy Authority) (ed) (2004), *Energy policy statement 2004.*

DEA (2005): Copenhagen strategy on offshore wind power deployment. Presented at the conference "*European policy seminar on offshore wind power."*, Danish Energy Authority, Copenhagen, Denmark.

DERA (Danish Energy Regulatory Authority) (ed) (2002a), *Annual Report 2002*, Annual Report, Copenhagen.

DERA (Danish Energy Regulatory Authority) (ed) (2002b), *Annual Report 2002*, Annual Report, Copenhagen.

DERA (Danish Energy Regulatory Authority) (ed) (2005a), *Annual Report 2004*, Copenhagen.

DERA (Danish Energy Regulatory Authority) (ed) (2005b), *Annual Report 2004*, Copenhagen.

DERA (Danish Energy Regulatory Authority) (ed) (2006), *Annual Report 2005*, Copenhagen.

DERA (Danish Energy Regulatory Authority) (ed) (2008), *Regulators' 2008 National Report to the European Commission*.

DERA (Danish Energy Regulatory Authority) (ed) (2009), *Regulators' 2009 National Report to the European Commission Denmark.*

DGCG (Distributed Generation Coordination Group) (ed) (2005), *Technical Architecture - A first report: The way ahead*.

Dispower (ed) (2006), *Distributed Generation with High Penetration of Renewable Energy Sources*, Final Public Report, Kassel.

DoE (U.S. Department of Energy) (ed) (2007), *The potential benefits of distributed generation and rate-related issues that may impede their expansion*.

Dooley, J.J. (1998), 'Unintended consequences: energy R&D in a deregulated energy market', *Energy Policy*, 26 (7), 547-555.

Dosi, G. (1988), 'The nature of the innovative process', in Dosi, G. et al. (eds), *Technical Change and Economic Theory*, London, New York: Pinter, pp. 221-238.

DTI (Department of Trade and Industry) (ed) (2003), *Energy White Paper: Our energy future - creating a low carbon economy*.

DTI (Department of Trade and Industry) (ed) (2006), *The energy challenge. Energy Review*, London.

EA Technology Ltd (ed) (2001), *Likely changes to network design as a result of significant embedded generation*.

Econnect (ed) (2006), *Accommodating Distributed Generation*, Report to the DTI to support the Energy Review.

Edison Electric Institute, NERA (ed) (2006), *Distributed Resources: Incentives*.

Eifert, M. and Hoffmann-Riem, W. (eds) (2009), *Innovationsfördernde Regulierung*, Berlin: Duncker & Humblot.

Eltra (ed) (2003), *Annual Report 2002*, Fredericia.

Elzen, B., Geels, F., Green, K. (2004), *System Innovation and the Transition to Sustainability. Theory, Evidence and Policy*, Cheltenham, Northampton: Edward Elgar.

Energinet.dk (ed) (2006), *Systemplan 2006*, Fredericia.

Energinet.dk (ed) (2007a), *Energy 07- Reserach, Development, Demonstration*.

Energinet.dk (ed) (2007b), *Systemplan 2007*, Fredericia.

Energinet.dk (ed) (2009), *The PSO programmes and the energy agreement - Strategy 2010+ for the ForskEL and ForskVE programmes. Contribution towards fulfilling the energy agreement and the climate goals*.

Energinet.dk (ed) (2010), *Annual Report 2009*, Fredericia.

ENSG (Electricity Networks Strategy Group) (ed) (2006), *Annual Report 2005*.

ERGEG (European Regulators' Group for Electricity and Gas) (ed) (2009), *Position Paper on Smart Grids*, Public Consultation Paper, Brussels.

European Commission (ed) (2003), *New ERA for electricity in Europe - Distributed generation: Key issues, challenges and proposed solutions*, Brussels.

European Commission (ed) (2006), *European SmartGrids Technology Platform; Vision and Strategy for Europe´s Electricity Networks of the Future*, Brussels.

European Commission (ed) (2007), *Towards a European strategic energy technology plan*, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, Brussels.

Finon, D. (2001), 'Reforms in the French power system: from weak contestability to effective competition?', *Energy Policy*, 29 (10), 755-768.

Finon, D., Johnsen, T.A. and Midttun, A., 'Challenges when electricity markets face the investment phase', *Energy Policy*, 32 (12), 1355-1362.

Fitzgerald, L., Waddams Price, C. (2003), 'Gas Regulation', in Vass, P. and Marchant, J. (eds), *The Development of Energy Regulation - A Collection of Reviews*, Bath, pp. 99-110.

Flick, U. (2006), 3. ed., *An Introduction to Qualitative Research*, London: Sage.

Freeman, C., Perez, C. (1988), 'Structural Crises of Adjustment, Business Cycles and Investment Behaviour', in Dosi, G. et al. (eds), *Technical Change and Economic Theory*, London: Pinter.

Frey, G., Leprich, U., Bauknecht, D., Schrader, K., Peter, S. and Bokelmann, H. (2008), *Optimierungsstrategien Aktiver Netzbetreiber beim weiteren Ausbau erneuerbarer Energien zur Stromerzeugung*, Saarbrücken et al.

Frontier Economics (2003), *Regulatory mechanisms for dealing with uncertainty*, Report for Ofgem.

Fucsko, J., Kis, A. and Bartus, G. (2004), *Regulatory road map for Hungary - Road Map for Transition of the Regulatory Framework of the Hungarian Electricity Supply System*, MAKK, Sustelnet project report.

Gans, J.S. and King, S. (2004), 'Access Holidays: The Panacea for Network Infrastructure Investment?', *Utilities Policy*.

Geels, F. (2002a), *Understanding the dynamics of technological transitions*, Enschede: Twente University Press.

Geels, F.W. (2002b), 'Technological transitions as evolutionary reconfiguration processes - A multi-level perspective and a case-study', *Research Policy*, 31, 1257-1274.

Gerpott, T.J. (2006), 'Innovation und Regulierung in der Telekommunikationswirtschaft', *Schmalenbachs Zeitschrift für betriebswirtschaftliche Forschung* (Special issue 54), 133-153.

Geyer, A. and Davies, A. (2000), 'Managing project-system interfaces: case studies of railway projects in restructured UK and German markets', *Research Policy*, Elsevier, Vl 29 (Issue 7-8, August), 991-1013.

Gilbert, R.J., 'Looking for Mr. Schumpeter: Where Are We in the Competition-Innovation Debate?', in Jaffe, A., Lerner, J. and Stern, S. (eds), *Innovation Policy and the Economy*: National Bureau of Economic Research, pp. 159-215.

Gray, A., Jenkins, B. (1995), 'Reassessing a revolution?', in , *Public Administration*, Cambridge, USA: Basil Blackwell Ltd., pp. 75-99.

Green, D. (2004): Rethinking Energy Regulation. Presented at the conference *"19th World Energy Congress"*, Sydney, Australia.

Green, R., Trotter, S. (2003), 'Electricity Regulation', in Vass, P. (ed), *The Development of Energy Regulation - A Collection of Reviews*, Bath, pp. 55-87.

Groenli, H. (2001), 'A Comparison of Scandinavian Regulatory Models: Issues and Experience', *The Electricity Journal*, 14 (7), 57-64.

Grohnheit, P.E. (2002), 'Denmark: long-term planning with different objectives', in Vrolijk, C. (ed), *Climate change and power: econimic instruments for european electricity*, London, pp. 108-130.

Grohnheit, P.E., Olsen, O.J. (2001), 'Organisation and Regulation of the Electricity Supply Industry in Denmark', in De Paoli, L. (ed), *The Electricity Industry in Transition - Organisation, Regulation and Ownership in EU Member states*, Milano: FrancoAngeli, pp. 123-162.

Gulli, F. (2006), 'Small distributed generation versus centralised supply: a social cost-benefit analysis in the residential and service sectors', *Energy Policy*, 34 (7), 804-832.

Gumerman, E.Z., Bharvirkar, R.R., Hamachi LaCommare, K. and Marnay, C. (2003), *Evaluation Framework and Tools for Distributed Energy Resources*, Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, California.

Haas, R., Eichhammer, W., Huber, C., Langniß, O., Lorenzoni, A., Madlener, R., Menanteau, P., Morthorst, P.E., Martins, A., Oniszk, A., Schleich, J., Smith, A., Vass, Z. and Verbruggen, A. (2004), 'How to promote renewable energy systems successfully and effectively', *Energy Policy*, 32 (6), 833-839.

Haas, R., Meyer, N.I., Held, A., Finon, D., Lorenzoni, A., Wiser, R., Nishio, K.-I. (2008), 'Promoting Electricity from Renewable Energy Sources - Lessons Learned from the EU, United Sates, and Japan', in Sioshansi, F.P. (ed), *Competitive Electricity Markets - Design, Implementation, Performance*, Oxford, Amsterdam: Elsevier, pp. 419-468.

Hadjilambrinos, C. (1999), 'Understanding technology choice in electricity industries: a comparative study of France and Denmark', *Energy Policy*, 28 (15), 1111-1126.

Harrison, G.P. and Wallace, R.A. (2004), 'Network integration of CHP', *Cogeneration & On-Site Power Production* (4), 69-76.

Helm, D. (2003), *Energy, the State, and the Market. British Energy Policy since 1979*, Oxford, New York: Oxford University Press.

Helm, D. (2004b), *The New Regulatory Agenda*, London: The Social Market Foundation.

Helm, D. (2004a), *The New Regulatory Agenda*, London: The Social Market Foundation.

Helm, D. (2005), 'The case for regulatory reform', in Helm, D. (ed), *The future of infrastructure regulation*, Oxford, pp. 1-9.

Helm, D. (2007), *The New Energy Paradigm*, Oxford, New York: Oxford University Press.

Hemmelskamp, J., Rennings, K. and Leone, F. (eds) (2000), *Innovation-oriented Environmental Regulation. Theoretical Approaches and Empirical Analysis*, Heidelberg, New York: Physica-Verlag.

Hendriks, C., Grin, J. (2007), 'Contextualising Reflexive Governance: The politics of Dutch transitions to sustainability', in Newig, J., Voß, J.-P. and Monstadt, J. (eds), *Governance for Sustainable Development. Steering in contexts of ambivalence, uncertainty and distributed power*, London: Routledge, pp. forthcoming-.

Heyes, A.G. and Liston-Heyes, C. (1998), 'Price-cap regulation and technical change', *Journal of Public Economics*, 68 (1998) 137–151.

Hirschhausen, C., Beckers, T. and Brenck, A. (2004), 'Infrastructure regulation and investment for the long-term - an introduction', *Utilities Policy*, 12 (4), 203-210.

Holt, D. (2005a), *Where has the innovation gone? R&D in UK utility regulation*, Oxera, Agenda November 2005.

Holt, D. (2005b), *Where has the innovation gone? R&D in UK utility regulation*, Oxera, Agenda November 2005.

Hood, C. (1991), 'A public management for all seasons', in , *Public Administration*, pp. 3-19.

Hoogma, R., Kemp, R., Schot, J.P., Truffer, B. (2002), *Experimenting for Sustainable Transport. The approach of Strategic Niche Management,* London/New York: Spon Press.

Hughes, T.P. (1983), *Networks of Power: Electrification 1880-1930,* Baltimore, MD: John Hopkins University Press.

Hughes, T.P. (1987), 'The Evolution of Large Technical Systems', in Bijker, W.E., Hughes, T.P. and Pinch, T.J. (eds), *The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology*, Cambridge, Massachusetts: MIT Press, pp. 51-82.

Iannucci, J.J., Cibulka, L., Eyer, J.M. and Pupp, R.L. (2003), *DER Benefit Analysis Studies: Final report,* National Renewable Energy Laboratory, Golden, Colorado.

IEA (International Energy Agency) (ed) (1999), *Electric Power Technology. Opportunities and Challenges of Competition*, Paris.

IEA (International Energy Agency) (ed) (2001a), *Electricity Information 2001*, Paris.

IEA (International Energy Agency) (ed) (2001b), *Regulatory Institutions in Liberalised Electricity Markets*, Paris.

IEA (International Energy Agency) (ed) (2002a), *Distributed Generation in Liberalised Electricity Markets*, Paris.

IEA (International Energy Agency) (ed) (2002b), *Energy Policy of IEA Countries: Denmark 2002 Review*, Paris.

IEA (International Energy Agency) (ed) (2005), *Lessons from Liberalised Electricity Markets*, Paris.

IEA (International Energy Agency) (ed) (2006), *Energy Policies of IEA Countries - Denmark 2006 Review*, Paris.

IEA (International Energy Agency) (ed) (2007a), *Electricity Information 2007*, Paris.

IEA (International Energy Agency) (ed) (2007b), *The United Kingdom 2006 Review*, Paris.

IEA (International Energy Agency) (ed) (2008), *Empowering Variable Renewables*, Paris.

IEA (International Energy Agency) (ed) (2009a), *CHP/DHC Country Scorecard: Denmark*, Paris.

IEA (International Energy Agency) (ed) (2009b), *Electricity Information 2009*, Paris.

IEA (International Energy Agency) (ed) (2011), *Technology Roadmap Smart Grids*, Paris.

IPART (Independent Pricing and Regulatory Tribunal of New South Wales) (ed) (2004), *NSW Electricity Distribution Pricing 2004/05 to 2008/09*, Final Report.

Jaffe, A. and Palmer, K. (1997), 'Environmental Regulation And Innovation: A Panel Data Study', *The Review of Economics and Statistics*, 79 (4), 610-619.

Jamasb, T., Neuhoff, K., Newbery, D.M. and Pollitt, M. (2005), *Long-Term Framework for Electricity Distribution Access Charges*, University of Cambridge, Faculty of Economics SUPERGEN and The Cambridge-MIT Institute Electricity Project CWPE 0551 and EPRG 07, CWPE 0551 and EPRG 07.

Jamasb, T. and Pollitt, M. (2000), 'Benchmarking and regulation: international electricity experience', *Utilities Policy*, 9 (3), 107-130.

Jamasb, T. and Pollitt, M. (2007), 'Incentive regulation of electricity distribution networks: Lessons of experience from Britain', *Energy Policy*, 35 (12), 6163-6187.

Jamasb, T. and Pollitt, M. (2008a), 'Liberalisation and R&D in network industries: The case of the electricity industry', *Research Policy*, 37 (6-7), 995-1008.

Jamasb, T. and Pollitt, M. (2008b), 'Reference models and incentive regulation of electricity distribution networks: An evaluation of Sweden's Network Performance Assessment Model (NPAM)', *Energy Policy*, 36 (5), 1788-1801.

Jamasb, T. and Pollitt, M. (2008c), 'Security of supply and regulation of energy networks', *Energy Policy*, 36 (12), 4584-4589.

Jäntti, S. (2003), *Connection of Distributed Energy Generation Units in the Distribution Network and Grid*, CODGUNet Final report, Vaasa.

Jenkins, N., Allan, R., Crossley, P., Kirschen, D., Strbac, G. (2000), *Embedded Generation*, London: The Institution of Electrical Engineers.

Jensen, J. (2002), 'Integrating CHP and Wind Power - how western Denmark is leading the way', *Cospp*, Volume 3 Issue 6 (Nov/Dez), 55-62.

Jordana, J., Levi-Faur, D. (2004), 'The Politics of Regulation in the Age of Governance', in Jordana, J. and Levi-Faur, D. (eds), *The Politics of Regulation*, Cheltenham: Edward Elgar, pp. 1-28.

Joskow, P.L. (1989), 'Regulatory Failure, Regulatory Reform, and Structural Change in the Electrical Power Industry', *Brookings Papers on Economic Activity*, 1989, 125-208.

Joskow, P.L. (2003), 'Electricity sectors in transition', *The energy journal*, 19 (2), 25-52.

Joskow, P.L. (2006a), *Incentive Regulation in Theory and Practice: Electricity Distribution and Transmission Networks,* MIT, CWPE 0607 and EPRG 0511.

Joskow, P.L. (2006b), 'Introduction to Electricity Sector Liberalization: Lessons Learned from Cross-Country Studies', in Sioshansi, F.P. and Pfaffenberger, W. (eds), *Electricity Market Reform - An International Perspective*, Oxford: Elsevier, pp. 1-32.

Kahn, A.E., Tardiff, T.J. and Weisman, D.L. (1999), 'The Telecommunications Act at three years: an economic evaluation of its implementation by the Federal Communications Commission', *Information Economics and Policy*.

Keller, K. and Wild, J. (2004), 'Long-term investment in electricity: a trade-off between co-ordination and competition?', *Utilities Policy* (12), 243-251.

Kemp, R. (1994), 'Technology and the transition to environmental sustainability. The problem of technological regime shifts.', *Futures,* 26, 1023-1046.

Kemp, R., Loorbach, D. (2006), 'Transition management: a reflexive governance approach', in Voß, J.-P., Bauknecht, D. and Kemp, R. (eds), *Reflexive governance for sustainable development*, Cheltenham, UK: Edward Elgar, pp. 103-130.

Kemp, R., Rip, A., Schot, J.P. (2001), 'Constructing Transition Paths Through the Management of Niches', in Garud, R. and Karnøe, P. (eds), *Path Path Dependence and Creation*, Mahwah, NJ/ London: Lawrence Erlbaum, pp. 269-299.

Kemp, R., Rotmans, J. and Loorbach, D. (2007), 'Assessing the Dutch Energy Transition Policy: How Does it Deal with Dilemmas of Managing Transitions?', *Journal of Environmental Policy & Planning,* 9 (3&4), 315-331.

Kern, F. and Smith, A. (2008), 'Restructuring energy systems for sustainability? Energy transition policy in the Netherlands', *Energy Policy,* 36 (11), 4093-4103.

Kinnunen, K. (2003): Electricity Network Regulation: Practical Implementation in the Nordic Countries. Presented at the conference *"3. Internationale Energiewirtschaftstagung "Die Zukunft der Energiewirtschaft im liberaliserten Markt""*, Wien.

Knieps, G. (2001), 'The Economics of Network Industries', in Debreu, G., Neuefeind, W. and Trockel, W. (eds), *Economic Essays - A Festschrift for Werner Hildenbrand*, Berlin et al.: Springer, pp. 275-293.

Kooiman, J. (1993), *Modern Governance. New Government-Society Interactions,* London: Sage.

Künnecke, R.W., Groenewegen, J.P.M. (2005), 'Process and Outcomes of the Infrastructure Reform: An Evolutionary Perspective', in Künnecke, R.W., Correlje, A.F. and Groenewegen, J.P.M. (eds), *Institutional Reform, Regulation and Privatization. Process and Outcomes in Infrastructure Industries*, Cheltenham: Edward Elgar, pp. 1-36.

L'Abbate, A., Peteves, S. and Fulli, G. (2008), 'The impact of DG on European electricity grids', *Cogeneration & On-Site Power Production* (may-june 2008), 19-25.

Laffont, J.-J., Tirole, J. (1993), *A Theory of Incentives in Procurement and Regulation,* Cambridge, MA: The MIT Press.

Lévêque, F. (ed) (2006), *Competitive Electricity Markets and Sustainability*, Cheltenham, UK: Edward Elgar.

Littlechild, S. (2001): Electricity: Regulatory Developments Around the World. Presented at the conference "*The Beesley Lectures on Regulation Series XI"*, IEA/LBS, London.

Littlechild, S. (2003), 'Electricity Regulation', in , *The Development of Energy Regulation- A Collection of Reviews*, Bath, pp. 17-54.

Littlechild, S. (2006a), *Beyond Regulation,* CWPE 0616; EPRG 0516.

Littlechild, S. (2006b), 'Foreword: The Market Versus Regulation', in , *Electricity Market Reform - An International Perspective*, Oxford: Elsevier.

Lorentzen, J. (2005), 'Decentralized Denmark', *Cogeneration & On-Site Power Production*, 6 (6), 67-75.

Lovins, A.B. (1977), *Soft Energy Paths: Towards a Durable Peace,* Harmondsworth: Penguin Books.

Lucha, C. (2006): *Optimisation of the share of renewable energies in electricity systems in the European Union - Cornerstones of an alternative political and institutional scenario*. Thesis, Universität Koblenz-Landau. Koblenz.

Lund, P., Cherian, S. and Ackermann, T. (2006), 'A Cell Controller for autonomous Operation of a 60 KV Distribution Area', *International Journal of Distributed Energy Resources*, 2 (2), 83-100.

Lundvall, B.-A. (1992), *National systems of Innovation: Towards a Theory of Innovation and Interactive Learning,* London: Pinter.

MacKerron, G. (2003), 'Electricity in England and Wales: efficiency and equity', in Finon, D. and Glachant, J.M. (eds), *Competition in European Electricity Markets - A cross-country comparison*, Cheltenham: Edward Elgar, pp. 41-56.

MacKerron, G. (2009), 'Lessons from the UK on Urgency and Legitimacy in Energy Policymaking', in Scrase, I. and MacKerron, G. (eds), *Energy for the Future - A new Agenda*, Basingstoke: Palgrave Macmillan, pp. 76-88.

Magat, W.A. (1976), 'Regulation and the rate and direction of induced technical change', *The Bell Journal of Economics*, 7 (2), 478-496.

Magnusson, T., Tell, F. and Watson, J. (2005), 'From CoPS to mass production ? Capabilities and innovation in power generation equipment manufacturing', *Industrial and Corporate Change*, 14 (1), 1-26.

Majone, G. (1997), 'From the positive to the regulatory state: causes and consequences of changes in the mode of governance', *Journal of Public Policy*, 17 (2), 139-167.

Majone, G. (1999), 'The regulatory state and its legitimicy problems', *West European Politics*, 22 (1), 1-24.

Markard, J. and Truffer, B. (2006), 'Innovation processes in large technical systems: Market liberalization as a driver for radical change?', *Research Policy*, 35 (5), 609-625.

Markard, J., Truffer, B. and Imboden, D. (2004), 'The Impacts of Market Liberalization On Innovation Processes In The Electricity Sector', *Energy & Environment*, 15 (2), 201-214.

Markiewicz, K., Rose, N. and Wolfram, C. (2004), *Has Restructuring Improved Operating Efficiency at US Electricity Generating Plants?,* UCEI, Working Paper, Berkley, CA.

Mayo, J.W. and Flynn, J.E. (1988), 'The effects of regulation on research and development: theory and evidence', *Journal of Business*, 61 (3), 321-336.

McGowan, F. and Wallace, H. (1996), 'Towards a European regulatory state', *Journal of European public policy*, 3 (4), 560-576.

Menanteau, P., Finon, D. and Lamy, M.-L. (2003), 'Prices versus quantities: choosing policies for promoting the development of renewable energy', *Energy Policy*, 31 (8), 799-812.

Mendez, V.H., Rivier, Juan, de la Fuente, J.I., Gomez, T., Arceluz, J. and Marin, J. (2006), 'Impact of Distributed Generation on Distribution Losses', *Electrical Power & Energy Systems*, 28 (4), 244-252.

Mevert, H. and Hobbeling, F. (2004), 'Praxis: Arealnetze', *Zeitschrift für Energie, Markt, Wettbewerb* (Nr. 6), 12-17.

Meyer, N.I. and Koefoed, A.L. (2003), 'Danish energy reform: policy implications for renewables', *Energy Policy*, 31 (7), 597-607.

Mez, L. (1997), 'The German Electricity Reform Attempts: Reforming Co-optive Networks', in Midttun, A. (ed), *European Electricity Systems in Transition. A comparative analysis of policy and regulation in Western Europe*, Amsterdam: Elesevier.

Midttun, A. (2005), 'Deregulation: Design, Learning, Legitimacy', in Künnecke, R.W., Correljé, A.F. and Groenewegen, J.P.M. (eds), *Institutional Reform, Regulation and Privatization. Process and Outcomes in Infrastructure Industries*, Cheltenham: Edward Elgar, pp. 39-66.

Ministry of Economic and Business Affairs (ed) (2004), *Agreement of 29 March 2004 to ensure a reliable energy infrastructure for the future*.

Mitchell, C., Bauknecht, D. and Connor, P.M. (2006), 'Effectiveness through risk reduction: a comparison of the renewable obligation in England and Wales and the feed-in system in Germany', *Energy Policy*, 34 (3), 297-305.

Mitchell, C. and Connor, P.M. (2002), *Review of Current Electricity Policy and Regulation - UK Case Study,* Sustelnet Project Report.

Moskovitz, D. (2000), *Profits and Progress Through Distributed Resources,* Maine.

Müller, J., Vogelsang, I. (1979), *Staatliche Regulierung - Regulated Industries in den USA und Gemeinwohlbindung in wettbewerblichen Ausnahmebereichen in der Bundesrepublik Deutschland,* Baden-Baden: Nomos.

NAO (National Audit Office) (ed) (2002), *Pipes and Wires*.

Neuhoff, C. and de Vries, L.J. (2004), 'Insufficient incentives for investment in electricity generations', *Utilities Policy* (12), 253-267.

Newbery, D. (2001), 3. ed., *Privatization, Restructuring and Regulation of Network Utilities,* Cambridge, MA: MIT Press.

Newbery, D. (2006), 'Electricity Liberalization in Britain And The Evolution of Market Design', in Sioshansi, F.P. and Pfaffenberger, W. (eds), *Electricity Market Reform - An International Perspective*, Oxford: Elsevier, pp. 109-143.

Newbery, D. and Pollitt, M. (1997), 'The Reconstructuring and Privatisation of Britains CEGB - Was it Worth it?', *The Journal of Industrial Economics*, 45 (3), 269-303.

Nielsen, J.E. (2003), *Analysis of how large scale DG affects network business - The Eltra case*, CODGUNET project report.

Nielsen, J.E. (2007): Progress in DG System integration and Research in Denmark. Presented at the conference "DER Integration in the Electricity System", Budapest.

Ocana, C. (2003), 'Trends in the management of regulation: a comparison of energy regulators in member countries of the OECD', *International Journal of Regulation and Governance*, 3 (1), 13-32.

OECD (Organisation for Economic Co-operation and Development) (ed) (1999), *Denmark - Regulatory Reform in Electricity*, Paris.

OECD (Organisation for Economic Co-operation and Development) (ed) (2002), *Regulatory reform in gas and electricity and the professions*.

Ofgem (Office of Gas and Electricity Markets) (ed) (2002), *Distributed Generation - "The way forward"*.

Ofgem (Office of Gas and Electricity Markets) (ed) (2003), *Innovation and Registered Power Zones*, Discussion paper.

Ofgem (Office of Gas and Electricity Markets) (ed) (2004a), *Electricity Distribution Price Control Review - Final Proposals*.

Ofgem (Office of Gas and Electricity Markets) (ed) (2004b), *Electricity Distribution Price Control Review - Regulatory Impact Assessment for Registered Power Zones and the Innovation Funding Incentives*, London.

Ofgem (Office of Gas and Electricity Markets) (ed) (2004c), *Electricity Distribution Price Control Review Policy Document*.

Ofgem (Office of Gas and Electricity Markets) (ed) (2004d), *Electricity distribution price control review. Appendix - Further details on the incentive schemes for distributed generation, innovation funding and registered power zones*.

Ofgem (Office of Gas and Electricity Markets) (ed) (2004e), *Regulatory Impact Assessment for distributed generation and structure of distribution charges*.

Ofgem (Office of Gas and Electricity Markets) (ed) (2008), *Electricity Distribution Price Control Review Initial consultation document Ref. 32/08,* London.

Ofgem (ed) (2009a), *Delivering desired outcomes: Ensuring the future regulatory framework is adaptable*, Regulating energy networks for the future: RPI-X@20 - Working Paper.

Ofgem (Office of Gas and Electricity Markets) (ed) (2009b), *Regulating energy networks for the future: RPI-X@20 Working paper 2*, London.

Ofgem (Office of Gas and Electricity Markets) (ed) (2010), *LCN Fund Governance Document v.3*, London.

Owen, G. (2004), *Economic regulation and sustainability policy,* London: Sustainability First.

Owen, G. (2006a), *Role of Regulators in Delivering Sustainable Energy Systems - SDC in-depth review,* SDC.

Owen, G. (2006b), 'Sustainable development duties: New roles for UK economic regulators', *Utilities Policy*, 14 (3), 208-217.

Panzer, C. (2008), *Economics and Regulatory Criteria for Distributed Generation,* Saarbrücken: VDM Verlag.

Pecas Lopes, J.A., Hatziargyriou, N., Mutale, J.D.P. and Jenkins, N. (2007), 'Integrating distributed generation into electric power systems: A review of drivers, challenges and opportunities', *Electric Power Systems Research*, 77 (9), 1189-1203.

Pehnt, M., Fischer, C. (2006), 'Environmental Impacts of Micro Cogeneration', in Pehnt, M. et al. (eds), *Micro Cogeneration - Towards Decentralized Energy Systems*, Berlin, Heidelberg, New York: Springer, pp. 87-114.

Pepermans, G., Driesen, J., Haeseldonckx, D., Belmans, R. and D'haeseleer, W.D. (2005), 'Distributed generation: definition, benefits and issues', *Energy Policy*, 33 (6), 787-798.

Perez-Arriaga, I. and Linares, P. (2008), 'Markets vs. Regulation: A Role for Indicative Energy Planning', *The energy journal*, 29 (David Newbery Special Edition), 149-164.

PIU (Performance and Innovation Unit) (ed) (2002), *The Energy Review*, London.

Pollitt, C., Bathgate, K., Caulfield, J., Schmullen, A. and Talbot, C. (2001), 'Agency Fever? Analysis of an International Policy Fashion', *Journal of Comparative Policy Analysis* (Nov 2001), 271.

Pollitt, M. (1999), *A survey of the liberalisation of public enterprises in the UK since 1979,* University of Cambridge, Working Paper, 1999/1, Cambridge.

Pollitt, M. (2008), 'Foreword: Liberalization and Regulation in Electricity Systems - How can We get the Balance Right?', in Sioshansi, F.P. (ed), *Competitive Electricity Markets: Design, Implementation, and Performance*, Oxford: Elsevier, pp. xvii-xxxiv.

Pollitt, M. (2009): The Future of Network Regulation. Presented at the conference "CRNI Annual Conference", Brussels. http://www.eprg.group.cam.ac.uk/wp-content/uploads/2009/11/future-of-network-regulation-1.pdf.

Porter, M.E. and van der Linde, C. (1995), 'Toward a New Conception of the Environment-Competitiveness Relationship', *Journal of Economic Perspectives*, 9, 97-118.

Porter, M.E. (1991), 'America's Green Strategy', *Scientific American*, 264 (4), 168.

Praetorius, B., Bauknecht, D., Cames, M., Fischer, C., Pehnt, M., Schuhmacher, K., Voß, J.-P. (2009), *Innovation for Sustainable Electricity Systems - Exploring the Dynamics of Energy Transitions*, Heidelberg: Physica-Verlag HD.

Prüggler, W., Kupzog, F., Benoît, B., Brunner, H. (2008): Active grid integration of distributed generation utilizing existing infrastructure more efficiently - an Austrian case study. Presented at the conference *"EEM 2008. 5th International Conference on European"*, Lisbon.

RAP (The Regulatory Assistance Project) (ed) (2000), *Performance-based regulation for distribution utilities*.

Rennings, K., Kemp, R., Bartolomeo, M., Hemmelskamp, J. and Hitchens, D. (2003), *Blueprints for an Integration of Science, Technology and Environmental Policy (BLUEPRINT)*.

Rhodes, R.A.W. (1996), 'The New Governance: Governing without Government', *Political Studies Association*, 1996 (XLIV), 652-667.

Riechmann, C. (2002): Strommarktregulierung in Großbritannien - Innovation ohne Ende? Presented at the conference *"Marktliberalisierung durch Netzregulierung"*, IZES and Minister für Wirtschaft Saarland, Saarbrücken.

Rip, A., Kemp, R. (1998), 'Technological Change', in Rayner, S. and Malone, E.L. (eds), *Human Choice and Climate Change*, Columbus, Ohio: Batelle Press, pp. 327-399.

Rohracher, H. (2008), 'Energy systems in transitions: contributions from social science', *International Journal Environmental Technology and Management* (Vol 9), 144-161.

Roques, F.A., Newbery, D.M. and Nuttall, W.J. (2005), 'Investment Incentives and Electricity Market Design: The British Experience', *Review of Network Economics*, 4 (2), 93-128.

Sanyal, P. and Cohen, L. (2009), 'Powering Progress: Restructuring, Competition and R&D in the U.S. Electric Utility Industry', *The energy journal*, 30 (2).

Scarsi, G.C. and Petrov, K., *Regulation by Incentives in Electricity and Gas Networks*, KEMA, mimeo.

Schoppe, S.G., Wass von Czege, A. (1984), 'Alternative Theorien über innovative Auswirkungen von Preisregulierungen', in Boettcher, E., Herder-Dorneich, P. and Schenk, K. (eds), *Jahrbuch für Neue Politische Ökonomie*, Tübingen: J.C.B. Mohr, pp. 142-156.

Scott, J. (2004): Culture & Relationships: Processes, Mindsets and Professionalism - Initial Thoughts. Presented at the conference *"Visions for Distribution Networks of the Future"*, IEE.

Scott, J., Evans, G. (2007), 'Electricity Networks: The Innovation Supply Chain', in Dieter Helm (ed), *The New Energy Paradigm*, Oxford, New York: Oxford University Press, pp. 36-62.

Scott, N.C. (2007), *European practices with grid connection, reinforcement, constraint and charging of renewable energy projects*, XERO Energy, Glasgow.

Scrase, I., Wang, T., MacKerron, G., McGowan, F., Sorrell, S. (2009), 'Introduction: Climate Policy is Energy Policy', in Scrase, I. and MacKerron, G. (eds), *Energy for the Future - A New Agenda*, Basingstoke: Palgrave Macmillan, pp. 3-19.

SDC (Sustainable Development Commission) (ed) (2007), *Lost in Transmission? The role of Ofgem in a changing climate*, London.

Sioshansi, F.P. (ed) (2008a), *Competitive Electricity Markets: Design, Implementation, and Performance*, Oxford, Amsterdam: Elsevier.

Sioshansi, F.P. (2008b), 'Introduction: Electricity Market Reform - Progress and Remaining Challenges', in , *Competitive Electricity Markets: Design, Implementation, and Performance*, Oxford, Amsterdam: Elsevier, pp. 1-23.

Sioshansi, F.P. and Pfaffenberger, W. (eds) (2006), *Electricity Market Reform - An International Perspective*, Oxford, Amsterdam: Elsevier.

Skytte, K. and Ropenus, S. (2005), *Regulatory Review and International Comparison of EU-15 Member States*, DG-GRID project report D1.

Smith, A. (2006), 'Niche-based approaches to sustainable development: radical activists versus strategic managers', in Voß, J.-P., Kemp, R. and Bauknecht, D. (eds), *Reflexive Governance for Sustainable Development*, Cheltenham, UK: Edward Elgar, pp. 313-336.

Smith, A. (2009), 'Energy Governance: The Challenge of Sustainability', in Scrase, I. and MacKerron, G. (eds), *Energy for the Future - A new Agenda*, Basingstoke: Palgrave MacMillan, pp. 54-75.

Späth, P., Bauknecht, D., Leprich, U., Auer, H. and Rohracher, H. (2006), *Integration durch Kooperation: Das Zusammenspiel von Anlagen- und Netzbetreiber als Erfolgsfaktor für die Integration dezentraler Stromerzeugung (InteKoop),* IFZ, Graz et al.

Stern, J., Levine, P. and Trillas, F. (2002), *Independent Utility Regulators: Lessons from Monetary Policy,* SSRN, Regulation Initiative Working Paper No. 52.

Stirling, A. (2009), *Direction, Distribution and Diversity! Pluralising Progress in Innovation, Sustainability and Development,* STEPS Centre, STEPS Working Paper 32, Brighton.

Stoft, S. (2002), *Power System Economics - Designing Markets for Electricity,* New York: John Wiley.

Strbac, G. (2006): Overview of innovative network concepts. Presented at the conference *"Integration of distributed generation into electricity networks"*, DG-GRID, Berlin.

Strbac, G., Jenkins, N., Green, T. and Pudjianto, D. (2007), *Review of Innovative Network Concepts,* DG-GRID project report.

Strbac, G., Jenkins.Nick and Green, T. (2006), *Future Network Technologies,* Report to DTI.

Summerton, J. and Bradshaw, T.K. (1991), 'Towards a dispersed electrical system. Challenges to the grid', *Energy Policy* (January/February), 24-34.

Surrey, J. (ed) (1996), *The British Electricity Experiment. Privatization: The Record, the Issues,the Lessons*, London: Earthscan.

Sweeney, G. (1981), 'Adoption of cost-saving innovations by a regulated firm', *The American Economic Review*, 71 (3), 437-447.

Swisher, J.N. (2001), 'Cleaner Energy, Greener Profits: Fuel Cells as Cost-Effective Distributed Energy Resources', *RMI Solutions*, Volume 17 (Nr. 3 Herbst/Winter), 10-22.

Swisher, J.N. (2002), 'Small is profitable. The economic benefits of distributed generation', *Cospp*, 3 (4), 17-27.

Takahashi, K., Baker, S. and Kurdgelashvili, L. (2005), *Policy Options to Support Distributed Resources,* Center for Energy and Environmental Policy, University of Delaware, Newark.

Tech-wise (ed) (2002), *Sustelnet: Review of current EU and MS Electricity Policy and Regulation - Denmark*, Report, Fredericia, Denmark.

The Government Office for Science (2008), *Foresight Sustainable Energy Management and the Built Environment Project*, Final Project Report, London.

Thielens, D.W. and Vaessen, P.T.M. (2005), 'The Transition of the Grid: It´s All in the Mix', *Electrical Power Quality and Utilisation Magazine*, 1 (1), 31-36.

Thomas, S.e.al. (2001), *DSM pilot actions, DSM bidding and removal of DSM disincentives from price regulation. A joint project in Italy, Germany and Austria. Part III: Price regulation and removal of DSM disincentives in monopoly segments of restructured electricity markets,* Final report.

Tidd, J., Bessant, J., Pavitt, K. (1997), *Managing Innovation: Integrating Technological, Market and Organizational Change*, Chichester: Wiley.

Truffer, B., Metzner, A. and Hoogma, R. (2003), 'The Coupling of Viewing and Doing. Strategic Niche Management and the electrification of individual transport', *Greener Management International .Special Issue on "Foresighting and Innovative Approaches to Sustainable Development Planning"*, 37, 111-124.

Unruh, G.C. (2000), 'Understanding carbon lock-in', *Energy Policy*, 28 (12), 817-830.

van der Vleuten, E. and Raven, R. (2006b), 'Lock-in and change: Distributed Generation in Denmark in a long-term perspective', *Energy Policy*, 34 (18), 3739-3748.

van der Vleuten, E. and Raven, R. (2006a), 'Lock-in and change: Distributed Generation in Denmark in a long-term perspective', *Energy Policy*, 34 (18), 3739-3748.

van Overbeeke, F. and Roberts, V. (2002), 'Active Networks as Facilitators for Embedded Generation', *Cogeneration & On-Site Power Production*, 3 (2), 37-42.

van Vliet, B. (2002), *Greening the Grid. The Ecological Modernisation of Network-bound Systems,* Wageningen: Wageningen University.

Varming, S., Gaardestrup, C. and Nielsen, J.E. (2002), *Review of technical options and constraints for integration of distributed generation in electricity networks,* Sustelnet project report.

Vinther, D. (2007): System planning - tasks and challenges. Presented at the conference *"EcoGrid kick-off"*.

Vogel, P. (2009), 'Efficient investment signals for distributed generation', *Energy Policy*, 37 (9), 3665-3672.

Voß, J.-P., Bauknecht, D. and Kemp, R. (eds) (2006), *Reflexive Governance for Sustainable Development*, Cheltenham, UK: Edward Elgar.

Voß, J.-P., Kemp, R. (2006), 'Sustainability and reflexive governance: introduction', in Voß, J.-P., Bauknecht, D. and Kemp, R. (eds), *Reflexive governance for sustainable development*, Cheltenham, UK: Edward Elgar, pp. 3-28.

WADE (World Alliance for Decentralized Energy) (ed) (2005), *World Survey of Decentralized Energy 2005*.

WADE (World Alliance for Decentralized Energy) (ed) (2006), *World Survey of Decentralized Energy 2006*.

Watson, J. (2009b), 'Is the move toward energy security at odds with a low-carbon society', in Giddens, A., Latham, S. and Liddle, R. (eds), *Building a low-carbon-future: the politics of climate change*, London, pp. 33-41.

Watson, J. (2009a), 'Is the move toward energy security at odds with a low-carbon society', in Giddens, A., Latham, S. and Liddle, R. (eds), *Building a low-carbon-future: the politics of climate change*, London, pp. 33-41.

Weber, K.M. and Hemmelskamp, J. (eds) (2005), *Towards Environmental Innovation Systems*, Berlin: Springer.

Weber, K.M. (2006), 'Foresight and adaptive planning as complementary elements in anticipatory policy-making: A conceptual and methodological approach', in Voß, J.-P., Bauknecht, D. and Kemp, R. (eds), *Reflexive governance for sustainable development*, Cheltenham, UK: Edward Elgar, pp. 189-221.

Weisman, D.L. and Pfeifenberger, J.P. (2003), 'Efficiency as a Discovery Process: Why Enhanced Incentives Outperform Regulatory Mandates', *The Electricity Journal*, 16 (1), 55-62.

Wissenschaftlicher Beirat BMWA (Wissenschaftlicher Beirat beim Bundesministerium für Wirtschaft und Arbeit) (ed) (2004), *Förderung erneuerbarer Energien*, BMWA-Dokumentation 534.

Woodman, B. (2002): *Shifting the balance of power? Renewables and distributed generation in liberalised electricity systems*. Thesis, SPRU - University of Sussex. Brighton.

Woodman, B. (2007), *Innovation in distribution networks,* Centre for Management under Regulation, University of Warwick, mimeo.

WRR (Scientific Council for Government Policy) (ed) (2008), *Infrastructure - Time to Invest*, Amsterdam.

Wuppertal Institut, DLR (DLR Stuttgart Institut für technische Thermodynamik) (ed) (2002), *Langfristszenarien für eine nachhaltige Energienutzung in Deutschland*, Berlin.

Yin, R.K. (2003), 3. ed., *Case Study Research. Design and Methods,* Thousand Oaks: Sage Publications.

Young, A. (2001), *The Politics of Regulation. Privatized Utilities in Britain,* Basingstoke: Palgrave.

List of interviewees

UK

Stephen Andrews, Director, Lower Watts Consulting, 4 April 2008

Philip Baker, Research Fellow, Exeter University, former Director of Electricity Technology, the Department for Business, Innovation and Skills, 25 September 2008

Duncan Botting, Head of Technology and Business Development, ABB, 24 April 2007

Rodney Brook, Director, Sohn Associates, 15 May 2008

Gareth Evans, Technical Advisor, Ofgem, 20 February 2007 and 30 September 2008

Gaynor Hartnell, CEO, Renewable Energy Association, 21 March 2007

Catherine Mitchell, Professor of Energy Policy, Exeter University, 23 September 2008

Andy Phelps, Head of Regulation and Dragana Popovic, Distributed Generation Engineer, Electricity Networks Association (ENA), 19 February 2007

Sarah Samuel, Team leader Energy, Transport and Buildings, Sustainable Development Commission, 15 May 2008

John Scott, Director, KEMA, former Technical Director, Ofgem, 31 March 2008

Goran Strbac, Professor of Electrical Energy Systems, Imperial College, 23 April 2007

Anthony White, Director of Research, Climate Change Capital, 27 March 2008

Denmark

Linda Aaberg, Lawyer, Danish Energy Regulatory Authority, 15 November 2007

Thomas Ackermann, CEO, Energynautics, 19 March 2008

Paul-Frederik Bach, former Planning Director, Eltra, 13 November 2007

Jakob Hanghøj, Manager Trade Department, Danish Embassy in Germany, 13 December 2006

Ole Holstroem, Specialist Electrical Power Engineering, Dong Energy Generation, 15 December 2006

Erik Leif Jacobsen, former CEO, Elsam, 14 November 2007

Niels E. Jensen, R&D Coordinator, Energinet.dk, 2 October 2008 and 12 February 2009

Per Lund, System Development Manager, Energinet.dk, 13 November 2007

John Eli Nielsen, Assistant Professor, Denmark Technical University, formerly with Eltra, 2 August 2007 and 14 November 2007

Georg Styrbro, former CEO, Eltra, 14 November 2007

Clement Johan Ulrichsen, Economist, Danish Energy Regulatory Authority, 17 September 2008

Appendix

The following questionnaires represent a generic list of questions for each of the two countries studies. For each interviewee, more specific questions were added.

Questionnaire Denmark

Technical network and system transformation in Denmark

- How would you describe the status of the system transformation process in Denmark?
- What are the different projects, how are they linked together, what is their status?
- What are the main drivers for these projects and the transformation process?
- Are there different visions for the future electricity system?

Actors

- Who are the most important actors in the transformation process?
- Are there any conflicts between actors regarding the transformation process? Are there opponents or supporters of the transformation process or different visions of the future electricity system?

Role of the government

- What is the role of the government and especially the ministry of Transport and Energy and the Danish Energy Authority?

Role of network regulation （energitilsynet)

- How would you describe the role of the regulator energitilsynet in promoting DG integration, network innovation and transformation?
- To what extent is the transformation process driven by revenue incentives? Are the regulatory incentives for network innovations?

- How would you compare this to the role of Ofgem in UK?
- What is the relationship between the government, the regulator and energinet.dk?

Role of energinet.dk

I would like to better understand the role of energinet.dk in the system transformation process. This includes

- its status as a stated-owned unbundled system operator
- How this came about? Was it influenced by the need to develop new solutions for the electricity system?
- What role this status plays in the process of network transformation?
- Why and through which mechanisms does energinet.dk influence the transformation process?

Governance of network innovation and transformation

- How would you describe the overall governance approach towards network innovations and transformation in Denmark?
- To what extent is this approach typical for Denmark?
- How would you describe the Danish approach as compared to the UK approach, where
    - DG and network innovation have been included in the incentive regulation of network operators
    - and individual actors change the network based on profit incentives?

Coordination between different actors and visions

- How are different actors that are involved in the transformation process coordinated?
- What is the role of cooperation (as opposed to coordination through markets and prices)?
- What is the relationship between energinet.dk and regional grid and distribution companies in system transformation?
- What is the role of the grid committee?

- Are there other mechanisms of cooperation between "energinet.dk", the distribution companies and other actors?
- What is the role of long-term planning? How is it done?

Alternative visions of the future electricity system

- Assuming that there are different visions of the future electricity system, how is it decided which visions to choose?
- How is uncertainty dealt with?
- Are there experiments to test different visions? Are different network operators testing different visions?

Questionnaire UK

How have DG and innovation mechanisms in network regulation developed?

- UK is the only country in Europe where the electricity network regulator has set up mechanisms specifically for DG – although there is not much DG yet on the ground. Why is this the case?
- How has the current regulatory DG policy developed?
  - actors, drivers, support, opposition?
  - Why was this specific approach chosen and not others?
- More specifically, what explains the shift of focus from DG connection to the existing network to network development and innovation?
  - Although there is no real pressure yet on the network to adapt (unlike e.g. in Denmark)

Evaluation of current DG instruments

- What do you make of the DG/innovation mechanisms within network regulation?
  - DG hybrid incentive
  - the RPZ/IFI
- How do the RPZ and IFI schemes need to be reformed?

Long-term network transformation to accommodate DG

- Would you agree that in order to promote a long-term transformation of the network, the regulatory process needs
  - be complemented by instruments that go beyond one regulatory period,
  - are not just based on financial incentives
  - 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.).
- How could such mechanisms look like?
- Are they emerging in the UK? Where and how?

- Electricity Network Strategy Group
  - To what extent is the Electricity Network Strategy Group such a cooperative arrangement to coordinate actors and provide for a forward-looking mechanism?
  - How does it work in practice? To what extent and how are the results of the ENSG translated into action?

The role of Ofgem

- What are the possibilities for the regulator to promote innovation in the liberalised system? Does Ofgem's traditionally narrow interpretation of 'economic regulation' limit its capacity to promote DG and network innovation and transformation?
- Do you see the role of Ofgem changing from a regulator mainly aiming at (short-term economic) efficiency towards a regulator
  - with a broader remit (->Utilities Act),
  - a more political role?
- To what extent is the DG and network transformation issue a driver of this development?
- How do you think the objectives and remit of Ofgem should be adapted?