CPB Discussion Paper

No 141

February 2010

Identifying options for regulating the coordination of network investments with investments in distributed electricity generation

Eva Niesten

The author thanks Rob Aalbers, Paul de Bijl, Jan Boone, and Viki Kocsis for valuable comments on earlier versions of this paper.

CPB Netherlands Bureau for Economic Policy Analysis
Van Stolkweg 14
P.O. Box 80510
2508 GM The Hague, the Netherlands

Telephone	+31 70 338 33 80
Telefax	+31 70 338 33 50
Internet	www.cpb.nl

ISBN 978-90-5833-439-8

Abstract in English

The increase in the distributed generation of electricity, with wind turbines and solar panels, necessitates investments in the distribution network. The current tariff regulation in the Dutch electricity industry, with its ex post evaluation of the efficiency of investments and the frontier shift in the x-factor, delays these investments. In the unbundled electricity industry, the investments in the network need to be coordinated with those in the distributed generation of electricity to enable the DSOs to build enough network capacity. The current Dutch regulations do not provide for a sufficient information exchange between the generators and the system operators to coordinate the investments. This paper analyses these two effects of the Dutch regulation, and suggests improvements to the regulation of the network connection and transportation tariffs to allow for sufficient network capacity and coordination between the investments in the network and in the generation of electricity. These improvements include locally differentiated tariffs that increase with an increasing concentration of distributed generators.

Key words: Distributed electricity generation, network investments, regulation
JEL code: L51; L94; Q42

Abstract in Dutch

De toename van decentrale elektriciteitsopwekking, met windturbines en zonnepanelen, vereist investeringen in het distributienetwerk. De huidige tariefregulering in de Nederlandse elektriciteitsindustrie, die gekarakteriseerd wordt door een ex post evaluatie van de efficiency van investeringen en een verschuiving van de efficiënte omzet in de berekening van de x-factor, vertraagt deze investeringen. In een gesplitste elektriciteitsindustrie moeten de investeringen in het netwerk gecoördineerd worden met de investeringen in decentrale elektriciteitsopwekking om er voor te zorgen dat de regionale netbeheerders voldoende investeren in het netwerk. De huidige Nederlandse regulering zet de netbeheerders en de decentrale producenten niet aan tot informatie-uitwisseling om zo de investeringen te coördineren. Dit artikel analyseert deze twee effecten van de Nederlandse regulering, en stelt een aantal verbeteringen in de tariefregulering voor. De netbeheerders moeten tarieven voor toegang tot het netwerk en voor het transport van elektriciteit bij de decentrale producenten in rekening kunnen brengen. Deze tarieven mogen verschillen tussen verschillende netwerkgebieden en ze mogen stijgen, bij een beperkte netwerkcapaciteit, wanneer de concentratie van decentrale opwekking toeneemt.

Steekwoorden: Decentrale elektriciteitsopwekking, netwerkinvesteringen, regulering

Contents

1	Introduction	7
2	Tariff regulation of Dutch DSOs and network investment	9
2.1	Price flexibility	10
2.2	Cost measures	12
2.3	Level of the price cap	18
3	Lack of investment coordination between DSOs and DGs	21
3.1	The electricity law on investment coordination	21
3.2	Information exchange with regulator on network investments	22
3.3	Network connection and electricity transportation for DGs	23
4	Improvements in regulating the coordination of investments	25
4.1	Matching investments in the network to distributed generation	25
4.2	Regulating the differentiated and increasing tariffs	27
5	Conclusions	29
References		31

1 Introduction

In the European electricity industries, the distribution system operators (DSOs) provide network connection and transportation services in their regional or national monopolies to the users of the network. The main function of the distribution network and the DSOs has always been to distribute electricity to consumers that is produced in large generating plants with a connection to the transmission network. The function of the distribution network will change when increasing amounts of electricity are produced at the decentralized level, and thus by small firms and electricity consumers that send their electricity to the distribution network. These small firms and electricity consumers that produce green electricity with (micro-) wind turbines and solar panels are referred to as distributed generators (DGs)[1]. The Dutch government expects that the share of green electricity in the European Union will increase to forty per cent in 2050, and that this electricity will mainly be produced by distributed generators (Ministry of Economic Affairs, 2008, p. 11). The increase in the distributed generation of electricity forces the DSOs to accommodate for increasingly larger amounts of electricity that are put on the distribution network, and to actively manage the supply and demand of electricity. This requires extensive investments in the network, that either expand the capacity of the distribution lines or that transform the distribution network into a smart grid[2] (Ministry of Economic Affairs, 2008, p. 101; Pollitt and Bialek, 2007). These investments must also enable the distribution network to cope with an increase in the consumption of electricity, which may be due to an increase in the use of electric cars and heat pumps. To make the right investment decisions on expanding network capacity, the DSOs will need information on where and by how much the distributed generation of electricity will increase. The DSOs will therefore want to coordinate their investment decisions with the investments of the DGs.

Many DSOs in the European electricity industries are regulated with incentive regulation, which focuses on increasing the efficiency of the DSOs, instead of on stimulating network investments. In addition, the European directives for the electricity industries prescribe the vertical unbundling of the distribution and transmission of electricity from the integrated energy firms, and thus require the transformation to new ways of coordinating the investments in the network with those in the generation of electricity.

This paper analyses the impact of regulation on investments in the distribution network, and focuses on the case of the Dutch electricity industry. In particular, it analyses whether the

[1] Distributed generation is defined as 'units producing power on a customer's site, and supplying power directly to the local distribution network' (Pepermans et al., 2005, p. 796).

[2] The creation of a smart grid refers to the modernization of the network with digital technology, to reduce energy costs, increase the reliability of the network, and facilitate the connection of decentralized electricity generators. For instance, a smart grid is able to communicate electricity price signals from the producers to the consumers. These price signals can stimulate consumers to use less electricity when prices are high, which reduces their energy bills, and it allows the producers to decrease their peak generating capacity. When the production of electricity is very expensive, a smart grid is able to use the electricity that is stored in, for example, electric car batteries, or it is able to reduce the load on the network. The grid's ability to adjust loads may increase the reliability of the grid. In addition, a smart grid is able to measure the electricity that the DGs put on the network at each moment in time.

current Dutch regulations stimulate investment in the network, and whether they permit the DSOs, in their investment decisions, to properly take into account the investments in distributed generation, and thus the demand for network services by the DGs. The focus is on the impact on investment of four attributes of the regulatory contract between the DSOs and the regulator: the flexibility and the level of the price cap, regulatory opportunism, and the regulatory asset base. The paper argues that the current regulations delay investment in the network, and that they are insufficient to coordinate the investments in the distributed generation of electricity with those in the distribution network. It suggests improvements to the regulation of the network connection and transportation tariffs to allow for the coordination of investments.

Studies on the distributed generation of electricity, investment in the distribution network, and changes in the regulation of the DSOs are beginning to emerge (Scheepers, et al., 2007; Cossent et al., 2009). This paper contributes to this literature by assessing the Dutch network regulations and by suggesting regulatory improvements on the basis of theoretical studies that focus on the intertemporal nature of regulating network connection and investment (Foreman, 1995; Dobbs, 2004; Guthrie, 2006). The focus on the intertemporal nature is relevant, because the regulated tariffs are for short run access to long-lived network capacity, and the investments in the network are largely irreversible (Dobbs, 2004, p. 421; Guthrie, 2006, p. 925). These studies inform the analysis of regulating the DSOs, because they show why network operators postpone investments in the network, and when regulation of the network operators will stimulate or further postpone these investments. They enable the suggestions on improving the regulation of DSOs. This paper thus also provides an empirical application of the theoretical findings of the studies by Foreman (1995), Dobbs (2004) and Guthrie (2006).

After a short introduction on the Dutch tariff regulation, section two reviews several studies that analyse the impact of tariff regulation on investment in the network, and applies the findings of these studies to the Dutch electricity industry. Section three discusses additional Dutch regulations on investment in the network, and on the connection of DGs to the network and the transportation of their electricity along the network. This illustrates that no information exchange or coordination exists between the DSOs and the DGs on investments in the network and generation. Section four presents options for improving regulation, which include network connection and transportation tariffs for the DGs that may differ across different areas within one network region, and increase with an increasing concentration of DGs. These tariffs should give the DSOs an incentive to invest in the network and allow for an information exchange between the DGs and the DSOs. Section five concludes.

2 Tariff regulation of Dutch DSOs and network investment

The tariffs that the Dutch DSOs charge to the electricity consumers for a connection to the network and for the transportation of electricity along the network are regulated[3]. The Dutch regulatory agency for the electricity industry[4], the Office of Energy Regulation, determines the price cap for these network services. The price cap in year *t* is based on the cap of year *t-1*, and is increased with a measure of inflation and a q-factor, and decreased with an x-factor, as is illustrated in the formula.

$$TI_t = \left(1 + \frac{cpi - x + q}{100}\right) TI_{t-1} \qquad (1)$$

where:

- TI_t are the total revenues of the tariffs in year *t*, which is the sum of each tariff multiplied with the volume parameter of each cost driver for which a tariff is determined. If only one network service was sold, the tariff would be determined by dividing the total revenues by the volume of that service.
- TI_{t-1} are the total revenues of the tariffs in year *t-1*
- *cpi* is a measure of inflation
- *x* stimulates the system operators to operate efficiently
- *q* indicates the change in tariffs in relation to changes in the quality delivered by the system operators in the previous regulation period[5].

The volume parameters, which are used in the calculation of the total revenues, are based on the actual volumes for which invoices have been sent in previous years (NMa, 2008, p. 95-97)[6]. The volume parameters for the fourth regulation period in the Dutch electricity industry, which lasts from January 2008 until December 2010, are based on data of 2006. The Office of Energy Regulation determines an individual x-factor for each DSO. In the calculation of the x-factors, it includes the average productivity improvement of all the DSOs in the previous regulation period. The x-factors thereby stimulate each DSO to increase its own productivity, and to decrease its operating and capital costs, at least more than the other DSOs. If a DSO wishes to increase its income, it needs to outperform the other DSOs. Similarly, the q-factor stimulates

[3] Currently, they do not charge these tariffs to the electricity generators.

[4] The Office of Energy Regulation (Energiekamer) is organized as a chamber within the competition authority (NMa). The board of directors of the NMa has mandated several tasks to the Office of Energy Regulation, but retains the final decision-making power for the regulation of the Dutch electricity industry. The Office of Energy Regulation and the NMa are here both referred to as the regulators of the electricity industry.

[5] Dutch electricity law (1998), article 41b.

[6] Dutch electricity law (1998), article 41.

each DSO to increase the quality of its network services as compared to the other DSOs. More information on the q-factor is mentioned in the box on page 12.

The relationship between the regulator and the DSOs can be summarized as a contractual relation, in which the regulator sets the tariffs that the DSOs may charge the network users (Goldberg, 1976; Williamson, 1976). Goldberg (1976) refers to these contracts between the regulator and the operators as administered contracts. These administered contracts govern the individual contracts that each network user has with a DSO. Guthrie mentions several characteristics of these administered contracts, such as the amount of freedom the regulated firm has in changing prices (the price flexibility) and the cost information that is used when the regulator sets the regulatory parameters (Guthrie, 2006, p. 930). The following subsections will discuss these two characteristics and the level of the price cap, and will analyse their effects on investment in the distribution network. In each subsection, first the literature on these effects will be presented, after which the findings of the reviewed studies will be applied to the Dutch electricity industry.

2.1 Price flexibility

2.1.1 Literature

Monopoly firms that are regulated with a price cap have more flexibility in setting their tariffs than monopoly firms that are restricted by a maximum rate of return (Guthrie, 2006, p. 930). Under rate of return regulation, the regulator determines the tariffs and an increase or decrease in these tariffs may only occur at the next regulatory hearing, while under price cap regulation, the regulated firms are free to increase (or decrease) their tariffs as long as they do not exceed the level of the price cap.

Foreman (1995) illustrates how firms that are regulated by a price cap are able to influence the height of their tariffs. He demonstrates that “the weighting scheme employed in many price-cap plans is subject to intertemporal manipulation” by the regulated firms (Foreman, 1995, p. 332). The weighting scheme refers to the weights that are assigned to each service in a basket of services, and these weights are the shares of the total revenues or of the total quantities that are generated by the services in the preceding period. If the regulated firms set a low price for a service in one regulatory period, the weight of that service (as a share of total revenues) will decrease when demand is inelastic. The reduction in the weight of that service allows the firms to increase the price of a service in a following regulatory period. This intertemporal manipulation is possible, because the price cap is the sum of the tariffs multiplied with the volume of each network service for which a tariff is determined.

Guthrie (2006) mentions that, under price cap regulation, firms may set their tariffs below the cap when demand for the services is low. When demand increases, firms will increase their tariffs until they reach the level of the price cap. He argues that because of this flexibility in setting tariffs, and because the cap affects tariffs in low and high demand states differently, the price cap accelerates investment. Monopoly firms are subject to the uncertainty of changes in demand for their services, and therefore they have an incentive to delay investments and to wait until future demand is known. Unregulated monopoly firms always have the possibility of raising tariffs when demand increases. The regulated firms are instead confronted with the price cap when demand increases, and they therefore prefer to invest early, as this allows them to sell more services and thus increase their income from the larger volume. The price cap can thus stimulate early investments in the network. Under rate of return regulation, the regulator sets the tariffs, and this effect will therefore not occur. The regulatory lags make this scheme too difficult to implement (Guthrie, 2006, p. 944)[7].

2.1.2 Dutch case

Regulated firms can have price flexibility for different periods. They may have the freedom to change their tariffs during a year, between different years or between different regulatory periods.

Every year, the Dutch DSOs send to the regulator a proposal for the maximum tariffs that they will charge their network users for a connection to the network and for the transportation of electricity. They are limited in their flexibility when proposing the tariffs, as they have to consider the x- and q-factors, and the volume parameters, which are set by the regulator, and their tariff proposal may not exceed the price cap. They may propose different tariffs for their different network services and their different types of customers, but they may not differentiate between different areas (i.e. the physical location of the customers) within their network region[8]. Within one year, the Dutch DSOs only have some flexibility in setting their tariffs by reducing them below the price cap.

The Dutch DSOs are limited in their ability for intertemporal manipulations (between different years), because of a cost principle that is included in the Dutch price-cap regulation. In their tariff proposal, the DSOs have to consider the basic rule that costs should be attributed to the cost drivers of the network services that cause these costs (Ministry of Economic Affairs, 2005, p. 4)[9]. The regulators altered the electricity law in 2004 to include this cost principle, because large cost differences between the DSOs could not be explained by objective differences between the regions (NMa, 2008, p. 18). The relation between the different tariffs that a DSO charges for the different network services that he provides should now be determined by the costs that the DSO must make to offer these services. The tariff proposals must also be consistent, which means that the tariffs may not differ a lot from one year to the next[10]. The DSOs can thus not set a low tariff for a network service in one year to increase the

[7] Although under rate of return regulation, the price flexibility is less than under price cap regulation, other effects may stimulate investments. For instance, under rate of return regulation all the risks of investing may be transferred to the consumer.

[8] Interview with Machiel Mulder of the NMa, July 7, 2009.

[9] Dutch electricity law (1998), article 41b.

[10] Interview with Machiel Mulder of the NMa, July 7, 2009.

tariff of this service in the next year, as suggested by Foreman (1995), when these tariff increases are not based on cost increases. The DSOs only have some price flexibility within a regulatory period, because they may propose to raise the tariffs due to an extensive and significant investment in the network. The Dutch DSOs have not yet asked for tariff increases that are due to an extensive investment.

Between the regulatory periods, the DSOs have some influence on the x- and q-factors: by increasing the quality of their services and increasing their investments, they may propose higher tariffs in the next period, but this is also dependent upon the performance of the other system operators. The box below discusses the quality regulation of the Dutch DSOs and their investments in the network.

Quality regulation

The q-factor has to stimulate the DSOs to optimise the quality of their transportation service. Quality is measured in terms of the reliability of the network with an index that is referred to as the system average interruption duration index (SAIDI). For each DSO, this index multiplies the number of network users that had an interruption in their electricity supply with the duration of the interruption in minutes, and these minutes are summed for each interruption. This is divided by the total number of network users of the DSO. This index of each DSO is compared to the national average. DSOs that have, on average, a higher quality than the other DSOs are given a higher q-factor, and thus higher tariffs, in the next regulation period. This quality regulation should give the DSOs an incentive to invest in the network. Meulmeester argues that this incentive is limited in the Dutch electricity industry, because DSOs will postpone investments in networks with a low chance of interruptions (Meulmeester, 2008, p. 106). Investments in these networks are not able to decrease the chance of interruptions a lot, and will therefore not increase the q-factor and the tariffs enough to justify the investment. These delayed investments are not necessarily a bad thing. The quality of the Dutch networks is still high, also when compared to many other countries (Mulder, 2009). The incentive regulation of the DSOs that is focused on increasing efficiency may, however, reduce the quality of the network (Mulder, 2009).

2.2 Cost measures

The second characteristic of the administered contracts between the regulator and the DSOs is the cost information that is used when the regulator sets regulatory parameters. A first key issue with respect to this cost information is whether a regulatory governance structure is able to restrain the opportunistic behaviour of the regulator, and thus whether it allows the DSOs to recover their sunk costs. Secondly, the determination of the regulatory asset base is important as it influences the tariffs that the DSOs may charge the network users.

2.2.1 Regulatory opportunism

Literature

Levy and Spiller (1996) argue that utility pricing is always going to have a political component, because of the wide base of domestic consumers. This makes the utilities vulnerable to administrative expropriation (Levy and Spiller, 1996, p. 3). The regulator may for instance reduce the tariffs that the firms are allowed to charge their customers, after the firms have sunk their capital in assets that cannot be re-used for other purposes. Such regulatory opportunism may delay investments or it may stimulate investments only in reversible technologies. The extent to which a regulator can transfer surplus from a firm to its customers is determined by the legal system and by the regulatory governance structure (Guthrie, 2006, p. 951; Levy and Spiller, 1994). The potential for administrative expropriation is limited when the law states that the system operators must be allowed to earn a fair rate of return. Gutiérrez (2003) has identified several attributes of a regulatory governance structure that have a positive effect on investments in the telecom industry. These include a separation of operating and regulatory activities, the creation of a regulatory body that is backed by law (instead of some minor norm), and several features of an independent regulatory agency, such as its accountability (the existence of mechanisms to resolve disputes between regulators and operators), the clarity of the regulator's roles in terms of its ability to set tariffs and fine or penalize operators, and its autonomy (limits on the government's ability to freely replace regulators and budgetary independence of the regulator) (Gutiérrez, 2003, p. 262).

Dutch case

The potential for administrative expropriation is limited in the Dutch electricity industry because the Dutch electricity law and regulations state that the DSOs should be able to earn a fair rate of return, and consequently that they should be able to attract enough capital to make the necessary investments in the network (NMa, 2008, p. 46)[11]. The regulatory governance structure in the Dutch electricity industry is characterized by several features that curtail the opportunism of the regulator. Firstly, there exists a separation between the operating activities of the energy firms and the regulatory activities of the government, which means that the government is not involved (anymore) in the management of the energy firms. Secondly, the creation of the regulatory body is backed by law: the board of directors of the competition authority is appointed as the regulator for the electricity industry by the electricity law of 1998. Thirdly, the Administrative Court for Trade and Industry (College van Beroep voor het Bedrijfsleven) must guarantee the accountability of the regulatory agency. This court resolves disputes between the DSOs and the regulator[12]. Fourthly, the regulator's roles in terms of its ability to set tariffs and fine or penalize operators are clear. The responsibilities and powers of the regulator are specified in the electricity law, and the regulator may give firms a binding

[11] Dutch electricity law (1998), article 41.

[12] Dutch electricity law (1998), article 82.

instruction, oblige them to abide by the rules in combination with a penal sum, or oblige them to pay a fine. Finally, the autonomy of the regulatory agency is promoted when the officers in the agency are protected from unfair dismissal (Stern and Holder, 1999, p. 21). The Dutch Minister of Economic Affairs has the power to propose the suspension or the resignation of the members of the board of the competition authority, only if he is of the opinion that the board neglects to perform its tasks[13]. The autonomy of the regulator could, however, be improved, because the budget of the competition authority is part of the budget of the Ministry of Economic Affairs (Algera, 2002, p. 105)[14]. Every year, the competition authority sends a report to the ministry with an estimate of the necessary financing for the coming year[15], but it is the minister who determines the budget of the competition authority. Only a small part of the budget of the Office of Energy Regulation is paid by the industry. The energy firms pay a fee for their licence to supply electricity. The quality of the regulatory governance structure is said to increase when the electricity regulator is funded from licence fees, instead of from the government budget (Cubbin and Stern, 2004, p. 18).

2.2.2 Regulatory asset base

Literature

The regulatory asset base "is the actual cost of the firm's physical capital adjusted for depreciation" (Guthrie, 2006, p. 935), over which the regulated firms, and in this case the DSOs, may earn a rate of return. It influences the tariffs that the operators may charge their network users. A regulatory asset base can be calculated in different ways, for instance, by adding the costs that the system operator has incurred when investing in the assets, or by estimating the current value of these investments. This first type can be a calculation on the basis of the historic costs of the investments, or a calculation in which the regulator only includes those costs of assets that are used and are considered useful. An example of the second type is pricing based on TELRIC (total element long run incremental cost), in which prices are based on the cost structure of an efficient cost-minimizing firm with an optimally configured network built with the current technology (Guthrie, 2006, p. 936).

A regulatory asset base that is calculated with the historic costs of the system operators gives the operators the largest incentive to invest early when the costs of investing decrease over the regulatory period, because the operators can transfer all of the costs and the risks associated with the investment to the consumers. When the regulator uses ex post information to decide on the usefulness of an investment and to calculate the regulatory asset base, this may result in a lower increase of the asset base than the actual costs of the investment. The risks of future unforeseen circumstances, such as a lower demand, are now borne by the system operators. The operators may therefore delay their investments (Guthrie, 2006, p. 956). When

[13] Wet van 9 december 2004, article 3.

[14] Relatiestatuut EZ-NMa, article 2. www.ez.nl.

[15] Wet van 9 december 2004, article 5i.

the regulatory asset base is calculated with pricing based on TELRIC, investments are also likely to be postponed. This type of calculation increases the uncertainty for the system operators, and this uncertainty does not only include the potential future changes in the demand for network services, but also the future changes in technology.

Guthrie mentions that the incentives to invest early may also be reduced under regulation that calculates the regulatory asset base with the historic costs of the operators. This may occur when the costs of investing increase over the regulatory period, which stimulates the operators to invest later when higher costs lead to a higher asset base. The opposite may also occur. When the costs of investing decrease over the regulatory period, the system operators will want to invest early.

Dutch case

In the Dutch electricity industry, the regulatory asset base is calculated on the basis of the historic costs of the operators (NMa, 2008, p. 45). This asset base was first calculated in 2000 for the first regulatory period, and for each subsequent year the investments in this year are added to the asset base of the previous year, and the depreciations are subtracted. Guthrie has argued that this type of calculation of the asset base gives the system operators the largest incentive to invest in the network. The calculation of the x-factor in the Dutch electricity industry may, however, delay the investments for two reasons.

Firstly, the x-factor accounts for technological improvements in the electricity industry. The income that the system operators may earn at the end of a regulatory period is equal to the expected efficient costs at the end of this period. Under incentive regulation, these expected efficient costs are lower than the efficient costs at the end of the previous regulatory period, because the system operators are expected to improve their productivity. Changes in sector average productivity include the aggregated frontier shift and the catch-up rates that are realised by the individual firms. The frontier shift represents the rate of productivity improvement (by the frontier firm) that is due to the general technological progress within the sector. The catch-up describes the productivity gap between an inefficient firm and the frontier firm (Oxera, 2008, p. 4). The productivity changes are used to calculate the x-factor. The investments in the network are therefore subject to the risk of technological changes, because these changes may increase the x-factor, and reduce the system operators' income. As a result, the system operators may not recover all of their investment costs, and therefore postpone their investments in the network.

Secondly, Meulmeester (2008) argues that the benchmark in the Dutch tariff regulation leads to system operators postponing their investments. The benchmark is the average productivity of the DSOs, to which each DSO compares its performance. PV_t in formula 2 is the average annual productivity change of all the DSOs.

$$PV_t = \left\{ \frac{\dfrac{\sum_i C_{i,t-1}^{WACC,2^e}}{\sum_i SO_{i,t-1}} - \dfrac{\sum_i C_{i,t}^{WACC,2^e} \cdot \dfrac{1}{(1+cpi_t)}}{\sum_i SO_{i,t}}}{\dfrac{\sum_i C_{i,t-1}^{WACC,2^e}}{\sum_i SO_{i,t-1}}} \right\} \tag{2}$$

SO is the output of the DSOs. The change in average productivity is measured by the change in operational costs and capital costs (C^{WACC}), which includes the investments of the DSOs. When capital costs are higher in period *t* as compared to period *t-1,* due to investments in the network by the DSOs, the average productivity decreases. A lower average productivity decreases the x-factor in the next period, as is illustrated in formulas 3 and 4.

$$EI_{i,2010}^{x} = \frac{\sum_i C_{eff,i,2007}}{\sum_i SO_{i,2007}} \cdot (1 - PV_{2007-2010})^3 \cdot SO_{i,2007} \tag{3}$$

$$(1 - x_{i,2008-2010})^3 = \frac{EI_{i,2010}^{x}}{BI_{i,2007}^{x}} \tag{4}$$

BI are the revenues at the beginning of a regulatory period, in this example, 2007. *EI* are the revenues at the end of the regulatory period, in this example, 2010. The calculation of the revenues for 2010 includes the expected average productivity change from 2007 until 2010, which is based on the realized average productivity change in the previous regulatory period (2003-2006). A lower productivity change in this period (from 2003 to 2006) will lead to a higher *EI* for 2010, and thus to a lower x-factor, as is illustrated in the formulas 3 and 4. A lower x-factor increases the tariffs. The productivity change in one period thus determines the tariffs for the next period.

If in a particular period one firm decides not to invest, while all other firms do invest, this firm that does not invest is rewarded for the investments of the other firms with a higher tariff. This DSO that does not invest, has lower capital costs and thus a higher productivity than the other DSOs, and is able to earn a higher income from its lower costs and the higher tariffs. The other firms are not fully compensated for the costs of their investments (Meulmeester, 2008, p. 98), because of this one firm that is not investing and is thus not raising the capital costs, nor the tariffs. The firms will therefore have an incentive to wait with investing until the other firms do. This impact on investments in the Dutch electricity industry is mitigated by the type of benchmarking that is used. The x-factor is based on the average performance of the Dutch system operators, and not on the best performing system operator. In an industry with a best performance benchmark, one firm that does not invest and thus has much lower costs in one regulatory period than the other firms, sets an unrealistic efficiency goal for the next period. With such a benchmark, it may even become impossible for system operators to invest in the network (NMa, 2008, p. 64). In a benchmark of averages, the efficiency goal is also determined by all the other firms that may have incurred costs for investments, and the x-factor will therefore not be as high as under a best performance benchmark.

In the Dutch electricity industry, two types of network investments are distinguished: normal investments and extensive investments. The regulator treats these two types of investments differently in terms of the costs that the system operators are allowed to recover from these investments. Normal investments are added to the regulatory asset base once every regulatory period, and are subject to the frontier shift and the catch-up rate. The tariff regulation of the extensive investments is somewhat different. In contrast to normal network investments, extensive investments may lead to an increase in the tariffs during a regulatory period (Algemene Rekenkamer, 2009, p. 48). The system operators may increase their tariffs when the Ministry of Economic Affairs has decided that the extensive investment is necessary and useful. At the request of the system operators, the Ministry of Economic Affairs will decide ex ante on the necessity and the usefulness of the investment, and thus before the operators begin investing in the network[16]. The uncertainty for the system operators on investing in the network therefore decreases, as they are sure to be compensated for their investments with higher tariffs. But the Office of Energy Regulation still has to determine whether the investments have been performed efficiently. It hires experts to evaluate the efficiency of the investments[17]. Only after the regulator has decided on the efficiency of the investments, will the system operators know by how much their tariffs will increase. Following the argument of Guthrie (2006, p. 956), the Dutch system operators will postpone their investments as a result of this ex post decision on efficiency. The uncertainty about the expert's judgement and about future changes that may alter the efficiency of the investment, leads the firms to delay investments. The costs of these extensive investments are subject to the frontier shift, but not to the catch-up rate, because the regulator has already determined the efficiency of the investments[18].

The changes in productivity as a result of technological progress, which are captured by the frontier shift, may become increasingly relevant in the future electricity industries. Innovations in smart grids may improve the productivity of system operators and reduce their network costs much faster than the regular expansions of network capacity.

[16] Interview with Machiel Mulder of the NMa, July 7, 2009.

[17] Interview with Machiel Mulder of the NMa, July 7, 2009.

[18] Interview with Machiel Mulder of the NMa, July 7, 2009.

2.3 Level of the price cap

2.3.1 Literature

Dobbs (2004) studies the effects of the level of a price cap on the investments by regulated monopoly firms. Three different levels of a price cap are distinguished: a cap that is set at the competitive price level under certainty, a cap at the competitive price level under uncertainty, and a cap at the monopoly price under uncertainty. Dobbs finds that even if the price cap is optimally chosen, the monopoly firms will generally under-invest and impose quantity rationing on their customers (Dobbs, 2004, p. 421). The optimally chosen price cap, at which investment attains its maximum level, is a price cap that is set at the competitive price level under uncertainty. Uncertainty refers here to the risk that demand will fall. Because of this risk, the monopoly firms have an incentive to postpone investments. Deferring investment can make sense because, if demand does fall in the future, with less installed capacity future tariffs are less depressed (Dobbs, 2004, p. 422). Monopoly firms have this possibility of delaying investments as they face no competition from other firms. If the demand for the network services rises, monopoly firms will at first prefer to increase the tariffs of their services over investing in new capacity, until the price cap is binding. They may also reduce the quantity of the network services they supply to their customers, or reduce the quality of their services in order to reduce demand. Only after demand has increased sufficiently, will the monopoly firms invest in new capacity[19].

Guthrie relates these findings to the timing of investments. He states that if the price is capped at a high level (at the monopoly price), the cap will not bind in a high or low demand state, and thus will have no impact on investment timing. If the price cap is set at a low level, the cap may postpone investments (Guthrie, 2006, p. 944). A cap that is set at a moderate level may encourage earlier investment, when compared to unregulated monopoly firms that always have an incentive to postpone investments. The key is to choose a price cap that will not be binding in a low demand state, but will bind when demand is high and capacity low, as this makes it more expensive for firms to delay investments (Guthrie, 2006, p. 944). When demand increases, the unregulated monopoly firms may increase their income from higher tariffs, but the regulated firms confront the price cap and must earn a higher income from selling a larger volume. They can only sell a larger volume of their services when they have invested in the network.

2.3.2 Dutch case

The Dutch DSOs are subject to the uncertainty of changing demand. When the volume that is sold by a system operator drops from, for instance, 100 (in period *t-1*) to 98 (in period *t*), the

[19] Investment reduces to zero when the WACC is set too low and the firms are thus insufficiently compensated for their risk. Investment converges on that of the unconstrained monopoly firm when the cap is set at the monopoly price level under uncertainty (Dobbs, 2004, p. 433).

total revenues decrease in period *t*. As is illustrated on page 9, the tariffs for period *t* are calculated by dividing the total expected revenues for period *t* by the volume of period *t-1*. The cap is, however, set on the tariffs and not on the total revenues. The DSOs thus charge the regulated tariffs to the consumers, and when these consumers start requesting less of the network service, the volume sold will drop and thus the total revenues decrease. The DSOs cannot increase their tariffs during a period as a result of a reduction in volume. In addition, the expected revenues in period *t+1* will decrease, because these revenues are the product of the period *t+1* tariffs and the volume of the period *t*. The tariffs in period *t+1* are not increased to compensate for this volume decrease[20].

Recently, the Dutch regulator for the electricity industry concluded that the four largest DSOs earned higher profits in the years 2004 and 2005 than the fair rate of return that was used in the calculation of the price cap (NMa, 2007, p. 3). From 2001 until 2003, the DSOs have benefited from extra revenue, in the range of 3 to 5 per cent of total asset value, as a result of lowered x-factors (Nillesen and Pollitt, 2004). The regulator has pointed to three reasons for this difference between the profits and the fair rate of return: the larger volumes of network services that were delivered by the DSOs, the faster increase to an efficient level of production by the DSOs, and the different accounting rules that were used by the energy firms as compared to those requested by the regulator. These three reasons are considered to be the result of the current regulatory framework, and are believed to be undesirable (NMa, 2007, p. 3).

Despite these high profits, the replacement investments in the Dutch network were lower than the depreciations of the network assets from 2002 until 2006 (Mulder, 2009). Dobbs (2004) and Guthrie (2006) illustrate that investments may be postponed, because of a price cap that is set below the competitive price level under uncertainty. Another reason for the low investments may be that there was enough distribution capacity available, as is illustrated by the ability of the system operators to sell larger volumes of the network services. Or the network investments may be postponed, because ex post information is used to regulate the system operators (Guthrie, 2006, p. 956). This use of ex post information increases the uncertainty for the regulated firms. In the method decision of 2008, the Dutch regulator stated that it would use the observations on high profits in its decisions on regulation for the new regulatory period (NMa, 2008, p. 28). The Dutch system operators may postpone their future investments in the network, because the regulator has indicated to use ex post information to determine the tariffs.

In sum, the Dutch DSOs are limited in their flexibility when proposing the tariffs. They have to consider the x- and q-factors, the volume parameters, and the price cap that are set by the regulator. They have no freedom to manipulate the height of the tariffs between different years. They may only set their tariffs below the price cap. If the regulator sets this cap at the competitive price level under uncertainty, it may in the future stimulate early investments in the

[20] The Dutch transmission system operator (TenneT) does not have this volume risk: an increase or decrease in volume is compensated for by lower or higher tariffs, respectively. TenneT is regulated on the basis of its revenue.

network. The determination of the regulatory asset base and the regulated tariffs, which include the ex post evaluation of the efficiency of investments, the frontier shift in the x-factor and the average benchmarking, do, however, postpone investments in the network. In addition, the following section demonstrates that there is a lack of information exchange and coordination between the DSOs and the DGs on investments in the network and in distributed generation. This may also postpone investments in the network.

3 Lack of investment coordination between DSOs and DGs

Before the liberalization of the electricity industries, the decisions on investments in the network and in the generation of electricity were often coordinated internally. It has been argued that the integration of generation and the network into a hierarchy reduces the total investment costs (Joskow, 1996). The European directives on the unbundling of the electricity industries have, however, prohibited this internal coordination of investment decisions (EC, 1996; 2003). The following subsections will show that very few regulations have provided an alternative to this vertical integration, to coordinate the investments in the network with those in the generation of electricity. The current electricity law only refers to an obligation of the system operators to take into account the distributed generation, but the industry lacks a specific set of rules on how this should be done (section 3.1). The DSOs do not exchange any information with the generators on investments. The law only requires that the system operators inform the regulator of the investments in and the capacity of the distribution network (section 3.2). The rules on connecting the DGs to the network and on transporting their electricity do not allow for an information exchange between the generators and the DSOs (section 3.3).

3.1 The electricity law on investment coordination

The electricity law does not prescribe the coordination of investments in the network with those in the generation of electricity by the DSOs and the DGs. Article 16 of the law only states that the DSOs have a duty to construct, maintain and renew the network, while taking into consideration measures in the area of sustainable electricity, energy reduction, and distributed generation of electricity in order to decrease the necessity of investing in new production capacity. But the industry lacks a specific set of rules on how the system operators should consider the distributed generation. Article 24 of the law even states that the DSOs may refuse to transport the electricity of DGs when there is not enough capacity available on the network. Two articles in the electricity law refer to reports by the Ministry of Economic Affairs that only publish the intention to alter the rules in the electricity industry with respect to investments in the network and in the generation of electricity.

Article 4a of the electricity law states that the Ministry of Economic Affairs analyses data on the security of supply in the electricity industry, and in particular on the construction and the construction plans of the network and the generating capacity, and the quality and maintenance of the networks. Every year the ministry publishes a report on this analysis, which includes measures that are (to be) taken with respect to the construction plans and the quality of the network. In order to perform this analysis, the ministry may set additional rules, in ministerial regulations, on the information that the various parties in the electricity industry have to disclose to the ministry[21]. The investments in new generation capacity are not regulated

[21] Dutch electricity law (1998), article 4a.

anymore. The Dutch government does not decide where and when new electricity plants will be build. Only if the Minister of Economic Affairs believes that too little new generation capacity is constructed in order to ensure the security of supply, he can open a tender for new generation capacity (EC, 2003).

Article 2 of the electricity law refers to an energy report with which the Ministry of Economic Affairs communicates its energy policy to the various parties in the electricity industry. At least every four years, the ministry publishes such a report that includes an agenda on what the ministry wants to achieve in terms of the stimulation of a reliable and sustainable energy supply. In the energy report of 2008, the ministry focuses on distributed generation and smart grids. It presents three future scenarios for the energy industry, of which one includes a substantial increase in the distributed generation of electricity, small consumers that turn into producers of electricity, the increase in the generation of green electricity with wind turbines and solar panels, and investments in smart grids. This report states that the ministry aims to adjust the regulations for the energy industry to stimulate the development to a smart grid that allows for the connection of distributed generators of green electricity (Ministry of Economic Affairs, 2008, p. 21). The ministry also aims to stimulate a better cooperation between network users and system operators to allow for good estimates of the needed future network capacity, and to enable the necessary investments in the network (Ministry of Economic Affairs, 2008, p. 104). These two reports express the intention to alter the rules, but currently the Dutch electricity industry lacks explicit regulations that coordinate the investments in generation with those in the network.

3.2 Information exchange with regulator on network investments

The electricity law stipulates what information the DSOs have to disclose to the competition authority with respect to the investments in and the capacity of the distribution network. Firstly, article 19b of the law states that the DSOs have to inform the competition authority every year of their investments in the network during the previous year, and on the financial means that they have available for maintaining, constructing, and repairing the network[22]. Secondly, article 21 of the law states that the system operators should have an effective system that ensures the quality of their network services, and that they should have sufficient capacity to meet the total demand for the distribution of electricity. Every two years, the system operators have to send a report to the competition authority on their quality and capacity of the distribution of electricity. The competition authority asks for this information on investments and the capacity of the distribution network to verify if the efficiency incentives (the x-factor in the price cap) decrease

[22] Dutch electricity law (1998), article 19b.

investment. It thus aims to check whether the system operators are investing enough in the distribution network[23].

3.3 Network connection and electricity transportation for DGs

As of January 2009, the transportation tariffs for the Dutch consumers are calculated on the basis of the capacity of the connection (instead of the consumption of electricity), and the consumers therefore pay a fixed monthly fee for the transportation of electricity. They do not pay additional network connection or transportation tariffs when they start producing electricity. In case the connection of distributed generation leads to higher network costs, the system operators will not have a financial incentive to connect the DGs to the network and to transport their electricity[24]. The system operators only get paid the fixed monthly fees by the electricity consumers for the transportation of electricity that is taken out of the network, and they do not get paid for the transportation of electricity that is put on the network. A potential consequence is that the system operators with a large number of DGs connected to the network, may not have sufficient financial means to invest in smart grids or to expand the capacity of their network (NMa, 2009, p. 27). Scheepers et al. (2007) also argue that price cap regulation makes too little allowance for the cost impacts of distributed generation on the DSOs, which may entail aversion on the part of the DSOs to facilitate the network integration of new distributed generation plants (Scheepers et al., 2007, p. 7). Although the system operators have an obligation to connect the electricity generators, they may postpone investments in the network, impose a quantity rationing, and they may refuse to connect the DGs to the network due to unavailable network capacity. Regulation should stimulate the operators to invest sufficiently in the network and it should aim to avoid excessive quantity rationing.

[23] Interview with Machiel Mulder of the NMa, July 7, 2009.

[24] Interview with Machiel Mulder of the NMa, July 7, 2009.

4 Improvements in regulating the coordination of investments

New regulations in the Dutch electricity industry will have to enable the coordination of investments in the network with those in the distributed generation, to allow for sufficient network capacity in the future and the development of smart grids. These regulations must stimulate an information exchange between the DSOs and the DGs. Elaborate ex ante information disclosure mechanisms, in which the generators inform the DSOs on their future investments well in advance of construction, will not work well at this decentralized level. Consumers and small firms must be able to decide from one day to the next to connect their wind turbines or solar panels and to start producing electricity, especially in an industry in which policy makers aim to promote the production of green electricity. The DSOs and the generators may therefore exchange information through network connection and transportation tariffs, as this information exchange takes place immediately.

4.1 Matching investments in the network to distributed generation

Currently, the Dutch DSOs may lack sufficient incentives to connect the DGs to the network, and consequently, they may lack sufficient incentives to expand the capacity of the network for the connection of the DGs. The tariff regulation for a network connection and the transportation of electricity may be adjusted in several ways to improve the coordination of investments in the network with those in the distributed generation and to stimulate the operators to invest in the network.

Firstly, new regulations should allow the DSOs to charge the DGs for a connection to the network and for the transportation of electricity. The tariff for the connection of the DGs may consist of a one-time contribution and/or monthly payments. The one-time contribution is paid to construct the connection, or to make adjustments to the connection when the generator already has a connection as a consumer of electricity. A smart meter may for instance be installed. This one-time connection charge can be a shallow contribution, as is currently the case for the Dutch consumers with a connection below 10 MW. The monthly contributions are paid for maintaining the connection. The transportation tariff may consist of a tariff that is dependent upon the transportation of electricity (to cover the costs of network investments) and a tariff that is not dependent upon the transportation of electricity (to cover the costs of the connection register and the administration of measurement data)[25]. The DGs will thus have to pay for the transportation of electricity that they put on the network. This tariff modification will provide the DSOs with an incentive to connect the DGs.

Secondly, the network connection and transportation tariffs for the DGs may be allowed to differ across different areas within one network region, as the impact on network costs of the

[25] Tariff Code Electricity 2009, article 3. www.energiekamer.nl.

connection of distributed generation can be location-specific (Cossent et al., 2009, p. 1152; Scheepers et al., 2007, p. 44; Pollitt and Bialek, 2007, p. 15)[26].

Thirdly, the DSOs should be able to increase the connection and transportation tariffs in a particular area of the network when the penetration and concentration of DGs increase in this area, because the network costs for the DSOs increase when the distributed generation increases. The tariffs should only be increased when the available distribution capacity is limited. Scheepers et al. (2007) identify three types of network costs that are affected by increasing levels of distributed generation. These are reinforcement costs (the costs of investing in the network), energy losses on the network, and changes in the capacity replacement value. Reinforcement costs and energy losses increase when the penetration and the density of distributed generation increase (Scheepers et al., 2007, p. 26). Cost savings from delayed capacity replacement decrease when distributed generation increases. Because DGs are located close to the consumers of electricity, one can expect that smaller amounts of electricity need to be transported along the network, and that therefore capacity replacement costs drop. Scheepers et al. find that this only holds for small amounts of distributed generation, but when the penetration of distributed generation increases, the cost savings from delayed capacity replacement drop (Scheepers et al., 2007, p. 31).

There are several advantages to these differentiated and increasing tariffs. A first advantage is that the increased income from the higher tariffs can be used by the operators for investing in the network. Jamasb et al. (2005) and Pollitt and Bialek (2007) propose the implementation of locationally differentiated pricing within distribution networks, as this signals the best places to build new capacity, and it can "be used to collect some revenue, which can be applied to finance new investments" (Pollitt and Bialek, 2007, p. 16-17).

Secondly, system operators that have some flexibility in setting their tariffs may decrease their tariffs when demand for the network services is low and increase their tariffs when demand is high. This induces early investment in the network (Guthrie, 2006). System operators are more likely to use this price flexibility for the tariffs of the DGs when compared to the tariffs of the consumers, because of the difference in price elasticity between these two types of network users. The demand for network services by the consumers is very inelastic, as they will not (immediately) stop consuming electricity when tariffs for the transportation of electricity rise. This inelastic demand may persuade the operators to keep the tariffs for the consumers close to the cap. The demand for network services by the DGs is less inelastic. The (potential) generators may decide not to start producing electricity and not to supply electricity to the network when the connection tariffs for distributed generation are high. The generators may, in the future, store the electricity instead of putting it on the network. The system operators are

[26] These tariffs for a network connection and the transportation of electricity for the small consumers of electricity do not need to differ between different areas.

affected by this larger elasticity of demand of the generators. Because the generators will not request a network connection when the tariffs for the connection are high, and they will request a connection when the tariffs are low, the system operators are given an incentive to adjust the tariffs.

Thirdly, these increasing and differentiated tariffs may not only stimulate the operators to invest in the network, but they may also allow for a better match between the supply and demand for network services. When the tariffs are increased in parts of the network with a larger penetration and concentration of distributed generation, the demand for a network connection in those parts of the network will decrease in the future. If the tariffs are set close to the global price cap, tariff increases in one area must require tariff decreases in another area of the network. The DSOs may prefer to decrease the tariffs in those areas where there are few DGs and demand for the network services is still low. These low tariffs may in the future stimulate the connection of DGs to the network. The flexibility in setting the tariffs by the DSOs thus stimulates a more even spread of distributed generation across the region or country. It will avoid the situation of very rapidly increasing demand for network services in a particular part of the network, up to the point where the DSOs do not have any distribution capacity available, and the investments in the network lack behind the investments in generation.

When the distributed generation increases in a part of the network, the tariffs may be increased for all the DGs in that part of the network, or they may be increased only for the new DGs that are requesting a connection. The one-time contribution for the connection can only be increased for the new DGs. In the future, a transportation tariff that is calculated for the amount of electricity that is distributed along the network (and thus in kWh) may be increased for all the generators in the particular area of the network. Such a tariff can only be used when smart meters are installed that measure the electricity that is put on the network by the DGs. This will stimulate the DSOs to use their price flexibility and thus to increase and decrease the tariffs. The generators may react to the changes in the tariffs by adjusting their production.

Several disadvantages of these differentiated tariffs can also be mentioned (Hiroux and Saguan, 2009, p. 5). Differentiated tariffs may increase the transaction costs for the DGs and the DSOs, and they may increase the risk of revenues for the DGs. Another issue concerns the fact that the tariffs for the DGs should not decrease the production of green electricity. The national governments may solve this issue through incentive schemes, such as feed-in tariffs or feed-in premiums for producers of green electricity.

4.2 Regulating the differentiated and increasing tariffs

These differentiated and increasing tariffs must be regulated, because the DSOs have a regional monopoly for the distribution network. In order to control an abuse of this monopoly position, the regulator may impose on the DSOs the restriction that they may only raise their tariffs when there is little capacity on the network, and the regulator may also oblige the DSOs to invest in the network when they have increased their network tariffs.

In recent literature, several suggestions have been made on how to set the regulated tariffs for the network connection and the transportation of electricity of the DGs and how to account for the increasing network costs. Scheepers et al. (2007) suggest to add the costs that are attributable to distributed generation to the regulatory asset base, or to include a measure of the penetration of distributed generation in the productivity benchmark. The x-factor is determined by the productivity change of the DSOs, and this productivity change is the mutation in the standardized economic costs divided by a composite output variable. Scheepers et al. suggest to add the units of electricity of the DGs that are distributed or the capacity of distributed generation on the network to this output variable (Scheepers et al., 2007, p. 45). In these two options, the costs of distributed generation are thus subject to the x-factor. The results of section two of this paper do, however, illustrate that this will delay investments in the network. The frontier shift that is included in the x-factor, the ex post efficiency evaluation of investments, and the average benchmarking postpone investments in the Dutch distribution network.

The costs of distributed generation can therefore better be included in the tariff regulation outside of the benchmarking procedure. This will avoid a delay in network investments. This can be achieved by including a z-factor in the calculation of the tariffs, and thus by increasing the cap for the different operators outside the benchmarking procedure. The z-factor represents the quantifiable regional difference factors. These factors differ between the DSOs and lead to higher costs that cannot be reduced with the x-factor. In the Dutch tariff regulation, the water crossings have been identified as a quantifiable regional difference factor (The Brattle Group, 2006). In this case, the capacity of distributed generation that is connected to the network or the amount of electricity of DGs that is distributed along the network can be used as measures for calculating the z-factor.

The suggestions for improving the regulation of the DSOs and the DGs are also relevant for other European electricity industries. In 2009, the European Parliament and Council issued a directive on the promotion of the use of renewable energy (EC, 2009). This directive stimulates the production of green electricity at the decentralized level, and refers to granting priority or guaranteed access to the network and priority dispatch for producers of green electricity. Scheepers et al. (2007) mention, however, that the regulatory regimes in the EU Member States do not yet address the issue of integrating rising levels of distributed generation in system operation. Moreover, they make too little allowance for the cost impacts thereof for the DSOs (Scheepers et al., 2007, p. 7).

5 Conclusions

The tariff regulation in the Dutch electricity industry has focused on increasing the efficiency of the system operators, which has led to lower tariffs for the electricity consumers. Currently, the regulator is investigating whether the regulation of the Dutch electricity industry should be altered, as it has observed that replacement investments in the network lag behind depreciation and that the incentive regulation may reduce the quality of the network.

This paper has argued that in a future with increasing amounts of distributed generation, regulation should stimulate the coordination of investments in the network with those in distributed generation. The coordination may take place through network connection and transportation tariffs for the DGs. The DSOs must have some flexibility to alter the height of these tariffs, and to set different tariffs in different network areas. The regulator must set the price cap at the competitive price level and take into account that network costs may increase when distributed generation increases. This type of tariff regulation can lead to a better match between the supply and demand for network services, avoid a situation of too little network capacity, and stimulate the DSOs to invest in the network.

Future price cap regulation should properly take into account the levels of uncertainty, in terms of changes in demand and technology, which are present in an electricity industry characterized by increasing amounts of distributed generation and developments to smart grids. If the regulator does not consider these uncertainties, and thus sets the price cap too tight, this can have a negative effect on the investments in the distribution networks.

References

Algemene Rekenkamer, 2009, Tariefregulering Energienetbeheer, brief van de Algemene Rekenkamer aan de voorzitter van de Tweede Kamer der Staten-Generaal, nr. 31901, Sdu Uitgevers, The Hague.

Algera, W., 2002, Is de ZBO status voor de NMa nu al wenselijk?, in J. van de Gronden and R. Widdershoven, eds., *Mededingingsautoriteiten als Zelfstandig Bestuursorgaan: Onafhankelijk Toezicht?*, pp. 95-121, Kluwer, Deventer.

Cossent, R., T. Gomez and P. Frias, 2009, 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*, vol. 37, no. 3, pp. 1145-1155.

Cubbin, J. and J. Stern, 2004, Regulatory effectiveness: the impact of good regulatory governance on electricity industry capacity and efficiency in developing countries, discussion paper series, 4-4, London Business School, London.

Dobbs, I., 2004, Intertemporal price cap regulation under uncertainty, *The Economic Journal*, vol. 114, no. 495, pp. 421-440.

EC, 1996, Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity, EC, Brussels.

EC, 2003, Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC, EC, Brussels.

EC, 2009, Directive 2009/28/EC of the European Parliament and of the Council of 23 April on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, EC, Brussels.

Elektriciteitswet 1998, Wet van 2 juli 1998, houdende regels met betrekking tot de productie, het transport en de levering van elektriciteit.

Foreman, R., 1995, Pricing incentives under price-cap regulation, *Information Economics and Policy*, vol. 7, no. 4, pp. 331-351.

Goldberg, V., 1976, Regulation and administered contracts, *The Bell Journal of Economics*, vol. 7, no. 2, pp. 426-448.

Guthrie, G., 2006, Regulating infrastructure: the impact on risk and investment, *Journal of Economic Literature*, vol. 44, no. 4, pp. 925-972.

Gutiérrez, L., 2003, The effect of endogenous regulation on telecommunications expansion and efficiency in Latin America, *Journal of Regulatory Economics*, vol. 23, no. 3, pp. 257-286.

Hiroux, C. and M. Saguan, 2010, Large-scale wind power in European electricity markets: Time for revisiting support schemes and market designs? *Energy Policy*, in press.

Jamasb, T., K. Neuhoff, D. Newbery and M. Pollitt, 2005, Long-term framework for electricity distribution access charges, report prepared for and commissioned by Ofgem, 5(7), Electricity Policy Research Group, Cambridge.

Joskow, P., 1996, Introducing competition into regulated network industries: from hierarchies to markets in electricity, *Industrial and Corporate Change*, vol. 5, no. 2, pp. 341-382.

Levy, B. and P. Spiller, 1994, The institutional foundations of regulatory commitment: a comparative analysis of telecommunications regulation, *Journal of Law, Economics and Organization*, vol. 10, no. 2, pp. 201-246.

Levy, B. and P. Spiller, 1996, *Regulations, Institutions, and Commitment - Comparative studies of telecommunications*, Cambridge University Press, Cambridge.

Meulmeester, P., 2008, Lange termijn investeringen in elektriciteitsnetwerken niet gegarandeerd, *TPEdigitaal*, vol. 2, no. 2, pp. 93-113.

Ministry of Economic Affairs, 2005, Regeling van de Minister van Economische Zaken van 9 januari 2005, nr. WJZ 5001015, houdende regels inzake tariefstructuren en voorwaarden voor elektriciteit, Ministry of Economic Affairs, The Hague.

Ministry of Economic Affairs, 2008, Energierapport 2008, Ministry of Economic Affairs, The Hague.

Mulder, M., 2009, Investments and regulation of distribution networks in the Netherlands: do we need to improve the regulatory framework?, presentation at workshop on Regulating Investments, NMa, The Hague.

Nillesen, P. and M. Pollitt, 2004, The consequences for consumer welfare of the 2001-2003 electricity distribution review in the Netherlands, CMI working paper, University of Cambridge.

NMa, 2007, Onderzoeksrapport inzake de winsten van energiebedrijven, nr. 102362/93, NMa, The Hague.

NMa, 2008, Besluit van de Raad van Bestuur van de Nederlandse Mededingingsautoriteit als bedoeld in artikel 41, eerste lid van de Elektriciteitswet 1998, methodebesluit elektriciteit vierde periode, nr. 102610_1 / 27, NMa, The Hague.

NMa, 2009, Bespiegelingen op de toekomst van de regulering van het netbeheer, NMa, The Hague.

Oxera, 2008, Should DTe adjust expected productivity growth for catch-up effects when setting the X-factor?, Final report prepared for DTe, April 2008, Oxera, Oxford.

Pepermans, G., J. Driesen, D. Haeseldonckx, R. Belmans and W. D'haeseleer, 2005, Distributed generation: definition, benefits and issues, *Energy Policy*, vol. 33, no. 6, pp. 787–798.

Pollitt, M. and J. Bialek, 2007, Electricity network investment and regulation for a low carbon future, working paper 0750, CWPE, Cambridge.

Scheepers et al., 2007, Regulatory improvements for effective integration of distributed generation into electricity distribution networks, ECN, Petten.

Stern, J. and S. Holder, 1999, Regulatory governance: criteria for assessing the performance of regulatory systems, An application to infrastructure in the developing countries of Asia, Regulation Initiative Discussion Paper Series, 20.

The Brattle Group, 2006, Regional differences for gas and electricity companies in The Netherlands, The Brattle Group, London.

Wet van 9 december 2004, houdende wijziging van de Mededingingswet in verband met het omvormen van het bestuursorgaan van de Nederlandse mededingingsautoriteit tot zelfstandig bestuursorgaan.

Williamson, O., 1976, Franchise bidding for natural monopolies: in general and with respect to CATV, *Bell Journal of Economics*, vol. 7, no. 1, pp. 73-104.