Social cost benefit analysis and energy policy

by

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Michiel
Declaration

I, Michiel de Nooij, confirm that this dissertation is my original work and a product of my own research endeavors. It includes outcome of work done in collaboration with Barbara Baarsma, Carlijn Bijvoet, Gabriël Bloemhof, Harold Dijk, Carl Koopmans, Weero Koster, Rogier Lieshout, Han Slootweg, and Cecilia van der Weijden, as declared in the preface. All sentences, passages or illustrations quoted in this dissertation from other people’s work have been specifically acknowledged by clear cross-referencing. A full list of the references employed has been included.
I further declare that this dissertation is not and has not been submitted at any other university for review.

Michiel de Nooij
May 22, 2012
Declaration on Joint Authorship

Several articles in this thesis are joint work. The following paragraphs lay out for each article the contributions of the several authors.

The first article “The Value of Supply Security, The Costs of Power Interruptions: Economic Input for Damage Reduction and Investment in Networks” is joint work with Carl Koopmans and Carlijn Bijvoet. Carl Koopmans developed the idea, while Carlijn Bijvoet and Michiel de Nooij did the calculations and drafted parts of the first draft. Michiel de Nooij made the successive drafts which were refined with comments from the other two authors.

The second article “Optimal blackouts: Empirical results on reducing the social cost of electricity outages through efficient regional rationing.” was joint work with Rogier Lieshout and Carl Koopmans. Michiel de Nooij set up the research, Rogier Lieshout made the calculations in close collaboration with Michiel de Nooij, and Carl Koopmans assisted with the literature and commented on the drafts. Michiel de Nooij drafted the published article. The revisions of the paper were realized jointly by alternating the draft between the three authors.

The third article “Development and application of a cost-benefit framework for energy reliability using probabilistic methods in network planning and regulation to enhance social welfare: the N-1 rule.” is joint work with Barbara Baarsma, Gabriël Bloemhof, Han Slootweg and Harold Dijk. Han Slootweg provided the information on the case included. Gabriël Bloemhof and Harold Dijk were responsible for the cost and probability figures and made the first probability calculations. Barbara Baarsma and Michiel de Nooij wrote the section on the costs of supply interruptions. For the academic paper Michiel de Nooij made the first draft and finalized the article based on comments from co-authors. When drafting the published article it turned out that it was necessary to completely rewrite the probability calculation and thus the social cost benefit analysis. Michiel de Nooij was the first to discover this need and made all necessary adjustment.
The fourth article “Divide and Rule, The economic and legal implications of the proposed ownership unbundling of distribution and supply companies in the Dutch electricity sector.” was co-authored by Barbara Baarsma, Weero Koster and Cecilia van der Weijden. Weero Koster and Cecilia van der Weijden wrote the legal part, while Barbara Baarsma and Michiel de Nooij jointly wrote the economic part. The introduction and conclusion was joint work of all authors. The revisions of the paper were realized jointly by all authors.

The fifth article “Divorce comes at a price: An ex ante welfare analysis of ownership unbundling of the distribution and commercial companies in the Dutch energy sector.” was joint work with Barbara Baarsma. Michiel de Nooij made all the calculations, gathered the literature and drafted the first version. Barbara Baarsma rewrote and shortened the draft. Michiel de Nooij made the final version ready.

The sixth paper “Social cost-benefit analysis of electricity interconnector investment: A critical appraisal” is single-authored by Michiel de Nooij.
Summary

The energy sector has changed considerably over the past few years, with more changes to come. Both liberalisation and the trend towards a less CO2-intensive society require a lot of different policy measures. Policymakers’ choices impact society; most policies benefit some actors but hurt others. This uneven distribution of effects makes it difficult for the government to choose the best welfare-maximizing policy. A social cost benefit analysis (SCBA) can help in this choice. A SCBA quantifies and values all of a policy’s effects for the whole society, and thus not only for the decision maker. This thesis contains six papers that focus on three policy topics and starts with two introductory chapters.

Chapter 1 discusses market failure as a reason for government intervention in the energy sector and how SCBA can be useful here. This chapter also introduces the six papers included in this thesis to highlight the overarching insight about the usefulness of SCBA and to emphasise the contributions of these papers to the academic debate.

Chapter 2 focuses on SCBA. First, the main method is described. This is followed by a critical assessment of SCBA and a discussion about the choice of alternatives and design of the counterfactual, valuing non-market goods, the distribution of effects, valuing effects over time (the discount rate), and uncertainty and risk. Chapter 2 concludes with a discussion of the main alternatives to SCBA and describes why SCBA should be preferred.

Chapter 3 studies the value of supply security. It estimates the costs of power interruptions for the Netherlands in terms of lost production and lost leisure time. Large differences in damage are found between sectors, regions and periods. Furthermore, the chapter shows that electricity outages caused by electricity shortages create huge transfers, while outages created by network failures do not create transfers. These estimates can be used to make optimal decisions in the case of electricity shortages and to optimise investments in the network.
Chapter 4 analyses how a Transmission System Operator can optimise an unavoidable blackout using the costs of supply interruptions. This paper explores the cost difference between efficient regional rationing (minimising social costs by rationing regions with low costs first) and random rationing (not taking social costs into account). The value of lost load calculations from Chapter 3 are refined for this purpose. In the Netherlands, efficient rationing can reduce social costs by 42 to 93 percent.

Chapter 5 uses the costs of supply interruptions to calculate the costs and benefits of a specific investment in the high voltage grid. The Dutch electricity grids must be able to maintain supply if one component fails (known as the N-1 rule), even in maintenance situations, unless the costs exceed the benefits. This study developed a method to operationalise the ‘unless the costs exceed the benefits’ clause, which was new to the rule. This chapter uses an actual case to prove that the method is indeed practical and that it is highly unlikely that N-1 during maintenance in all cases will enhance welfare.

Chapter 6 is the first of two papers analysing the unbundling of the energy distribution companies in the Netherlands. The economic and legal issues at stake are analysed, leading to the conclusion that important steps in the decision to unbundle were taken without evidence that this would increase Dutch welfare. Chapter 6 concludes that a SCBA is therefore necessary.

Chapter 7 presents an ex ante SCBA of unbundling the distribution grids in the Netherlands. All costs and benefits are included in the calculations, such as the benefits of improved competition, easier regulatory oversight, security of supply and the permanent and one-off reorganization costs. The conclusion is that it is unlikely that this unbundling act would enhance welfare.

Chapter 8 examines the economic analysis (SCBA) underlying two decisions to build an interconnector (NorNed and the East-West Interconnector) in Europe. The main conclusion is that current interconnector and transmission investment decisions in Europe are unlikely to maximize social welfare. To conclude, two research recommendations are derived.
1 Introduction

Setting the background

The energy sector has changed considerably over the past few years, with more changes to come. One major development is that the electricity and gas sectors are being liberalized: energy users may now choose their supplier, entry into the generation and retail markets is allowed, and distribution grids and transmission grids are regulated more stringently to increase efficiency. Another more recent development is a transition towards a less CO$_2$-intensive society by increasing energy efficiency and decarbonizing the remaining energy use (by using more renewable energy sources such as wind energy). These changes require a lot of different policy measures and the choices made by policymakers impact society. Most policies benefit some actors but hurt others. For example, companies may benefit from a subsidy scheme but the taxpayers must pay the costs. This thesis predominantly deals with three issues in the currently changing energy sector and policy choices in this area which attracted a lot of policy attention in the Netherlands and elsewhere:

- How much reliability should an electricity grid deliver? Is more reliability better or should more priority be given to lower costs for the end-users? This trade-off must be solved at a general level because the connection of customers to the same grid makes individual quality choice impossible. The government should set the right reliability level or the efficient incentives for the energy companies. Energy companies will try to reduce their costs and thus their reliability if they cannot pass on the costs to their customers, and if they can pass on all costs to the end–users, the energy companies have an incentive for too high reliability.

- Should the government spur competition in the electricity and gas sectors by forcing ownership unbundling between the grid operators and the commercial companies in the value chain? Or are the costs of reorganizing and the loss of information exchange between generation and grid larger than the benefits of more competition and thus more efficiency?
• Is a new high voltage electricity interconnector between two countries good for the electricity users who will pay the price, directly or indirectly, if the revenues from trade are lower than the costs? What are the benefits exactly: only the revenues from trade, or also an increase in competition and thus efficiency even if the line is not used at all? How does investing in transmission capacity influence private sector investments and what is the impact on the desirability of new interconnector capacity?

To solve these three issues, a social cost benefit analysis (SCBA)\(^1\) will be introduced in this thesis, which can help in choosing the welfare maximizing policy by quantifying and valuing all effects of a policy for the whole society rather than only the effects for the decision maker. This thesis is a critical reflection on the usefulness of social cost benefit analysis in general, and the applicability of the SCBA in the energy sector in particular.

**Outlook of the thesis**

The section 1.2 discusses in more detail why SCBA is applied to real world problems. Section 1.3 provides an overview and briefly outlines the major findings of the six papers included in this thesis. Chapter 2 discusses the SCBA methods and alternative methods in more detail. The six following chapters contain the six papers on the costs of supply interruptions of electricity (Chapter 3 till 5), the welfare effects of ownership unbundling (Chapters 6 and 7) and the welfare effects of new interconnectors (Chapter 8), which all deal with certain issues of the changing energy sector and which apply the SCBA to the issues already mentioned in the introduction.

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\(^1\) In the literature, ‘Social cost benefit analysis’ is also referred to as ‘cost benefit analysis’ or ‘benefit costs analysis’. The order of the words has no real impact. The term ‘social’ is used here to stress that not only the effects for the decision maker are taken into account, but all effects in society.
1.1 Government intervention in the energy sector and social cost benefit analysis

Why do economists apply SCBA?

In general, economists see markets as efficient ways of providing goods and services. However, markets may fail. As a result of market failure, a socially desirable service (that is, one whose social benefits exceed social costs) may not be offered privately because it is unprofitable for firms. This can be a reason for government intervention to improve welfare. However, government intervention is not without costs (e.g., the government has to pay civil servants to make and enforce new rules, or it must pay for a subsidy). Sometimes other actors in society incur a cost as well, for example, if new rules restrict their behaviour or if taxes increase (which benefits the government). Because a new policy has both costs and benefits for society, a SCBA can help in choosing the policy that is best for welfare. A SCBA adds up all the costs and benefits for the whole society. This includes not only the government’s costs and benefits but those of companies and households, such as – in the energy sector - the value of lost load or the effects of a new interconnector for the energy companies and the energy users. If benefits exceed costs, a government intervention is said to be welfare improving et v.v. Because a SCBA can compare different forms of policies, it not only helps to determine whether government policy is welfare improving but can also help to determine which form, quantity or price (i.e., tax) is best for welfare. Redistribution between different actors might result in policies whose costs exceed the social benefits.

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3 Economists mostly distinguish between five types of market failure: public goods, external effects, failure of competition, information asymmetry, and macroeconomic fluctuations in output and employment. See, for example, Inman (1987) and Stiglitz (1988, p. 71-80).

4 Other possible reasons for government intervention are: the definition and enforcement of ownership rights, which is a prerequisite for the market to function; the government’s desire to increase or decrease the consumption of specific goods (i.e., paternalism); or the government’s desire to redistribute welfare.

5 See, for example, Winston (2006, esp p 2-3) and Salanié (2000, p. 44).
It is difficult for economists to judge redistribution (i.e., it is difficult to value and include it in the aggregate outcome of a SCBA). However, a SCBA can help clarify the redistribution, leaving it to the politicians to decide which redistribution is desirable and how the redistribution balances against the measure’s costs and benefits. The whole thesis can be understood as a critical reflection on the usefulness of social cost benefit analysis for the purpose of informing governments about the welfare implications of possible choices.

**What reasons, such as market failure, underlie the SCBA’s in this thesis?**

As market failures are a starting point for performing a SCBA in this thesis, they will be briefly discussed in the following section. Market failures in the energy sector are occurring because the security of the energy supply is a public good, positive external effects are existing, and electricity grids are natural monopolies.

Chapters 3 and 4 describe how to calculate the value of electricity supply interruptions and use this value in case there is a sudden electricity supply shortage. During a shortage, the system operator has to ration some users to prevent the whole system from collapsing. Here, the market failure is an extreme form of a competition failure; it is impossible to arrange a market that can respond quickly enough given the technical characteristics of electricity.

Chapters 3 and 5 describe how the value of supply interruptions is used to optimize investments in the grid. Here there are two market failures. The first market failure is that security of supply is a public good. Two characteristics of a public good are that it is nonrivalrous (one person’s consumption does not lower another one’s consumption possibilities) and nonexcludable (one person cannot prevent anyone else from benefiting from a public good). Consequently, people will not pay enough for the good but will try to free-ride on the contributions of others. If left to the market, public goods will be undersupplied. Reliability of the grid is such a public good. The second market failure is that electricity and gas grids are a natural monopoly, that is, it is most efficient (the long run average costs are lowest) if all production is supplied by one company. This can be the case in capital intensive industries with large economies of scale. Given that
everyone uses electricity, this gives distribution system operators and transmission system operators market power which they can abuse to increase the price or to reduce quality. Regulation of such monopolies, not only of price but also of quality, is welfare improving.

Chapters 6 and 7 investigate a change in market structure, ownership unbundling, which means that the grid-operating companies are no longer part of the commercial energy companies who generate or retail electricity. The market failure at hand is a failure of competition. If only one or a few firms are active in a market they might have market power: they might be able to reduce their output and increase their profits by charging a higher price than the marginal costs. In economic terms, allocative and productive efficiency will not be realized. Generation and retail (i.e., the commercial functions of the value chain) are, in principle, competitive and in most countries several companies are active. In the transmission and distribution grids, the economies of scale are so large that only one company is active (i.e., a natural monopoly). Because the grid companies were part of the same holdings as some of the generation and retail companies, the grid companies could use their market power to give the commercial companies of their own holding a competitive advantage. Unbundling was aimed at removing this possibility and incentive. Unbundling also aimed at simplifying and thus strengthening the regulation of the monopolistic grid companies.

Chapter 8 studies investments in high voltage transmission capacity between countries, such as interconnectors, which are impacted by two market failures: a lack of competition and external effects. Mostly, these investments are made by the transmission system operators (TSO’s). These TSO’s are natural monopolies, which are regulated to increase cost efficiency and to prevent overinvestment (e.g., gold plating). Whether or not an interconnector investment improves social welfare on the benefits of trade caused by the price differences between the markets (i.e., caused by differences in the composition of the generation capacity, natural endowments and uncorrelated variability in, for example, wind power), the benefit for supply security, and the generation companies’ effect on competition (an interconnector increases the geographical market and, potentially, the number of competitors). Some of these effects,
like security of supply and more competition, are an external effect for the TSO’s, which means that they would invest less than is socially desirable if they only take their own costs and benefits into account.

### 1.2 Introduction of the papers in this thesis

This section introduces the six papers included in this thesis, to highlight the overarching insight about the usefulness of SCBA, and to underline the contributions of these papers to the academic debate.

#### 1.2.1 Chapter 3: The value of supply security, the costs of power interruptions: Economic input for damage reduction and investment in networks

The central question of Chapter 3 is how large are the costs of electricity supply interruptions for society (companies and households)? This information is needed to answer the question of how much supply security is optimal, which requires a trade-off between the costs of supply interruptions and the costs of measures to increase supply security. This trade-off is present in the regulation of the distribution companies where both costs and quality are important. But this trade-off is also present in the non-market mechanisms of which many are still in place or are imposed on the electricity markets (Joskow and Tirole, 2007, p. 60-61).

Valuing reliability of energy supply is, in essence, valuing a non-market good, for which several methods are available, each with advantages as well as disadvantages (see Chapters 2–4; Sintef, 2010, p. 63 and further; Tol, 2007). Here, the production function approach is used, which estimates how much production and leisure is lost during an outage, values these effects (value added respectively hourly wage net of taxes), and then aggregates these as the value of supply interruptions. This approach uses statistical information and assumptions, like that all production is lost during an outage, no other productive activity can be done during the outage, and no substantial material damages occur. These assumptions can be debated. For example, not all production is electricity-dependent. However, activities are more electricity-dependent than often thought. This method is relatively easy to apply. In contrast to other methods, it is able to include the
society-wide effects of interruptions, and it can calculate the costs per sector and per region.

The other methods to value supply interruptions have serious drawbacks as well. The market behavior method which uses revealed preferences, like the expenditures on backup facilities, has the drawback that not enough investments are done to derive the value of supply interruptions. One drawback of the contingent valuation method and the conjoint method is that response rates are often very low\(^6\) often making reporting at a detailed geographical level or sectoral level impossible. The last two methods require careful drafting of the questions to avoid misunderstanding or strategic or protest answers. Conjoint questions give a more reliable response, while technical requirements and costs go up. The most interesting, but expensive and labour intensive follow up would be a questionnaire to compare the outcomes and assumptions of all methods. Such a questionnaire would include willingness-to-pay questions, conjoint questions and questions about the substitution, material damages, timing of the damage, electricity use within service sectors, how crucial it is to have any power, how long starting-up takes, and so on.

This chapter shows that supply interruptions are costly and that the costs vary considerably between sectors (e.g., manufacturing, agriculture, services and the government), regions and times. On average, about half the cost of a supply interruption is lost leisure.

Other follow-up research should be about useful applications of the concept of the Value of Lost Load (VOLL). For example, the VOLL might be useful to determine the correct level of capacity payments in generation (Kirschen and Strbac, 2004b, p. 220), because energy only payments as is customary in Europe might be insufficient to warrant enough investments in peak and super peak generation (Stoft, 2002, p. 144).

\(^6\) The response rates for companies in Baarsma and Hop (2009) and Kema (2004) are seven and five percent respectively.
These estimates can be the basis for a SCBA which makes decision making for policy makers aiming at maximizing social welfare possible. Chapters 4 and 5 contain such SCBAs.

### 1.2.2 Chapter 4: Optimal blackouts: Empirical results on reducing the social cost of electricity outages through efficient regional rationing.

In case of emergency, the grid operator may have to ration electricity use in specific areas to balance demand and supply in the rest of the grid. This chapter compares the social costs of: (i) efficient rationing in which municipalities with a low VOLL are rationed first; and (ii) random rationing where rationing is done without taking the VOLL into account. By comparing these two rationing schemes a SCBA of different rationing mechanisms is made.

A rationing about the size of a large generator unit failing during four hours is simulated for the Netherlands. To calculate the damage of efficient rationing, the VOLL of all municipalities is calculated (methodologically identical to Chapter 3) and the municipalities are ranked according to their VOLL, and the municipality with the lowest VOLL are rationed first. For random rationing, the amount of power to be saved is multiplied by the average Dutch VOLL. Unsurprisingly, efficient rationing has lower social economic costs. The magnitude of the difference is surprising: on average, efficient rationing saves 88 percent of the costs of random rationing.

Crew et al. (1995) already theoretically showed that efficient rationing can improve welfare compared to random rationing. Serra and Fierro (1997) found that for a long lasting production shortage, the outage cost in Chilean industry fell by more than 50 percent when the distribution was based on minimizing economic cost instead of proportional to demand. Chapter 4 contributes to the literature by showing empirically how large this welfare effect can be, including welfare costs for services and households. Serra and Fierro (1997) used sectoral rationing. Here, zonal rationing is studied, in which customers are interrupted based on their location not on their value of having power, because it is the most common and quickest form of rationing and thus most relevant for sudden shortages.
Improving the VOLL estimates at the municipal level requires better electricity use data and better value added data, preferably for each municipality. Ideally, these would be made by the statistical office, since they have access to more data directly (like the data from the tax office). Such refinements are unlikely to change the conclusion that efficient rationing is substantially less costly than random rationing, but these refined methods might improve efficient rationing.

Improving the estimates could also be using a non-linear cost-duration function, which now assumes damage to be linear to the duration of the outage (see KEMA, 2004, p. 20; Sintef, 2010, p. 112; and Billinton, 2001). This might help to optimize the period individual areas are blacked out before the outage is rolled on towards the next area.

Further research on how to implement better rationing mechanisms is desirable, especially if smart meters are installed. Theoretically, rationing using individual mechanisms is more efficient than the efficient zonal rationing studied here (Joskow and Tirole, 2007; Chao and Wilson, 1987). One should also ask whether more detailed rationing schemes are socially attractive given that they require households and companies to reveal their VOLL. To do so, they need to spend time and efforts to think about their VOLL, especially since they never thought about it. Given that rationing in western countries is extremely rare, the benefits of more efficient rationing might not justify these extra costs for users.

Finally, a compensation scheme for interrupted users might increase public support for efficient rationing. How this should be done is left for further research.

1.2.3 Chapter 5: Development and application of a cost benefit framework for energy reliability using probabilistic methods in network planning and regulation to enhance social welfare: The N-1 rule.

Chapter 5 investigates whether bringing a part of the grid in compliance with N-1 during maintenance improves welfare? Initially, the Dutch rule was that high voltage electricity networks consisting of N components should be able to supply power if one component fails even in a maintenance situation (the so-called ‘N-1 during
maintenance rule’). This rule was changed by adding ‘unless the costs exceed the benefits’.

This change is relatively small: if grid operators decide to invest, they are still not required to make a SCBA. Economically it would be more logical to require grid operators to always underpin investment proposals with a SCBA. This small change can only be explained by political motives, which are not discussed in official documents.

In network planning, deterministic rules such as the ‘N-1 during maintenance criterion’ are often used (Joskow and Tirole, 2005, p. 254). Deterministic rules do not take the costs and benefits into account, but they are easy to apply and compliance is relatively easy to check. Probabilistic criteria take the probabilities for specific events, such as a supply interruption (IEA, 2005, p.127-135) into account. ‘N-1 during maintenance, unless the costs exceed the benefits’ is such a probabilistic criteria. This requires complex calculations and more inputs, such as failure rates and component repair times, and outage costs. Probabilistic measures are not new (i.e., Nippert, 1997; Chowdhury and Koval, 2001). However, these applications do not always involve the cost of supply interruptions to the end-user.

The core of the SCBA in this chapter is a calculation of the expected costs and expected benefits of a specific investment. For the maintenance and investment costs engineering estimates are available. The expected benefits are more uncertain: it requires determination of the area affected by the investment, estimation of the VOLL for that area and calculation of the change in probability of an interruption due to an investment (and the expected duration of that interruption). The VOLL used is based on three studies (Chapter 3; Kema, 2004; and Baarsma and Hop, 2009) done more or less simultaneously in the Netherlands. The results of these studies are remarkably close.

Chapter 5 shows that some investments that are required under N-1 during maintenance do not pass a social cost benefit analysis, so adding a welfare criterion to the

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7 This is the author’s expert judgment since there is no formal test to determine whether or not the differences in outcome are small.
requirements for an investment is welfare improving. It also shows that the benefits were less than one percent of the costs. This case shows that the exact value attached to a non-market good may not matter. For any reasonable estimate of the VOLL, the cost will exceed the benefits by far, so difficulties in valuing a non-market good should not stop the analysis.

In Chapter 5, a linear relationship between outage costs and duration is assumed. However, such a linear relationship might not always hold, for example, if the outage duration exceeds the normal outage duration by much. If a tail fails, repair might take much longer than it takes to restore the electricity supply in a ring structure. The outage costs might increase strongly after, for example, a day, when the outage might become socially unacceptable. If that is the case, ‘N-1 during maintenance’ can be more attractive than calculated in Chapter 5. Unfortunately, no information about the cost-duration relationship after 24 hours is known. See for studies of outages of up to 24 hours for example, Baarsma and Hop (2009), Kema (2004), Sintef (2010, p.112 and further), and Billinton (2001). Only a small percentage of the outages last longer than 24 hours; 90 percent last less than four hours (EnergieNed, 2008, p. 38). De Nooij et al. (2009a) also discussed the impact of the duration on the cost of a supply interruption for two tails that had just experienced an outage of more than 50 hours.

1.2.4 Chapters 6 and 7: An ex ante welfare analysis of ownership unbundling of the distribution and commercial companies in the Dutch energy sector

In 2008, the Dutch government decided to implement ownership unbundling, legally forbidding the grid companies (both distribution and transmission companies) to be part of a company that also owns commercial activities in the energy sector (mostly supply/retail or generation). Chapter 6 argues that a SCBA was necessary for policy makers to choose the policy that maximizes welfare but at that moment was impossible to make because too much information was still missing. Chapter 7 presents later research containing that SCBA to answer the question whether this policy will contribute to Dutch welfare. Therefore, both papers are discussed jointly.
Ownership unbundling has costs and benefits, which are difficult to estimate. The main benefit is that unbundling prevents integrated energy companies from using the grid, which is a natural monopoly, to discriminate in favour of their own generation and retailers. This increases competition in generation and retail and thus efficiency, which will lower the costs for end-users. At the same time, unbundling simplifies regulatory oversight, making the distribution grid companies better focused and thus more efficient. These benefits come at a cost: there are reorganization costs in the beginning and higher costs afterwards because synergy effects might be missed. Most likely, the costs will exceed the benefits.

Because the calculation was subject to substantial uncertainty, three scenarios were calculated in this chapter. Uncertainty could have been reduced by adopting alternatives such as tightening regulations to reap the most benefits at lower costs or waiting to see whether other European countries would follow the Dutch policy proposal. However, the politicians felt that the costs of not having unbundled directly were too high.

In chapter 7, both the consumer and producer surplus and gains are aggregated to total welfare, which is the most common approach in SCBA’s. Sometimes a lower weight is used for the effects for companies. This can be motivated by companies being owned by richer people who have a lower marginal utility of money (because marginal utility of money decreases if one has more of it) or by companies being owned by foreign residents. Determining the weight is difficult. In this case, both motivation to give companies a lower weight in the calculations do not apply: the energy companies were owned by the Dutch municipal and provincial governments, which pass on their costs and benefits to their citizens.

A SCBA helps to focus research on the effects that matter most. In the unbundling discussion, much attention was paid to almost irrelevant details, like the costs of legal cases. Note that the legal cases themselves might be highly relevant for a proper decision, but the costs of the legal cases are small compared to the other costs and the costs are therefore irrelevant for a proper decision. Other effects did not get the attention they deserved, like estimating the permanent reorganization cost and the benefits of
more competition. If the SCBA was made earlier in the debate, more time for this research would have been available. The following valuations are still subject to substantial uncertainty and therefore deserve more research.

First, the benefits of more competition are estimated and included, but are still rough estimates (see also Chapter 8). It is unclear how much ownership unbundling will increase competition. For example, it is unclear how much cross-subsidies and anti-competitive behaviour the integrated companies showed, or what their exact incentives to do so were (Willems et al., 2008). Also, it is unclear how much increased competition will increase efficiency. A limited number of studies try to value an increase in efficiency through more competition. A well known study is Newberry and Pollitt (1997), which is an ex post study of liberalising an electricity market (in their case the British market). Brunekreeft (2008) ex ante estimated the competition effect of ownership unbundling at the transmission level, using the residual supplier index as calculated by London Economics (2007). Unfortunately, this index of competition has no direct link to unbundling the TSO or Distribution System Operator, but it is a step forward.

Second, the estimation of synergy effects is based on the Deloitte and Roland Berger reports and the judgments of the Ministry of Economic Affairs (CPB) as well as the own judgment of the authors of chapter 7. The wide gap between the first and the final estimates underlines the need to better understand synergy effects.

Third, the impact of changing technology, like smart meters or small scale generation, on markets with or without unbundling, which Künneke and Fens (2007) started to analyze, deserves more attention. New technologies may simplify the detection of abuse of the distribution grid to hinder competition or might increase the importance of a well-managed grid.
1.2.5 Chapter 8: Social cost benefit analysis of electricity interconnector investment: A critical appraisal.

This paper examines the SCBA made by transmission system operators and regulators underlying two decisions to build an interconnector (NorNed and the East-West Interconnector) in Europe. The main aim of the chapter is to study the lessons of these two case studies for future decisions. This chapter critically reviews the methods and assumptions used, and makes proposals for improvement. The chapter includes back-of-the-envelope calculations to estimate the size of effects not included in the original SCBA and calculations of the effect of different assumptions for effects included. This chapter shows that the analysis underpinning these decisions is incorrect on several accounts. It is therefore unlikely that they support efficient investments in interconnectors (i.e., welfare maximizing decisions).

For transmission investments, several discussions on investment decisions exist, for example Kirschen and Strbac (2004b, Chapter 8). Littlechild (2004) analysed an Australian investment decision and found that not all relevant alternatives were included, leading to a wrong investment decision. This chapter is the first to add a detailed analysis of two actual European investments to the literature.

Chapter 8 discusses the SCBA’s made to underpin the decisions. It does not look at how the regulation of the TSO’s can be done so that they will invest efficiently (see Hogan et al. 2010; Rosellón and Weigt, 2011) or how that regulation can trigger TSO’s to invest efficiently which increases in relevance due to the need for large investments to accommodate renewable energy (see Brunekreeft and Meyer, 2011). Chapter 8 leaves a detailed analysis of the models used to calculate the revenues from trade for future research. A first step would be to compare these models with Parail (2009).

Both SCBA’s differ substantially in approach. Apparently there is no standard approach for interconnector investments. Both SCBA’s can be criticized in some aspects, leading to a potentially false conclusion. The biggest improvement in interconnector evaluation is to come from scientific progress, on two topics especially. First, a better understanding of the effect of interconnectors on increased competition and the effect of
more competition on the efficiency of generators is needed. Second, the effect of interconnection on generation investments needs to be estimated, both in terms of the location choice and the quantity and types of generation investment. Van der Fehr and Sandbråten (1997) already modelled the connection of an electricity system with fossil-based prices to a system where the price was hydropower determined (like the NorNed cable). Still, the impact of the interconnection on generation investment was not included in the SCBA of NorNed. Both effects are difficult to quantify and value and can be substantial.
2 Social cost benefit analysis: Main method and alternatives

This chapter builds the basis to understand the SCBA applied in chapter 3 to 8. The first section (2.1) describes what a SCBA is and the critical steps required. The second section (2.2) discusses five themes which the papers (Chapters 3 to 8) have shown to be crucial in SCBA. The last section of this chapter (2.3) discusses alternative techniques to SCBA, and their drawbacks.

2.1 The method of social cost benefit analysis

Many texts about SCBA exists. The main ones used for this section are Brent (2006), Salanié (2000) and especially Layard and Glaister (1994). Also a Dutch guidebook written for infrastructure investments is useful; see Eijgenraam et al. (2000).

Not all authors writing about social cost benefit analysis clearly define it; the descriptions used in the literature differ from each other and are complementary. Salanié (2000) does not give a definition. For example, Layard and Glaister (1994, p. 1) describe SCBA as ‘do a project if its benefits exceed its costs and not otherwise. Applying this rule to all possible choices generates the largest possible benefits given the constraints within which we live.’ Eijgenraam et al. (2000, p. 54) define SCBA as ‘a confrontation of all costs and benefits experienced by all parties in the (national\(^8\)) community associated with the implementation of a project expressed in monetary terms, supplemented by (preferably quantitative) information on impacts which cannot reliably be expressed in monetary terms’. According to the Benefit-Cost Analysis Center (2012), a social cost benefit analysis ‘measures in monetary terms of willingness to pay for a change by those who will benefit from it, and the willingness to accept the change by those who will lose from it. The use of monetary terms provides a common

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\(^8\) Mostly the national community is taken as basis for evaluating the welfare effects of a project. It is also possible to use a regional or a supranational community (like the European Union) as basis.
metric. Its purpose is not to price everything, but rather to order choices in a way that is informative about social choices for decision makers.’

Brent (2006, p. 5) has the most detailed description:

A social cost benefit analysis maximizes the present value of all benefits less that of all costs subject to specific constraints. All benefits and costs are to be included: private and social, direct and indirect, tangible and intangible. Benefits and costs are given by the standard principles of welfare economics. Benefits are based on the consumer’s willingness to pay for the project. Costs are what the losers are willing to receive as compensation to give up the resources. The social discount rate (which includes the preferences of future generations) is to be used for discounting the annual net-benefit stream. Constraints are not allowed for separately, but are included in the objective function. For example income distribution considerations are to be included by weighting the consumer’s willingness to pay according to an individual’s ability to pay. A fund’s constraint is handled by using a premium on the costs of capital, that is the social price of capital is calculated which would be different from its market price.

Based on this literature, a social cost benefit analysis:

- Orders possible projects in a way that is informative about social choices for decision makers;
- Finds that a project is attractive if its benefits exceed its costs;
- Includes the effects to society, not only the private effects to the decision maker;
- Uses willingness to pay and willingness to accept to quantify costs and benefits. These values differ from market prices, which may give a wrong indication of the value of a product for the users;
- Uses opportunity costs;
- Focuses on monetary values, not because they are a goal in themselves. Monetary values are attractive because they help to aggregate and compare effects; and
- Uses the social discount rate rather than the interest rate to aggregate effects over time.
The necessary steps in a social cost benefit analysis

De Nooij (2009) and Eijgenraam (2000) define several steps for a social cost benefit analysis.¹

1. Analysis of the problem at hand and investigation of the different technical and non-technical solutions possible. A too-narrow set of possible solutions limits the usefulness of the analysis because the outcome might suggest that policy P₁ is best, while an unstudied policy P₂ is better. One of the alternatives that should be included is the counterfactual, in which the problem is not solved. For example, Chapter 5 presents a social cost benefit analysis of investing in the electricity grid to make sure that it also keeps functioning during maintenance if one other component fails; the counterfactual is not to invest at all.

2. Analysis of all effects for society with each of the solutions vis-à-vis the society without a solution for the problem (i.e., the counterfactual). The counterfactual is important for the analysis, but it does not show up in the tables with the outcome because it has no effects (compared to itself) by definition. Analyzing the effects helps to quantify and prevent counting effects twice (both are discussed below).

3. Quantification of each effect. Non-economists, like engineers or environmental specialists, often have to provide crucial impact in this step. This step might be difficult because the focus is often on solving a problem, determining whether a rule is satisfied or determining whether a change causes improvement or deterioration. However, in order to determine the social costs and benefits it is also necessary to determine what exactly is different if a rule is violated or a problem is solved or not.

4. Valuation of each effect. Goods traded on a market can be valued using standard economic techniques. For non-market goods like security of supply, economists have developed a number of methods to value these effects. One type of method uses revealed preferences, for example, travel expenditures, house prices, proxy goods, or production functions. The other type of method uses stated preferences, for example, questionnaires on the willingness to pay or indirect questionnaire

¹ For a longer description of the necessary steps, see, for example, De Nooij (2009). The precise breakdown in steps can differ; see, for example, Eijgenraam et al. (2000), who includes a quick cost benefit analysis in the beginning to eliminate alternatives that will not be attractive early in the process to focus on those alternatives which might be socially attractive.
techniques like conjoint analysis. If possible, economists prefer revealed preference methods to stated preference methods. Section 2.2.2 discusses the issues around valuing in detail. Sometimes it is impossible to value one or more effects; this is discussed in sections 2.2.2 and 2.3.

5. Aggregation of all effects for each actor and for all actors together. The aggregation shows whether the benefits exceed the costs, whether a policy improves welfare and which policy is best. Aggregating all effects for each actor clarifies who benefits from a specific policy and who loses. Aggregating effects over time, aggregating for different actors (e.g., companies and households, poor and rich, different regions), and a discussion about how to take risk into account will be discussed in the next section.

6. A sensitivity analysis of parameters used to focus the discussion on the assumptions that influence the outcome most and make clear how robust the outcome is to alternative assumptions.

The strength of a social cost benefit analysis is that it can give clear information for decision making. The better the researcher succeeds in quantifying and valuing all effects, the more complete and useful the analysis is. If some effects cannot be valued, other methods might be useful in informing the decision maker (these other methods are discussed in section 2.3). However, these alternative methods will not be able to determine whether a specific policy measure increases welfare.

The main assumption used in a social cost benefit analysis

The main assumption in a SCBA is that the individual effects can be aggregated. This deviates from the Pareto improvement criterion, the well-known economic criterion used to judge what the right policy is. A policy is a Pareto improvement if at least one person is made better off without anyone else being worse off. Most policies fail this test: one ‘victim’ s’ suffering will shatter the attainment of a Pareto improvement. Many policies require public funds and are therefore ultimately paid for by the taxpayers. Failure of the Pareto improvement condition only requires a single taxpayer to insufficiently benefit from the new or adjusted policy.
Given its strictness, the Pareto test is hardly applicable and has therefore been made less strict by adding the compensation principle. This says that an outcome is more efficient if those who are better off can, in theory, compensate for those who are worse off, resulting in a Pareto improvement. This is called a ‘potential Pareto efficiency’ or the Hicks-Kaldor criterion. This potential Pareto improvement is the argument behind aggregating all costs and benefits to get an overall welfare effect of a project, even though losers are not actually compensated (Layard and Glaister, 1994, p. 6).

**Direct, indirect and general equilibrium effects**

To give a proper account of the welfare implication of a policy, it is important to avoid double counting effects. This is helped by distinguishing between direct effects and indirect effects (Eijgenraam et al., 2000, p. 54, 55). Direct effects are caused directly by the policy while indirect effects are caused by a direct effect. An indirect effect is often a passed-on direct effect. For example, if a public investment (e.g., in new transmission capacity) lowers the cost of an electricity retailer importing electricity, the lower transmission or transport costs are a direct effect. The retail company will pass on this direct effect to their owners (in the form of higher profits) and to their customers (in the form of lower prices). In this case, counting both the direct effect and the passed-on indirect effect is often a double counting.

Related are general equilibrium effects, (i.e., the behaviour of people and companies responds to changes in prices and costs). This change in behaviour might takes years to materialize but can be important for the attractiveness of a project. For example, the decision to build NorNed, a high voltage direct current connection between Norway and the Netherlands, did not take into account reactions to the changes of electricity prices. This line will be used for arbitrage, which means that the electricity flows to the country with the higher electricity price. As a result, the price pattern has become flatter and, on average, a bit lower. Therefore, NorNed is expected to reduce the producers’ surplus by €45 million annually. Producers (i.e., electricity generators) are likely to respond to such a change in profits and to prevent making economic losses; they will react by changing investments and or operations. Such a general equilibrium effect should be taken into
account because it will influence total costs in society, such as investments, and the ultimate price level (Chapter 8).

2.2 Critical assessment

There are several important issues involved in making a social cost benefit analysis along the steps sketched above. This section discusses five key issues. First is the discussion of the choice of alternatives, which is seen as a key element by, for example, Eijgenraam et al. (2000, p. II). The last four issues are what Layard and Glaister (1994, p. 4) see as the four different valuation issues in a social cost benefit analysis: valuing at the time effects occur (here, valuing non-market goods), valuation of distributional effects, valuing effects over time, and valuation of risk. For a more extensive treatment and further references to the literature see Layard and Glaister (1994).

2.2.1 Choice of alternatives and design of the counterfactual

A social cost benefit analysis is, in essence, a comparison of two or more different policy options, with the aim of finding the best policy. A too-narrow choice of policy options may lead to a second best policy being incorrectly chosen as the best. Social cost benefit analysis theory cannot give much guidance about which policy options are relevant because this choice depends on the problem analyzed. Often, a SCBA is made late in the political process when several options have already been dismissed. The solutions still considered may remain because everyone involved thinks they are the best, because of lobbying or because of focus on one type of solution. Alternatives can be found by postponing a project, making a project smaller, investing in stages, organizing the project differently with a different role for the private and public sector, or finding different technical and non-technical solutions (e.g., regulation, prices). A clear problem analysis helps to define the relevant project alternatives and should answer questions such as: What are the aims of a project? What problem does it solve or which opportunity does it seize? What alternative ways are there to solve the problem or seize the opportunity? (Eijgenraam et al., 2000, p. 10).
For example, if there is congestion in the electricity transmission grid, often only technical solutions are considered to solve it. However, an analysis of the problem would say that there is more demand for the capacity than there is supply, so in economic terms there is scarcity. A standard way to deal with scarcity is to increase prices to reduce demand, to increase supply, or both. A price increase to reduce demand might be easier and cheaper than building a new line. The policy is not to limit transport and trade within a country to stimulate competition. Often this results in pretending that the whole country acts as a copper plate, meaning that there is unlimited transport capacity inside a country. Solving congestion with a congestion charge is not uncommon for congestion between countries (for example, if capacity is auctioned).

Note that to solve congestion, a TSO always looks at investing in the grid, which is its business, perhaps its core business. However there are other solutions possible, like a different geographical pattern of demand and supply. A TSO or the national government can influence the location of demand and supply with incentives and rules. However, these alternatives are not always seen as real alternatives.

Not only are the alternatives used to solve a problem critical, so is the choice of the counterfactual (sometimes called the base case). Eijgenraam et al. (2000, p. 53) define the counterfactual as the most likely economic development should the current project under review not be implemented. In this definition, doing nothing can be the counterfactual but it does not need to be the base case. For example, in the case of ownership unbundling analyzed in Chapters 6 and 7, in the counterfactual the government does not require the energy companies to break up, but it will issue new regulations and improve compliance with existing rules over time. Doing nothing is not an option. Making a social cost benefit analysis as if nothing happens in the counterfactual will increase the impression of attractiveness of the project alternative(s). However, as long as all possible policies are analyzed, including the most likely economic development should the current project under review not be implemented, than it does not matter what the counterfactual is because the analysis will show what policy maximizes welfare.
2.2.2 Valuing non-market goods

Valuing effects in a social cost benefit analysis can be difficult when there are only market goods. For example, the SCBA of unbundling ownership of the distribution grids (Chapter 7) has the main effects of increased efficiency of the companies and the price effects of reduced market power. These effects are priced, but difficult to quantify because they require the ability to predict companies’ reactions over several years. Another difficulty in estimating costs and benefits in a SCBA is that the relevant costs and benefits are not equal to the market price: consumer surplus and opportunity costs are more relevant than the price itself. However, a market price helps in valuing, as does information on the traded quantity and reactions to price changes.

Sometimes, important effects in a social cost benefit analysis are not traded on a market. This makes it much more difficult to value these effects and make an informative SCBA. Examples of non-market goods related to energy policy are clean air and supply interruptions of electricity (the latter is discussed in Chapters 3, 4, and 5). The value of supply interruptions of electricity is often called the value of lost load (VOLL). Not only can it be difficult to value an effect, but it can also be difficult to quantify the size of the effect or a change in probability. This may be true for the change in probability of an outage resulting from specific grid investments. Valuing non-market goods poses two questions: how can non-market goods be valued and what can be said about the usefulness and ethical implications of valuing a non-market good?

First, how can non-market goods be valued? Economists have developed two types of techniques for valuing non-market goods. Revealed preference methods use people’s actual choices as can be observed in market data like travel expenditures, house prices, proxy goods or production functions. For example, investments in backup generators can be used to derive the value of the non-market good ‘supply interruptions’ for which the backup generators act as an insurance mechanism. In contrast, stated preferences methods are not based on observable market data but instead use people’s statements to value an effect (Baarsma, 2000, p. 54). This value can be derived from a simple willingness-to-pay questionnaire asking how much someone values a supply interruption of electricity, or from a more sophisticated, indirect questionnaire technique.
like conjoint analysis, which give respondents a choice amongst a range of price and outage scenarios. In general, economists consider revealed preference methods to be more reliable than stated preference methods.

Economists choose a method depending on the problem at hand and the data and time available. For example, the revealed preference method to value supply interruptions using investments in backup generators is difficult because the data on the sale of the equipment is not registered on a central level, like in a statistical office, and the company data is not publicly available because of its competitive sensitivity. All methods used to value a non-market good are imperfect and more indirect than market data where people reveal their valuation for an effect much more directly.  

The second question asks about the usefulness and ethical implications of valuing non-market goods. Valuing non-market goods is difficult, and the values calculated cannot be more than rough valuations. That might already help rational choice because it will often be sufficient to know that the price lies within some finite range; the answer will be unaffected by exact values (Layard and Glaister, 1994, p. 1-2). For example, in the Chapter 5 SCBA (N-1 during maintenance), the benefits are less than 0.2 percent of the costs and therefore the exact value of supply interruptions does not matter.

Combining more methods to estimate the same effect might help to make an estimate more reliable. For example, the valuations of the security of supply in Chapters 3-5 depend on assumptions about how leisure time is valued and on the assumptions that the labour market functions well and households make rational choices. Leisure can also be

\[10\] As a result there are several studies that try to improve a method or point to its weaknesses. See, for example, Hartman et al (1991) for an analysis of the problems with contingent valuation studies, which are amongst the most used methods to value a non-market good. Diamond and Hausman (1994, especially p. 46 and 62) are very critical about contingent valuation studies. In a review titled ‘Contingent Valuation: Is Some Number Better Than No Number?’, they argue that contingent valuation surveys do not measure the preferences they attempt to measure, that little progress should be expected from alternative survey methods, and that, therefore, contingent valuation studies should not be used in policy.
valued in several other ways. For example, Baarsma et al. (2006) looked at how much households are willing to pay for travel time gains and how much households are willing to pay for proxy goods (i.e., goods or services consumers pay for that saves them time, like hiring a cleaner, informal child care or home delivery of groceries). These studies give a bandwidth which confirms the value of leisure used in Chapters 3, 4 and 5.

It is sometimes asked whether it is ethical to value non-market goods. For example, valuing environmental amenities starts from the use or utility these amenities have for humans. Not everyone agrees with that starting point: some see the environment as having an existence right on its own. Similarly, it is crucial in a number of economic problems to use a value for the number of lives saved to calculate which policy is best. Calculating this value is difficult and, of course, highly sensitive to ethical arguments. Cost-effectiveness studies might help in choosing the best policy in a lot of circumstances without such a value; however, they cannot fully quantify the overall worth of a project that increases safety. The literature can supply information on the order of magnitude of the value of a life saved (see Layard and Glaister, 1994, p. 21-25). Using the value of a statistical life saved can be refined by using a value for the quality adjusted life years (QALY) gained. Such a value for a life saved or for a QALY gained is not a goal in itself but is useful in helping to prioritize different policies to maximize welfare.

2.2.3 Distribution of effects

The consequences of any policy are unevenly distributed over companies and households, rich and poor, regions and so forth. These effects can be aggregated to a total welfare effect. But does this distribution matter for the overall evaluation and how can it be accounted for?

Section 2.1 discussed the Pareto criterion (everyone is at least as well off with as without the policy) as being such a strict criterion that it hardly helps to prioritize possible policies in a way that is informative for decision makers. It is much more likely
that some people will benefit from a policy whereas others will lose. The question of how these effects may be aggregated in a useful way is relevant.

One argument used for unweighted aggregation of the individual effects is the potential Pareto improvement (the Hicks-Kaldor criterion), which asks whether the winners can compensate the losers (Layard and Glaister, 1994, p. 6). Because, in practice, no compensation is paid, there is no ethical justification behind the potential Pareto improvement. Another argument for unweighted summation of all effects is a case where interpersonal comparisons are made but it is judged that in the prevailing income distribution each euro has equal value to all parties concerned. This may be a quite reasonable assumption in some cases (Layard and Glaister, 1994, p. 6).

Many cost benefit analyses assume in practice that unweighted aggregation of individual surpluses is permissible. If unweighted aggregation is not permissible, there are only two alternatives: to use some system of distributional weights or simply to show each party’s net benefits and let the policymaker apply his own evaluation (Layard and Glaister, 1994, p. 6). If welfare weights are used, the best policy does not need to be a potential Pareto improvement because compensation might not be possible. For example, an evaluation in which the benefits for the poor are counted as twice as important as the cost paid by the rich might be socially attractive even if compensation is not possible. But using welfare weights in aggregating individual effects poses two problems for a researcher: how to determine those welfare weights and how to calculate the effects for each actor in detail. The only workable approach may be to show the distributional effects and leave it to the policymaker to choose the best policy for including the distribution problem in public policy analysis (Layard and Glaister, 1994, p. 48).\textsuperscript{11}

In practice there are few studies that apply welfare weights in aggregating the effects of different actors. A notable example is Newbery and Pollitt (1997), who calculated the efficiency gains of restructuring and privatizing the Central Electricity Generating

\textsuperscript{11} For a more elaborate discussion of redistribution and the use of welfare weights, see Layard and Walters (1994) as well as Brent (2006, p. 323 and further).
Board in England and Wales. They extended the calculation of efficiency gains with a calculation of social welfare using welfare weights with lower weights for producer surpluses than consumer surplus, which in turn has a slightly lower value than government surpluses. The reason for using a lower weight for producer surplus is that the owners of companies are usually richer than the general public and the marginal utility of money decreases with wealth. Other reasons for using a different weight for consumers and producers is that producers are sometimes owned by foreign companies or households which fall outside the scope of a national social cost benefit analysis. For example, the energy companies experiencing an effect from the NorNed interconnector between Norway and the Netherlands are partly foreign owned. In the NorNed case, the regulator not only looked at unweighted national welfare (i.e., efficiency) but also separately at the effect for consumers (in which case the effect for producers gets a weight of zero).

Social cost benefit analyses mostly aggregate the effects for producers and consumers with equal welfare weights and report the effects of consumers and producers separately, leaving it to the policymakers to judge the distributional effects. The distinction between rich and poor is less often made. In other cases, the redistribution is specific to a project. For example, in the cost benefit analysis of an investment in the electricity grid where the grid functions even if one component is in maintenance and one other component fails (Chapter 5), the redistribution is regional: from all households and companies paying for the grid to the households and companies in the specific part of the grid that gets improved.

It is not only difficult to determine the welfare weights of the distribution of effects, but it is sometimes also difficult to determine the distribution of effects after the general equilibrium effects are taken into consideration. This requires the use of a general equilibrium model to see where initial effects will end up. Companies facing higher

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12 Using the argument that some of the companies are in foreign ownership to weigh them less in making government policy might cause detrimental effects by making foreign companies reluctant to invest. This is an argument against using a lower weight for companies because they are partly foreign owned.
costs will pass them on to consumers if they can, or leave the market if business has become unprofitable and prices cannot be raised. For example, in the NorNed case, the regulator assumed that the electricity generators in the Netherlands would lose €45 million annually. However, the generators will react by changing their investment patterns. This lowers their damage (and lowers the effect on consumers), but it is difficult to determine the size of this effect. Therefore, social cost benefit analyses often assume that effects can be aggregated and present a national outcome. Depending on the study, they can also show who gains or losses and how much, although the latter is often only possible after the first effects are taken into account and not always in much detail.

2.2.4 Valuing effects over time (the discount rate)

In a social cost benefit analysis, costs and benefits are often not realized at the same moment. This poses the question of how to aggregate effects over time. People value an outcome now more than an outcome in the future. This can be because people dislike waiting or because an amount of money can be invested productively now so that consumption in the next period exceeds the current available amount. In all social cost benefit analyses spanning several years, future effects are corrected by the time preferences or discount rate. The value of an effect in the future is equal to the present value increased with the interest or discount rate. Most SCBA’s use one year’s prices as the present rate and a real discount rate: current and future consumption are compared. This section ignores the fact that future effects are often more uncertain than effects in the future. Uncertainty is discussed in section 2.2.5.

This illustrates how important the choice of discount rate can be for choosing the best project if a project has a long life. For the papers included in this thesis, the discount rate is most relevant in Chapter 8 (the NorNed interconnector), where it matters for the size of the outcome but not for the sign. The transmission system operator, while

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13 The real interest rate is the nominal interest rate minus inflation.
14 The alternative, to increase all effects in the future with the expected inflation and to increase the discount rate with the inflation rate, would always yield the same result.
applying for permission, claimed to be using a 6.3 percent discount rate and a 40 year
horizon, which would lead to a net present value\(^{15}\) of €448 million. However, since it
falsely corrected for taxes, it actually used a discount rate of 9.65 percent, which gives a
net present value of €175 million (for an extended discussion seen chapter 8). The
regulator used a nine percent discount rate and used a time horizon of 25 years to
correct for the higher risk later on and found a net present value of only €3 million.

Choosing the appropriate discount rate for a social cost benefit analysis is difficult
because there is not a direct market for the time preference for projects aiming at
correcting a market failure. This makes it theoretically difficult to choose the
appropriate discount rate. The following paragraphs illustrate parts of that discussion
and describe an often-used practical solution.

Stiglitz (1994, p. 118) discusses three extreme views about the appropriate social
discount rate. First, the social discount rate should equal the producers’ rate of interest
or the producers’ marginal rate of transformation (i.e., the increase in next period output
generated by a decrease in this period). If capital markets are perfect, this will equal the
interest rate at which producers can borrow. Second, the social discount rate should
equal the consumer rate of interest or the consumers’ marginal rate of substitution (i.e.,
the amount of income consumers require at this moment to compensate for a decrease in
income in the next period). If there are perfect capital markets, this should equal the
interest rate at which consumers can borrow. Third, the social discount rate should equal
the social rate of time preference, which should be derived from a social welfare
function. There is also a more common eclectic view that the social discount rate used
should be the average of the producer and consumer interest rate. All these simplistic
views are generally invalid.

In his discussion of these discount rates, Stiglitz starts (p. 117) from the assumption that
the economy is in some sort of a steady state. This might be so for some investments
like reliability-increasing investments in the grid as in Chapter 5, but is unlikely to hold
for other cases, like investments in climate change prevention, which aim at changing

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\(^{15}\) Net present value: the present value of all benefits minus the present value of all costs.
the long run steady state of the economy. Furthermore, Stiglitz lists several reasons why private interest rates are unlikely to be correct for evaluating public projects. For example, the marginal rate of substitution between private goods at different moments and the marginal rate of public goods at different moments do not need to be the same: consumption and public goods are different. Furthermore, the government may be subject to different constraints (like the ability to raise sufficient revenues using taxes). In addition, market rates often include a payment for inflation and a risk component. A clear reason why the private and government discount rate should differ is that a company that invests takes into account the fact that it has to pay taxes, which are a loss for the company but which are only a transfer for the whole society.

One frequently-applied solution in choosing a discount rate is to use the long-term interest rate the government has to pay. Based on this approach, the official Dutch real discount rate is currently 2.5 percent (Minister of Finance, 2007). Note that using the same discount rate for all public projects (unless the use of different rates can be underpinned) prevents giving preference to one project over another based solely on the fact that it was evaluated with a lower discount rate than the other projects.

The literature offers no clear-cut solutions for determining an appropriate discount rate. That is also unexpected, since one would ideally like to know all future markets when determining the time preference. However, most future markets are missing. The capital market trades effects in the future, but is imperfect and only available for some future effects. Given that most future markets are missing, valuing the time preferences is similar to valuing non-market goods. To complicate it further, a lot of the people who will trade on those future markets are not even born yet. Especially if the time horizon is long, questions about fairness become relevant; is it fair not to value future generations completely?

For example, in environmental policy (e.g., reducing global warming), a relevant question is how much the consumption possibilities of future generations should be counted. Implicitly discounting assumes that the amounts not invested in a project now will have an alternative return and it assumes that future consumers will have the same
preferences as current consumers. If a SCBA of climate change is made, the preferences of future generations might differ from those of current generations, especially since climate is not a normal good.

The Stern review (2007) on climate change used a low discount rate and concluded that ‘the benefits of strong, early action on climate change outweigh the costs’. Weitzman (2007) did not agree with Stern’s reasons but agreed with the low discount rate, whereas Nordhaus (2007) did not agree with using a lower value than the real market rate. Aalbers (2009) elaborated on this matter and proved that investments to reduce climate change should be discounted at a lower rate than normal investments. To summarize, choosing the appropriate discount rate is important for the results of many social cost benefit analyses, but it is difficult and probably impossible to derive a definitive discount rate.

2.2.5 Uncertainty and risk

People do not like uncertainty. The utility people derive from a certain outcome is larger than the utility people derive from the same expected outcome (which can be higher or lower). This is exactly the reason why people buy insurance: they want to avoid the largest uncertainties. There are several ways to deal with uncertainty in a social cost benefit analysis.

First, if the development of the economy is important for the outcome of a SCBA and that development is uncertain, it is possible to use two or more scenarios, such as high or low growth, or fast or slow development of renewable generation technologies. Using these scenarios shows which policy alternative is best in which scenario. Sometimes one policy alternative is best in all scenarios or sometimes different alternatives are attractive. Choosing the alternatives can be done with explicit methods like maximizing expected welfare (though assigning values to the different scenarios is problematic) or maximizing the minimum welfare. The best alternative method can also be chosen in a less explicit way.
Second, the choice of the variables used in the calculations is sometimes subject to uncertainty. A sensitivity analysis can show how much the outcome might change if one or more variables vary at the same moment. For example, the social cost benefit analysis of ownership unbundling (Chapter 7) depends on a lot of different assumptions; however, most assumptions (like a lower discount rate) do not matter for the outcome (i.e., the best alternative).

Third, given that future effects are more uncertain than current effects, an addition to the discount rate can be used as an insurance premium. This is, for example, the Dutch approach for government projects. Ideally, one should determine effects to non-diversifiable risk (the risk that cannot be pooled against risks with an opposite sign) and multiply this with a standard risk factor of three percent. In practice, most researchers making applied SCBA in the Netherlands use a standard value of one for the non-diversifiable risk. The real discount rate of two-and-a-half percent is then increased by three percent (see Ministry of Transport, 2004; and Van Ewijk and Tang, 2003). This approach is followed in the papers in this thesis.

Fourth, another way to deal with uncertainty is to calculate the value of waiting for better information. A project or policy can be seen as a real option (see Dixit and Pindyck, 1994) but executing the project kills the option not to do the project. Real options are valuable if waiting delivers better information and if the costs of doing the project are irreversible. For example, waiting is valuable if a project requires an investment of 100 in year zero, and in year two it has a benefit of 50 or 200 with equal probability. The net present value of the project using the expected value would be 25 (=½*(50-100)+½*(200-100)). However, if waiting until year one delivers better information, then the investment in year one will only be made if the benefits in period two are 200. The net present value is 50 (=½*0+½*(200-100)). So the real option of waiting has a value of 25.

For example, a real option is found for an investment in new transmission capacity in an electricity market that changes towards liberalization or towards more renewable energy resources like wind, which is more intermittent. It is valuable to wait for better
information on how the market develops and how the demand for the interconnector will develop because it reduces the probability that the investment will have a low return. However, waiting also has costs: the interconnector will be used later, leading to missed benefits. In the NorNed case (Chapter 8), waiting would also have led to substantial additional costs because an important permit was on the brink of expiring. So here the real option might have been too expensive, but that was not quantified. For the social cost benefit analysis of ownership unbundling, a real option could have been calculated because after some time one could see whether stricter policy would work or whether other European countries would follow the Dutch politicians’ idea. Both would help in discovering whether ownership unbundling was the best available policy, but politicians were not willing to wait.

The approaches described above show how risk and uncertainty should be dealt with in order to properly value the effects of a proposal. Of course, it is also possible to design the policy so that it minimizes the costs of uncertainty. For example, Roques et al. (2009) studied the geographical deployment of wind energy in Europe to reduce the overall variability. Van der Weijde et al. (2011) studied optimal transmission investment in a multistage model and showed that explicitly considering uncertainty can yield decisions that have lower expected costs than traditional deterministic planning methods. For the choice of policy, the degree of risk aversion (risk-neutral or risk averse) can matter. Roques et al. (2006) studied the influence of increased uncertainty on the investment decisions of private investors in the electricity market.

There are many ways to deal with uncertainty. Most of them are difficult to apply; for example, valuing a real risk is difficult in practice. In applied work, such methods are less frequently used than in the more academic literature, which leaves room for future improvements.
2.3 Alternatives to social cost benefit analysis\textsuperscript{16}

Because of the concerns discussed above, especially the concerns about how to take redistribution into account and the problem of valuing non-market goods, researchers have looked for decision support methods other than social cost benefit analysis. This section briefly reviews the main alternatives to SCBA and describes why SCBA should be preferred.

Cost-effectiveness analysis

This method, either the goal is taken as given and the analysis studies how to obtain the goal with the least cost, or the budget is taken as given and the analysis determines which alternative gives the best results. This method is limited compared to SCBA because the goal is not valued. Cost-effectiveness analysis can be applied if a specific reliability level should be met (e.g., determined by law). If a project will definitely go forward, cost-effectiveness analysis often has the advantage that it does not require valuation of effects, which are hard to value. A drawback is that it is not clear whether the policy increases welfare and thus whether it should be pursued in the first place. If more than one effect or goal cannot be valued, cost-effectiveness analysis cannot help to select the best policy.

Economic impact analysis

This approach (sometimes called regulatory impact analysis) describes the effects of a policy on the economy but does not try to quantify or value effects in the same unit of measurement. It is less helpful than social cost benefit analysis in preventing double counting and it does not aggregate the effects. An example of a regulatory impact analysis is the European Commission’s analysis of the benefits of unbundling the electricity grids (EC, 2007c). The effects can be measured with many different

\textsuperscript{16} For a description of the various techniques, see, for example, Baarsma (2002). Asafa-Adjaye (2000) has a chapter on social cost benefit analysis and one on multi-criteria analysis, both balanced. For a multi-criteria analysis guidebook, see Munda (2008), and for a social cost benefit analysis guidebook (applied to infrastructure), see Eijgenraam et al. (2000).
variables, like employment, added value, economic growth, income and wages, income tax and indirect taxes, payroll taxes, relocation of companies, investments, and so on. Because no net effect (i.e., benefits minus costs) is calculated, the welfare effect of a policy proposal is not clear.

Regulatory impact analysis has a practical background and is not grounded in theory such as welfare theory. As a result, several other descriptions of the method are available. For example, OECD (2009, p. 77, 80) describes multi-criteria analysis and social cost benefit analysis as two methods for doing a regulatory impact analysis. OECD (p. 74) strongly prefers SCBA because it is the only methodology theoretically capable of answering the fundamental question of whether a particular policy intervention provides net benefits from the point of view of society as a whole. Goodstein (1995, p. 177) uses regulatory impact analysis and social cost benefit analysis as equivalents.

**Multi-criteria analysis**

This method assesses projects using multiple criteria such as physical quantities, rankings, scored values and money. After weights are allocated to the criteria, an aggregate score is calculated to find the best project. The basis for the allocated weights is not always clear and can mirror the preferences of the decision maker, policymaker or researcher. Such weights do not need to reflect the preferences of society as in a social cost benefit analysis and, as such, the project with the highest score does not need to be the project that most improves welfare. A multi-criteria analysis has the advantage that it does not require a monetary valuation of all effects, which is especially helpful if a project has significant environmental and social impacts which are hard to assign monetary values or even quantities to (OECD, 2009, p. 74; Strijker et al., 2000). Drawbacks of multi-criteria analysis are: (i) determining the weights used to calculate the aggregate scores is difficult and is not based on welfare theory (and is therefore arbitrary); (ii) double counting of effects is more difficult to avoid; and (iii) effects do not need to be formulated as precisely as in a SCBA before they enter into the overall score because they can also be ranked or scored using expert judgment.
To sum up, multi-criteria analysis and social cost benefit analysis are the two most comprehensive decision support procedures for policy options with benefits and costs. All the remaining procedures either deliberately narrow the focus on benefits (e.g., to health or environment) or ignore costs (OECD, 2006, p. 276). Social cost benefit analysis is grounded in welfare theory and, as such, is able to determine which policy is best for welfare. Multi-criteria analysis is unable to answer this question. This drives the dominant preference amongst economists towards social cost benefit analysis.

The choice of method for applied work depends on the possibility of valuing all effects and the importance of the distributional effects. A social cost benefit analysis should be preferred if the main effects can be expressed in monetary terms. If valuing an important effect is not only difficult but impossible, a cost-effectiveness study should be done. If it is impossible to value several effects, a multi-criteria analysis should be done (Koopmans, 2010, p. 89). Because environmental policy evaluations have relatively many valuation issues (because environmental effects are unpriced), most proponents of multi-criteria analysis seem to be in this field. However, not all environmental economists prefer multi-criteria analysis. For example, OECD (2006; David Pearce, one of the authors, is a well-known environmental economist) prefer social cost benefit analysis. Because of its stronger foundation in welfare theory, this thesis focuses on social cost benefit analysis.
3 The Value of Supply Security. The Costs of Power Interruptions: Economic Input for Damage Reduction and Investment in Networks*

Abstract: Most research into the reliability of electricity supply focuses on the suppliers. Reductions in the number of power interruptions will often be possible, but also very costly. These costs will eventually be borne by the electricity users. This paper studies the value of supply security in order to determine the socially optimal level of security. The costs of interruptions are estimated for the Netherlands in terms of lost production and lost leisure time. Large differences in damage are found between sectors, regions and periods. Furthermore, electricity outages caused by electricity shortages create huge transfers, while outages created by network failures do not create transfers. These estimates can be used to make optimal decisions in the case of electricity shortages and to optimize investments in the network.

Keywords: electricity markets, supply security, value of lost load (VoLL), electricity outages, network quality

JEL Classification: Q40, Q41, D61, H4, L94, R10


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3.1 Introduction

Interruptions in the power supply have attracted a great deal of attention in recent years. The discussions on the security of supply were boosted by the electricity crises in California in 2000 and 2001. Because the supply of electricity did not meet the demand, electricity had to be suspended in some areas to prevent a failure of the entire network. Electricity prices rose dramatically as a result of the power shortage. Since then, several incidents in Europe have attracted further attention. In 2003, for example, network failures led to large-scale interruptions in London, Copenhagen and Italy. Another example is the hot, dry summer of 2003, during which power stations ran short of cooling water. In the Netherlands, for instance, this reduced the power production capacity to such an extent that prices on the spot market increased strongly. Large power users reacted to the high prices by reducing their production in order to sell back the electricity that they had bought earlier at low prices. Furthermore, TenneT – the Dutch transmission system operator (TSO) – asked the Dutch public to cut back on their electricity use in order to prevent the need to introduce rolling blackouts.

Although almost everyone considers the security of power supply to be very important, it is not known what value society places on it. Normally, one could derive this kind of information from a market. However, there is no market in which power supply interruptions are traded. This research is an attempt to fill this gap by valuing the consequences for the Netherlands of having no electricity. The value of these consequences can be seen as the demand for the security of the supply of electricity.

This information can be used in two kinds of decision-making related to the security of supply. First, it can be used to make socially optimal investment decisions. For example, TSOs, electricity producers and local network operators make decisions about

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17 See Bialek (2004) for a description and analysis of the Italian and the Danish/Swedish blackout referred to in the text. He also describes the large blackout in the north-east of the USA and in Canada on 14 August 2003, which also attracted much attention.

18 Very large electricity users are an exception: they often have provisions in their contracts for interruptions at times when demand peaks occur.
maintenance and investments that influence the probability of a supply interruption. Knowing the value of the security of supply is a first step in calculating economic optimal interruption levels, which could replace the reliability standards that in most countries are still based on past engineering practice and rules of thumb (see Munasinghe and Gellerson, 1979, p. 353). Telson (1975) made some rough calculations that seem to suggest that the engineering standards for US power generation were too high from an economic point of view. Only a few calculations of this type have been published in recent decades. Second, this information can be used in the case of electricity shortages to decide which regions and sectors should be cut off. This paper shows that the costs to households of electricity interruptions are substantial and – expressed per kWh (the ‘VoLL’) – exceed the costs to companies. Households should therefore receive serious attention in electricity plans.

Section 3.2 addresses different kinds of supply interruptions. Section 3.3 describes the different methods that are available to monetarize the effects. Section 3.4 discusses the different consequences of electricity interruptions and the monetarization of these effects using the production-function approach. Section 3.4.1 describes the valuation of electricity outages for firms and the government (hereafter, the term ‘firms’ includes the government, unless stated otherwise), while section 3.4.2 discusses the valuation of the damage suffered by households. Section 3.4.3 discusses transfers, which can occur when power outages are caused by production shortages. In section 3.5, the results of this method for the Netherlands are presented. The transfers due to production shortages are not presented, since these depend on the market design, which makes these transfers difficult to establish. Section 3.6 comprises the conclusion and some suggestions for future research.

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19 Serra and Fierro (1997) found that, in the case of a production shortage when scarce electricity needed to be distributed, the outage cost in Chilean industry fell by more than 50 per cent when the distribution was based on minimizing economic cost instead of on an equiproportional distribution.
**3.2 Characterizing supply interruptions**

There are many reasons why the consequences of one supply interruption differ from the consequences of another.

There are different types of electricity users. Interruptions in hospitals, in industrial plants and in private households have very different consequences.

- The perceived reliability level: the higher the perceived reliability, the less firms and households are inclined to take precautionary measures (e.g. backup facilities), and the greater the damage caused by an interruption. This is also known as the ‘vulnerability conflict’ (Rathenau, 1994, p. 101).

- The moment when the interruption occurs. The season, the day of the week and the time of day determine which activities are interrupted. For many households, an interruption at 8 p.m. interferes with recreation (e.g. television, Internet), while at 3 a.m. an interruption has much smaller effects because most people are asleep.

- The length of the interruption also determines the costs. Some forms of damage (e.g. the loss of computer files) occur instantaneously. Some effects (e.g. the loss of working hours) are proportional to the length of the interruption, while other effects will start only after a while (e.g. the spoilage of food in refrigerators).

- A notification before an interruption lowers the consequences of that interruption. For example, if people know that the electricity is about to be interrupted, they will not use the lift and get stuck halfway up or down the shaft.

- The effects of electricity interruptions are smaller when the interruptions are structural (e.g. daily) than when they are incidental. If the supply is interrupted regularly, people prepare for it even if they are not warned beforehand. Although the costs per interruption are lower, the total damage will be greater because of the larger total number of interruptions and because additional costs (e.g. lower foreign investments) might arise.

- Finally – and generally not included in this list – the source of the outage: if the outage is caused by a failure in the network, the price effects will mostly be small,

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20 See Ajodhia et al. (2002, pp. 4-5), Billinton et al. (1993, p. 96), Day and Reese (1992, pp. 2.4.2-2.4.3), Sanghvi (1982).
whereas if the outage is caused by the fact that the production capacity is smaller than the demand, prices tend to rise strongly. A price increase leads to large transfers of wealth from users to suppliers. Although such transfers are not a social cost, they do matter from a policy perspective.

Here, the focus is on who is affected, when and where. Prior notification and structural interruptions do not occur in the Netherlands. Therefore their effect on the extent of the damage caused is not studied in this paper. The establishment of a more precise relation between the length of the interruption and the damage is left for future research. Transfers are studied in section 3.4.3.

3.3 Valuation methods

Because there is no market where electricity interruptions are traded, there is no market price that shows the marginal cost per minute of supply interruption. Therefore, economists have developed several methods for calculating the effects of a supply interruption.\(^{21}\)

**Surveys/interviews (stated preferences).** In surveys, people are asked how much damage they have suffered as a result of supply interruptions, how much they are willing to pay (WTP) for a given reduction in interruptions, the minimum amount of money they are willing to accept (WTA) as compensation for an increase in interruptions, or which combination of electricity price and number of interruptions they prefer (conjunct analysis).\(^{22}\) Interviews are often problematic, because people have to answer questions about trade-offs they rarely make. These answers are often influenced by the way in which the questions are asked (the framing problem; see Sanghvi, 1982, p. 185). Another effect in interview studies is that people do not want fewer or more interruptions but prefer the status quo (see e.g. Hartman et al., 1991, or Beenstock et al., 1998).

\(^{21}\) This overview is to a large extent based on Billinton et al. (1993) and Ajodhia et al. (2002).

\(^{22}\) See Day and Reese (1992) for an example of a willingness to pay study and Beenstock et al. (1998) for a conjoint analysis.
The results of surveys may further be obfuscated by scepticism on the part of consumers that electricity prices really will drop if reliability is decreased.

**The production-function approach.** The production-function approach estimates the consequences of outages through lost production (for firms) or lost time (for households). This approach uses quantitative statistical information (see e.g. Munasinghe and Gellerson, 1979, and Tishler, 1993). A drawback is that some aspects – such as restart time in businesses and stress in households – are difficult to include. Within this approach, several choices are possible. First, the lost production in each sector during an outage can be estimated directly, and this can be aggregated to a macro-economic total. Second, linkages between sectors can be included by manipulating input-output tables (see Chen and Vella, 1994). This study applies the first approach but incorporates the latter option, because we assume that during an outage virtually all activities grind to a halt and an already interrupted activity cannot be disturbed further by the non-production of another sector.

**Market behaviour (revealed preferences).** Both the expenditures on backup facilities and the use of interruptible contracts can provide information on how households or industries value interruptions of the power supply. For example, expenditures on backup facilities show how much firms and households are willing to pay for a higher level of supply security than is currently provided by the network (see e.g. Caves et al., 1992). Sanghvi (1982) advocates this method. In his example he uses an average of 10 hours of interruptions per year. In the Dutch situation of high reliability (on average about 30 minutes of supply interruptions a year), a backup generator would have to be used for only very short periods of time. Therefore, the cost of capital per minute of operation would be so high that it is hardly ever attractive for firms or households to invest in backup technology. (For hospitals, however, the ‘costs’ of electricity interruptions are so high that Dutch hospitals are obliged to have backup generators.) Therefore, in countries with few interruptions, the expenditures on backup facilities most likely cannot be used to estimate an upper bound for the cost of outages. In the Dutch context, interruptible contracts also cannot be used to estimate the value of power interruptions
for the whole economy: only very few Dutch firms use this kind of contract, while households do not use them at all.

**Case studies.** One type of case study approach lists the effects of an actual supply interruption; these are then monetized (Corwin and Miles, 1978). Another case study approach is to carry out a survey directly after an outage (Serra and Fierro, 1997). An advantage of case studies is that an actual rather than a hypothetical interruption is studied. A drawback is that the large number of possible effects makes it difficult to arrive at one overall picture. Furthermore, the interruption studied is not representative of interruptions in general, which makes it difficult to generalize the results. Both methods 1 and 4 use surveys, but method 1 (stated preferences) tries to ascertain the value of an outage, while method 4 (case studies) only lists the effects.

Each of the above methods has its advantages and disadvantages. This study uses the production-function approach, because it provides a top-down estimate of total costs without the need to study every user separately, as is required when one uses the bottom-up methods (1 and 4). Method 3 does not seem useful because of the current high reliability level in the Netherlands and many other developed countries.

### 3.4 Consequences of interruptions

Households and firms differ substantially as to their output. The main output of firms is traded on markets, which show the value of the products. The main ‘output’ of households is well-spent leisure time, which cannot be traded on markets. This does not imply that leisure time is not valuable, only that assigning a value to it requires a different approach. Section 3.4.1 discusses the potential consequences of electricity supply interruptions for firms and the government, and describes the effects that are measured in this study (hereafter, the term ‘firms’ includes the government, unless stated otherwise). Section 3.4.2 discusses the effects of supply interruptions for households and the way in which these are measured here. Section 3.4.3 compares the effects of interruptions caused by network failures and those of interruptions caused by a shortage of supply.
3.4.1 Consequences for firms and the government

Firms suffer three kinds of damage in the case of an outage. First, they produce less. Without electricity, many production processes stop, some production is lost (e.g. unsaved computer files) and it takes time to start up production again. So, value added is lower due to an interruption. Second, costs may rise. An example is that, after an outage, firms sometimes need extra labour input, for which they may have to pay overtime bonuses. Third, some goods and inputs may be lost. For example, hot steel in a steel plant may cool down (making it difficult to process) and have to be reheated (the earlier input of heat is then lost).

This study considers only the production lost during the supply interruption. The damage caused by an electricity interruption in a firm is assumed to equal the value added it would normally have produced during that period. This might be an overestimate if, during an interruption, some other productive activities are possible. On the other hand, the time needed to start up again and other forms of damage are not included. On the whole, the method used here is assumed to provide an estimate of the order of magnitude of the total damage.

3.4.2 Consequences for households

Basically, households face two kinds of damage: the lost possibility to use their leisure time, and the loss of goods (e.g. the contents of the freezer if an interruption lasts too long). In winter, households could experience additional problems during very long interruptions if the heating stops. Here, only lost leisure time is studied. It is assumed

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23 Different classifications are possible. Tishler (1993) distinguishes foregone profits, a possible reduction of productivity, damages to materials, and payments for labour during the interruption. Here, the cost of an interruption is estimated by assuming the loss of all value added that normally (i.e. without the power interruption) would have been created during this period. This includes three of Tishler’s categories of damage (only damage to materials is not included).

24 These costs can be substantial. For example, in Canada it has been found that industrial firms need on average 1 hour and 56 minutes to start up again after a one-hour supply interruption (Wojczynski et al., 1984, p. 442).
that, during an interruption, all leisure is lost, which is valued against the marginal value of leisure time. The following subsection describes the method used to estimate the value of lost leisure time.

### 3.4.2.1 Method for valuing time

Lost leisure time is monetized by using the model developed by Becker (1965). The core of Becker’s model is that people do not get utility (welfare) from money or goods alone, but from the combination of goods (bought with money) and time. Households produce welfare (utility), using time and money as inputs. The marginal utility of money decreases with the increasing amount of money one has, while the utility of free time increases with the number of hours worked. As a consequence, there is an optimal amount of time for a person to work. In this optimum, the income generated with one hour of work equals the value of an additional hour of leisure time. Put differently, the value of a marginal hour of leisure time equals the income per hour.\(^{25}\) This method assumes a well-functioning labour market, in which individuals are more or less free to choose the number of hours they work. This seems justified for the Netherlands, where about 40 per cent of the working population works part time (employees have the legal right to work part time). Furthermore, most employees (83.4 per cent) are satisfied with their working hours; only 5.5 per cent would like to work more and 11.1 per cent to work less (Netherlands Bureau of Statistics).

Here, it is assumed that household activities that are interrupted due to an outage are carried out later, that is, at times that would otherwise have been spent on leisure. Under this assumption, the value of a marginal hour of household activities equals the value of

\(^{25}\) This method to value leisure time turned out to be controversial, especially to non-economists. In economics, this idea is used regularly. For example, in cost-benefit analyses of infrastructures, economists often use a generalized travel cost, which includes the financial cost, the time and the comfort of travel (see e.g. Eijgenraam et al., 2000, p. 86). In labour economics, economists use a reservation wage. If people cannot earn more than this reservation wage, they will not accept a job because, to them, their leisure time is more valuable than the earnings from the job offered.
a marginal hour of leisure. Munasinghe (1980) applies this method, while Sanghvi (1982) discusses some drawbacks to it.

This marginal value of leisure time could be an overestimation of the damage if, during the outage, people are able to engage in leisure activities that do not need electricity, such as reading a book. However, surveys show that most leisure time activities do depend on electricity, mostly watching television and surfing the Internet. (Reading a book, one of the most often mentioned alternatives, is hardly done. Besides, after sunset, reading also is electricity dependent). More importantly, following Becker implies that the marginal hour of leisure time is lost, whereas in reality a random hour is lost. This might lead to an underestimation of the damage. For example, an interruption during the final of the world football championship would be terrible for a lot of people, and for them the cost would far exceed the marginal income for working during that period. Day and Reese (1992) note that, while interviewing people in the USA about power interruptions in the previous year, many people recalled an interruption that had occurred five years earlier. This interruption happened shortly before the Thanksgiving dinner. Some of the victims became so angry that they drove to the electricity company and threw their half-cooked turkeys at the office building. Again, this method provides an estimate of the order of the total damage suffered.

3.4.2.2 Valuing time in practice

The Netherlands Bureau of Statistics (CBS) and the Social and Cultural Planning Office of the Netherlands (SCP) have collected information about the amounts of time spent on work, household activities and leisure (data of the Netherlands Bureau of Statistics are available at http://statline.cbs.nl. For the SCP study, see Breedveld et al., 2001). SCP data refer to 2000 and reflect the average day over the whole week; CBS data refer to 2001 and also cover the whole week. Table 3.1 shows the time that the average Dutch person (aged over 12) spends on different activities per day. Note that people spend (on average) more time on leisure activities than on paid work.
Table 3.1 Activities per day, in hours, 2001

<table>
<thead>
<tr>
<th>Activity</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal care, total</td>
<td>10:15</td>
</tr>
<tr>
<td>Sleeping, resting</td>
<td>8:30</td>
</tr>
<tr>
<td>Washing, dressing</td>
<td>0:38</td>
</tr>
<tr>
<td>Eating (at home)</td>
<td>1:07</td>
</tr>
<tr>
<td>Taking care of others, total</td>
<td>0:29</td>
</tr>
<tr>
<td>Of which caring for and playing with own children</td>
<td>0:21</td>
</tr>
<tr>
<td>Travel, total</td>
<td>0:54</td>
</tr>
<tr>
<td>Paid work, total</td>
<td>2:47</td>
</tr>
<tr>
<td>Education, total</td>
<td>0:34</td>
</tr>
<tr>
<td>Of which attending courses, lectures, classes</td>
<td>0:25</td>
</tr>
<tr>
<td>Domestic activities, total</td>
<td>2:27</td>
</tr>
<tr>
<td>Of which shopping (for example, shopping, post office, bank)</td>
<td>0:30</td>
</tr>
<tr>
<td>Domestic activities</td>
<td>0:53</td>
</tr>
<tr>
<td>Preparing food and drinks</td>
<td>0:26</td>
</tr>
<tr>
<td>Maintenance, home improvement, gardening</td>
<td>0:25</td>
</tr>
<tr>
<td>Voluntary work, total</td>
<td>0:11</td>
</tr>
<tr>
<td>Leisure, total</td>
<td>5:55</td>
</tr>
<tr>
<td>Practising sports</td>
<td>0:20</td>
</tr>
<tr>
<td>Television, video, radio, CDs, cassettes</td>
<td>1:57</td>
</tr>
<tr>
<td>Social contact (friends, family and acquaintances)</td>
<td>1:26</td>
</tr>
<tr>
<td>Visiting restaurants, pubs, discos, etc.</td>
<td>0:18</td>
</tr>
<tr>
<td>Reading</td>
<td>0:32</td>
</tr>
<tr>
<td>Walking, biking, church, museum, theatre, etc.</td>
<td>0:23</td>
</tr>
<tr>
<td>Games, tinkering, playing music, theatre</td>
<td>0:31</td>
</tr>
<tr>
<td>Nothing at all</td>
<td>0:29</td>
</tr>
</tbody>
</table>

Dutch population older than 12 years, both male and female. Subcategories covering less than 15 minutes omitted.

Source: Netherlands Central Bureau of Statistics (CBS).

Although there are differences in the definitions and breakdowns between the two studies, the general picture is rather similar. The following stylized facts can be derived from the SCP study: working people have 40 hours of leisure per week, while people
without a job have 55 hours of leisure per week. The population between 20 and 64 years spends some 17.5 hours per week on domestic activities (2.5 hours a day).

SCP also studied the times when things are done. For the population aged 12 and older, of all paid work (22 hours per week), 14 per cent is done during the evening, night and/or weekend, whereas of the domestic work (23 hours per week), 46 per cent is done during these periods. The rest of all paid work and domestic work is done during ‘office hours’. Most leisure time is concentrated in the evenings and at weekends. We assume that an interruption during the day leads to a loss of leisure time in 35 per cent of households. For evenings and Sundays, these figures are 80 per cent and 60 per cent, respectively. These assumptions are consistent with the CBS and SCP findings on total leisure time and the figures they give on the timing of leisure and work. The present study provides and discusses figures for only three periods (i.e. weekdays, weekday evenings and Sundays during daytime). In the calculations, nine periods are used, covering the whole week (i.e. weekdays, Saturdays, and Sundays, which are subdivided into day, evening and night).

The electricity dependence of household activities and the degree to which activities that do not use electricity can be substituted for electricity-dependent activities are crucial in quantifying the consequences of power outages for households. Table 3.2 discusses this for the five main activities of households. The activities are ordered from the most time-consuming (watching TV, video, listening to the radio, etc.) to the least time-consuming main activity. This shows that the activities that consume the most leisure time are partly or completely electricity dependent. The possibilities for alternative activities during a power outage are limited.
Table 3.2  Electricity dependence of household activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Electricity dependent?</th>
<th>Substitution possible?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watching TV, video, listening to the radio, etc.</td>
<td>Completely</td>
<td>Limited</td>
</tr>
<tr>
<td>Social contacts</td>
<td>Partly (e.g. traffic, telephone, email)</td>
<td>Partly</td>
</tr>
<tr>
<td>Travel</td>
<td>Partly (e.g. train, traffic lights)</td>
<td>Hardly</td>
</tr>
<tr>
<td>Domestic activities</td>
<td>Mainly (e.g. washing, vacuuming, ironing)</td>
<td>Mainly</td>
</tr>
<tr>
<td>Washing, dressing</td>
<td>Partly (e.g. hot water, lighting)</td>
<td>Hardly</td>
</tr>
</tbody>
</table>

The average gross hourly wage in the Netherlands is €18.65 (in 2001; Netherlands Bureau of Statistics). The net marginal income is about half the gross average wage. Laan et al. (2002) found that the marginal tax rate, including social security insurance and income-dependent subsidies, ranges from 40 to 140 per cent for modal incomes. Lower values within this range are common, while high values are rare. On average, 50 per cent seems a reasonable estimate.

For the unemployed, the retired and those who are studying, half of this net marginal wage is used as the marginal value of time. The value of time of these groups is lower because they have more leisure time and unemployed persons tend to have lower skills and thus would have a lower hourly wage if they were to have a job. Of the total population of 16 million, about 7.9 million have a job. Using these stylized facts, it is estimated that households create €362 billion a year in leisure value.\(^{26}\) If everybody were to enjoy leisure at the same moment, a one-hour interruption would cause a loss of

\[ (15,987,000-7,865,000) \times 18.65 \times 0.5 \times 0.5 \times (55 + 17.5) \times 52 + 7,865,000 \times 18.65 \times 0.5 \times (40 + 17.5) \times 52 \]
€111 million.\textsuperscript{27} In the following subsection, these estimates are corrected for the fact that everyone does not enjoy leisure at the same time (as discussed above).

### 3.4.3 Interruptions with or without transfers

Shortages of supply and network failures have different consequences. If the network fails, both the users and the suppliers of electricity are affected: users produce fewer products or leisure without electricity, and suppliers cannot supply electricity. Figure 3.1 illustrates this. As usual, the demand for electricity is assumed to be price inelastic.\textsuperscript{28} Some producers can no longer supply electricity and lose their producer surplus (one is illustrated). Furthermore, several electricity users cannot consume electricity during the interruption and their consumer surplus is lost (six are illustrated). Which consumers and producers are affected depends not on their marginal cost or their marginal willingness to pay, but on their geographical location. Therefore, it is not the producers and consumers closest to the market equilibrium that are interrupted, but some arbitrary (from an economic point of view) consumers.

\textsuperscript{27} €18.65*0.5*7,865,000 + (15,987,000 - 7,865,000)* €18.65*0.5*0.5

\textsuperscript{28} Apart from the fact that electricity is a price-inelastic good, this is also caused by the fact that consumers do not pay the spot price but an average price during a period.
The situation in the case of a shortage of power is different. For brevity’s sake, the analysis here is kept as simple as possible. Market design is left out (e.g. no attention is paid to the existence of long-term contracts, which may reduce the transfers as well). In addition, the reason why the supply does not meet the demand is not touched upon. This can be either market manipulation, natural constraints on production (e.g. a shortage of cooling water or low investments in new capacity) or a price-inelastic demand in combination with a price cap.

In the case of a shortage of power, the price increases strongly (even before an interruption is necessary). Increases in the price of electricity can be extremely large, because the price elasticity of electricity is low and electricity is non-storable. As an example of the large volatility of the electricity price, Newbery (2002, p.921) when analysing the liberalization of the European electricity market, found price peaks of a 100 times the original price in 24 hours in the UK spot market.
These high prices lead to very large transfers of wealth from electricity users to electricity producers. These are transfers of wealth, because the benefits for producers and the costs for users are of the same magnitude. Although they are not costs to society as a whole, these transfers play an important role in policy discussions, because (i) electricity consumers are voters and producers are not, or because (ii) utility decreases more due to a negative transfer than it increases due to a positive transfer of wealth, or because (iii) the people that suffer from high prices live in the country or state concerned, while those who benefit live outside the high-price country or state. An example of the third case is the Californian power crisis, where Texan power companies benefited from the high prices paid by the Californian electricity users and tax payers.

Therefore, these transfers may induce the government to intervene in the market, by for example imposing a maximum price. Although this will limit the size of the transfer, additional costs will arise. Under the regime of a maximum price, the demand for electricity will be larger than the supply. Suppliers will have fewer incentives to increase production, while users will have fewer incentives to reduce demand. Investments might be stimulated by factors other than peak prices, for example capacity markets. However, this will not clear the market if sudden unexpected shortages occur. Electricity will become scarce and will have to be distributed through a rationing system, and such systems tend to be inefficient. In addition, some users will get no electricity at all, because their supply is interrupted. These interruptions are a real cost to society. Therefore, in a supply shortage situation there is a trade-off between two evils: high transfers or more interruptions. Figure 3.2 illustrates such a market: supply is smaller than demand, and a maximum price limits the transfers and causes interruptions.
The transfers of wealth can be so large that they attract a lot of attention. The most notable example is California, where the transfer from electricity users to producers in 2000 and 2001 amounted to about $40 billion (Weare, 2003a). The damage caused by the outages in 2001 was ‘only’ $0.25 billion. This figure was estimated by multiplying the non-supplied electricity by a value of lost load of $10/kWh, which is in the upper range of values used in American courts (Weare, 2003b). For an elaborate discussion of the electricity market during the Californian crisis in 2000 and 2001, see Borestein and colleagues (2002).

Transfers occur only in the case of supply shortages. As in the Netherlands there has never been an outage caused by a shortage of supply, no estimated value for such transfers is presented here.
3.5 Results

The costs of supply interruptions are measured in two ways. First, as the damage per unit of electricity that is not delivered. This is the value of lost load (VoLL). This value is particularly useful if a supply shortage occurs. In such cases, some users have to be cut off. The total costs can be minimized by cutting off the users with the lowest VoLL. Second, the costs of supply interruptions are also measured as the amount of damage per hour. These latter values are useful when making decisions about investments in network reliability. If the damage caused per hour in certain regions is high, the benefits of investments in these regions are also high.

3.5.1 The value of lost load (VoLL)

There are large differences between the distribution of electricity use and that of value added over the various economic sectors (see table 3.3). For example, manufacturing uses 38 per cent of total electricity, but creates only 8 per cent of total value (note that ‘value’ includes both the standard value added and the value of leisure). Households are also large users of electricity: they consume 25 per cent of total electricity production. However, they create 48 per cent of total value (the value for households has been calculated using the method described in section 3.4.2). The last column of table 3.3 shows how much value each sector creates on average with one kWh of electricity. This is also the average damage per unit of electricity not delivered due to an interruption (the value of lost load, or VoLL). For the Netherlands as a whole, this amounts to €8.6 per kWh. For households, the VoLL is relatively high (€16.4 per kWh) compared to the value for firms (€6.0 per kWh). The construction sector and the government have the highest VoLL, namely more than €33 per kWh. These high VoLLs are caused by a low electricity use compared to the value added generated. Therefore, when electricity is scarce and needs to be rationed, the economic cost is lowest when construction, the government and households are cut off as little as possible, and manufacturing is cut off first. The economic costs are lowest when the best (i.e. the largest) customers are treated worst.
This VoLL cannot be compared with the VoLLs calculated using a different method for the Netherlands, because no such estimates are known to exist. Kirschen (2003) reports on the British VoLL that was used in the UK regulation model (i.e. £2.768 per kWh in 1999). This VoLL was derived from a Finnish study from the 1970s; it was converted into pounds sterling and corrected for inflation. The resulting value is substantially lower than our finding. Caves et al. (1992) report on the VoLLs found in several survey-based estimates. Per study they document intervals of the estimates. Roughly, most intervals lay between $10 and $20 per kWh not supplied (1986 $), although some estimates are well below $10/kWh whereas the highest reported upper bound exceeds $50/kWh. All surveys reported on are for some industries only, whereas the estimates in this study cover society as a whole. The authors’ own estimate of $4/kWh (Caves et al., 1992) is based on interruptible service contracts. Woo and Pupp (1992) give an overview of previous outage costs studies. They find outage costs ranging from $1/kWh to $5/kWh for households, from $0.24/kWh to $27/kWh for the industrial sector and from $2.3/kWh to $27/kWh for the commercial sector. However, most of the reviewed studies only concern one of these three sectors of society, while the current study uses one consistent methodology.

Note that Ramsey pricing indicates that those consumers with the lowest price elasticity should get the highest cost. In the same way, those electricity users that are most sensitive to quality should get the least number of outages. In practice, this means that companies should get the least number of outages because they can relocate to other countries, while households and the government cannot. However, this quality elasticity should be eight times as big for industrial companies for it to be efficient to be more strict on them than on households. Furthermore, given the low total amount of damage caused by outages due to electricity shortages, these costs will be too small to play a substantial role in the location decision of companies; such other factors as wage costs, the availability of skilled personnel and the quality of the government are more important.
Table 3.3  Welfare and electricity usage of households, firms and government (2001)

<table>
<thead>
<tr>
<th></th>
<th>Electricity demand(^A) (gWh)</th>
<th>Electricity use as percentage of total electricity use</th>
<th>‘Value’ (million euros)(^B)</th>
<th>‘Value’ as percentage of total ‘value’</th>
<th>‘Value’ of lost load (€/kWh)(^C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>2,889</td>
<td>3.3</td>
<td>11,261</td>
<td>1.5</td>
<td>3.90</td>
</tr>
<tr>
<td>Energy sector</td>
<td>-72,361</td>
<td>*</td>
<td>22,910</td>
<td>3.0</td>
<td>-0.32</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>34,009</td>
<td>38.4</td>
<td>63,441</td>
<td>8.4</td>
<td>1.87</td>
</tr>
<tr>
<td>Construction</td>
<td>750</td>
<td>0.9</td>
<td>24,791</td>
<td>3.3</td>
<td>33.05</td>
</tr>
<tr>
<td>Transport</td>
<td>1,577</td>
<td>1.8</td>
<td>19,587</td>
<td>2.6</td>
<td>12.42</td>
</tr>
<tr>
<td>Services</td>
<td>24,944</td>
<td>28.1</td>
<td>198,126</td>
<td>26.1</td>
<td>7.94</td>
</tr>
<tr>
<td>Government</td>
<td>2,389</td>
<td>2.7</td>
<td>80,040</td>
<td>10.5</td>
<td>33.50</td>
</tr>
<tr>
<td>Firms and government(^D)</td>
<td>66,558</td>
<td>75.1</td>
<td>397,246</td>
<td>52.3</td>
<td>5.97</td>
</tr>
<tr>
<td>Households</td>
<td>22,100</td>
<td>24.9</td>
<td>362,055</td>
<td>47.7</td>
<td>16.38</td>
</tr>
<tr>
<td>Firms, government and households(^D)</td>
<td>88,658</td>
<td>100</td>
<td>759,301</td>
<td>100</td>
<td>8.56</td>
</tr>
</tbody>
</table>

A: Electricity demand is the quantity of power taken from (or supplied to) the grid. B: For households this is the value of leisure time, while for businesses and for the government this is value added. C: For the energy sector per delivered kWh. D: Excluding the energy sector.

Source: Netherlands Central Bureau of Statistics (CBS), Netherlands Bureau for Economic Policy Analysis (CPB); own calculations

So far, the values presented here have been average values, implicitly assuming that all sectors are equally active all the time. However, most sectors are not active 24 hours per day, nor are they active seven days per week. Some industrial firms (and the electricity sector itself) produce continuously, while service industries mostly produce during office hours only. Households enjoy leisure mostly after office hours and in the
weekends. Since data about firms’ production time specify the time pattern of production in only a very general way (round the clock, round the clock on weekdays only, during the day on weekdays, etc.), it was necessary to make assumptions about this (see the appendix).

Due to the variation in the times when sectors are active and the differences in VoLL between sectors, the VoLL changes during the day (and night) and during the week. The VoLL is a weighted average over all sectors that are active at that moment. Table 3.4 reports the VoLL for all nine different periods.

<table>
<thead>
<tr>
<th>Table 3.4</th>
<th>Value of lost load (VoLL) for nine periods, in 2001 (€/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekdays</td>
<td>day (08.00-18.00)</td>
</tr>
<tr>
<td></td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>evening (18.00-24.00)</td>
</tr>
<tr>
<td></td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td>night (24.00-08.00)</td>
</tr>
<tr>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td>Saturdays</td>
<td>day (08.00-18.00)</td>
</tr>
<tr>
<td></td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>evening (18.00-24.00)</td>
</tr>
<tr>
<td></td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>night (24.00-08.00)</td>
</tr>
<tr>
<td></td>
<td>3.9</td>
</tr>
<tr>
<td>Sundays</td>
<td>day (08.00-18.00)</td>
</tr>
<tr>
<td></td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td>evening (18.00-24.00)</td>
</tr>
<tr>
<td></td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>night (24.00-08.00)</td>
</tr>
<tr>
<td></td>
<td>3.9</td>
</tr>
<tr>
<td>Average</td>
<td>7.4</td>
</tr>
</tbody>
</table>

Source: Netherlands Central Bureau of Statistics (CBS), Netherlands Bureau for Economic Policy Analysis (CPB); own calculations

On weekdays in the daytime, the service sector is dominant: this sector generates relatively much value added per unit of electricity. The VoLL is even higher in the evening and on Sundays during the daytime. At these times, the share of households in total electricity use is relatively large. The VoLL is lowest at night, because that is when the manufacturing industry is the dominant electricity user.

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29 The value of leisure is used for households, while the value added is used for businesses and the government. The VoLL reported is the VoLL excluding the energy sector.
The VoLL also differs over regions, because some regions have a larger share of manufacturing while in other regions services dominate. Figure 3.3 plots the VoLL in different regions for three periods. The regions are based on an economic division as used by the CBS; they are not the regions served by different parts of the network.

Figure 3.3  Value of lost load (€ per kWh) at different periods, 2001

Source: Netherlands Central Bureau of Statistics (CBS), Netherlands Bureau for Economic Policy Analysis (CPB); own calculations

Especially the regions around the lake in the middle of the country (the IJsselmeer) have a high VoLL; the northern and southern parts of the Netherlands have a relatively low VoLL. The high VoLL in the areas around the IJsselmeer is caused by a high share of services, agriculture and households in these areas, and thus a low share of manufacturing.

30 The VoLL during the night is omitted from the figures, because of space considerations.
31 For each region, both the value added of each sector and the number of households are known. Electricity use per region is not known, however; therefore this study assumes that the intensity of electricity use for each sector in that region equals the intensity of electricity use of that sector in the Netherlands as a whole.
3.5.2 Amount of damage per hour

Figure 3.4 depicts the amount of damage caused by one hour of interrupted power supply for the different sectors and for society as a whole. Because not all sectors are equally active at the different moments, the amount of damage per hour varies throughout the week. A one-hour supply interruption for the whole of the Netherlands on a weekday during the daytime leads to an estimated damage (reduction in value added) of €120 million for firms and the government, and of €37 million for households (lost leisure). Although manufacturing uses most electricity, the damage is greatest in the services sector (€69 million compared to €10 million in manufacturing). In the evening, the total amount of damage is smaller: €101 million per hour compared to €159 million in the daytime. However, the composition of the damage changes drastically in the evening: instead of the services sector, households suffer the largest amount of damage, that is, €85 million (of the total damage of €101 million). Although most attention in the literature is focused on the costs for firms, households incur large costs due to electricity interruptions as well.

The welfare costs are substantially greater than the value of the electricity not supplied: the value (price times quantity) of the electricity supplied during one hour on a weekday during the daytime is €2.8 million, whereas on a weekday evening it is €0.91 million and on a Sunday during the day €0.45 million.\(^\text{32}\)

\(^\text{32}\) The price of €0.18 per kWh is assumed to be constant during the week.
Figure 3.4  Value added per hour per sector for different periods, 2001 (million euro)

Because not everybody is active at all periods, the damage caused by a one-hour power interruption for a consumer varies strongly over time.

Source: Netherlands Central Bureau of Statistics (CBS), Netherlands Bureau for Economic Policy Analysis (CPB); own calculations
Table 3.5 Damage a one-hour power interruption causes for an average person (€/hour)

<table>
<thead>
<tr>
<th></th>
<th>Day (08.00-18.00)</th>
<th>Evening (18.00-24.00)</th>
<th>Night (24.00-08.00)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weekdays</td>
<td>2.38</td>
<td>5.44</td>
<td>0.34</td>
</tr>
<tr>
<td>Saturdays</td>
<td>4.08</td>
<td>5.44</td>
<td>0.34</td>
</tr>
<tr>
<td>Sundays</td>
<td>4.08</td>
<td>5.44</td>
<td>0.34</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td>2.67</td>
</tr>
</tbody>
</table>

Note: The table gives the figures per person. When multiplied by 2.27, these become the figures per household.

Source: Netherlands Central Bureau of Statistics (CBS), Netherlands Bureau for Economic Policy Analysis (CPB); own calculations

Table 3.5 depicts the amount of damage for the average person resulting from a power outage. People enjoy most of their leisure at weekends and in the evenings; that is, the proportion of people with leisure at those times is relatively large, while during other periods the number of people working or sleeping is relatively large. As a result, the average amount of damage per person peaks at €5.44 per hour in the evening and drops to €0.34 per hour at night. On average, the damage caused by a one-hour interruption per person is €2.67 per hour.

Finally, figure 3.5 gives for each region the total cost of a one-hour supply interruption. The large number of people living in and around the largest Dutch cities, and the large size of the services sector in those areas, means that these costs are especially high in and around the largest Dutch cities.
Figure 3.5  Total welfare costs per hour at different periods, 2001 (million Euros per hour)

Source: Netherlands Central Bureau of Statistics (CBS), Netherlands Bureau for Economic Policy Analysis (CPB); own calculations

3.5.3  Sensitivity analysis

The assumptions about when sectors are active (see the appendix to this chapter) could not to a satisfactory level be underpinned with actual data. Therefore a sensitivity analysis was carried out in which different assumptions on timing were used. More specifically, we assumed relatively more activity outside normal working hours. This alternative assumption, as described in the appendix, is more extreme and therefore functions as a limit case. The average value over the week of the VoLL and that of the damage caused per hour do not change. The damage caused by a one-hour interruption decreases on a weekday during the day from €156 to €146 million. On a weekday during the evening, the damage caused per hour increases from €97 to €106 million, while on a Sunday during daytime the figure increases from €81 to €96 million. The VoLL changes on a weekday during daytime from €8.0/kWh to €7.9/kWh. On a weekday evening, the VoLL remains unchanged at €8.9/kWh. On a Sunday, during daytime the VoLL decreases from €10.3/kWh to €9.7/kWh. On a weekend night, the VoLL increases most, namely from €3.9/kWh to €5.2/kWh. Also for regions (figures 3.3 and 3.5) changes occur in the same order of magnitude.
Although these different assumptions about when sectors are active have an effect on the outcomes, these effects are not so large that they affect the conclusions.

3.6 Conclusion and suggestions for further research

In this paper, we used the production-function approach to estimate the welfare costs of a power-supply interruption. The main findings are as follows:

First, the costs vary considerably between sectors, between regions and over the week. The damage caused by an interruption on a Sunday in the daytime is about 10 per cent of the damage caused on a weekday.

Second, the welfare losses of households (lost leisure) are as important as the value added lost in firms. On a weekday during the day, the value added by firms is larger than the value of lost leisure, while in the evening the cost of a supply interruption is largest for households. Households should therefore receive adequate attention in decisions about supply security. Of all economic activities, an interruption in the service sector leads to far greater damage than does an interruption in manufacturing.

Third, the welfare costs of supply interruptions strongly depend on the way in which scarce electricity and scarce investments are allocated across sectors or regions. One way to minimize total costs is to invest relatively much in the four largest cities in the Netherlands.

Fourth, the welfare transfers caused by high prices are not a social cost: the gains for the suppliers of electricity equal the additional costs for the buyers of electricity (of course, the costs of the outages themselves, and of their consequences, are definitely a social cost). However, the transfers can be so large that they become an important policy issue. High prices leading to large transfers result from production shortages. During network failures, the price most likely will not rise.
Fifth, the costs of an interruption are far higher than the value of the electricity not delivered. The costs of a one-hour interruption on a weekday during the daytime are about €159 million, while the money paid for the electricity used during that period would be only €3 million.

Sixth, decisions about investments in networks and production and about the possible distribution of scarce electricity should be made while taking into account the economic effects. Giving households and the services sector priority over manufacturing reduces the amount of damage caused by interruptions.

Although our research yields important information about the economic effects of power supply interruptions, substantial improvements are possible. First, some effects could not be included in the current research (e.g. the stress in households, and material damage in both the manufacturing industry and households). The inclusion of more effects would improve the accuracy of the results. Second, in this paper, a uniform relation between the damage caused and the length of the interruption is assumed. It would be more realistic to have a high cost at the beginning, followed by a lower cost per minute that increases after a while (see Rathenau, 1994). To make the pattern of damage over time more realistic, it would be especially useful to have more information about the start-up costs and the loss of production at the very beginning of an interruption. Another important though currently unknown aspect is the degree to which firms and households are able to substitute activities that do not use electricity for activities that do use electricity. Third, the assumed types of interruptions could be made more like actual interruptions. Fourth, in the current research it was necessary to make assumptions about the level of production and consumption of sectors over time. It would be better to replace these assumptions by actual data. Fifth, since transfers are relevant in policy discussions, a possible extension of the present analysis would be to estimate the circumstances in which transfers may result, as well as the size of such transfers, and who would benefit and who would pay. This could be done by using existing electricity-market models. Sixth, further research could focus on the question whether the market could generate optimal solutions with respect to reliability, and if so, under what conditions. Currently, it is not clear whether the market leads to an
optimal number and duration of interruptions. Since both the interruptions and the investments in reliability are costly, it might be a good idea to search for ways in which the market could generate an optimum, without policy intervention, or to see how the market could generate more information on the optimal number of interruptions.

Finally, better data are always on the wish list of those involved in applied research. Here, there are two points on which better data would be especially welcome. First, during this research it became clear that data on electricity use are scarce. Although the services sector is extremely large, it was impossible to present a breakdown of the services sector into sub-sectors per region. Neither the electricity use per service sector nor a breakdown of the service sector per region is available in the Netherlands. These service industries differ strongly in their economic impact (e.g. the value added by a worker in the retail sector differs strongly from that added by a worker in the business services). Second, we used data gathered in different regions. These regions are defined by the CBS to facilitate the study of regional economic development, not of electricity use, and therefore they do not correspond with the areas supplied by different parts of the electricity network. Improvements on such a match between areas may be possible in future research.
Appendix: data construction

Table A1 shows the economic and energy characteristics of the Dutch economy. It was necessary to make several assumptions in order to construct this table. These assumptions are discussed below.

This table also includes the energy sector. This is troublesome for two reasons. First, during a power interruption, electricity firms (part of the energy sector) can be either a victim or the cause, while the other firms can only be the victims. Second, the electricity firms generate so much electricity that they have a negative electricity demand.

The second column shows the electricity use in gigaWatt-hours (1 gWh = 1 million kWh). The electricity use is the total quantity of electricity used by firms and households. The third column shows the electricity demand from firms and households. This is the quantity of electricity they use minus the quantity they generate themselves. This is equal to the amount they take from the grid. Because some firms generate their own power, there is a discrepancy between their electricity use and their demand for power. As electricity firms generate more electricity than they use, the electricity demand for the energy sector is negative.

The fourth column shows the value added and not the turnover. This assumes that the reduction of the turnover during an electricity outage also means that the use and thus also the costs of inputs supplied by other firms decreases.
Table A1: Economic and energy characteristics per sector of the Dutch economy, 2001

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Electricity use (gWh, 2001)</th>
<th>Electricity demand (gWh, 2001)</th>
<th>Value added (billion €, 2001)</th>
<th>Hours per year</th>
<th>Electricity use (gWh) per hour</th>
<th>Electricity demand (gWh) per hour</th>
<th>Value added per hour (million €)</th>
<th>Value added per kWh electricity demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>3,639</td>
<td>2,889</td>
<td>11.3</td>
<td>8,760</td>
<td>0.42</td>
<td>0.33</td>
<td>1.29</td>
<td>3.90</td>
</tr>
<tr>
<td>Energy</td>
<td>8,456</td>
<td>-23,361</td>
<td>23.0</td>
<td>8,760</td>
<td>0.97</td>
<td>-8.26</td>
<td>2.62</td>
<td>0.32</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>39,292</td>
<td>34,009</td>
<td>63.4</td>
<td>6,649</td>
<td>5.91</td>
<td>5.11</td>
<td>9.84</td>
<td>1.87</td>
</tr>
<tr>
<td>Food products, beverages and tobacco</td>
<td>6,819</td>
<td>5,378</td>
<td>12.6</td>
<td>6,240</td>
<td>1.09</td>
<td>0.86</td>
<td>2.03</td>
<td>2.35</td>
</tr>
<tr>
<td>Textile and leather products</td>
<td>534</td>
<td>525</td>
<td>1.4</td>
<td>2,600</td>
<td>0.21</td>
<td>0.20</td>
<td>0.54</td>
<td>2.69</td>
</tr>
<tr>
<td>Pulp and paper; publishing</td>
<td>3,623</td>
<td>2,587</td>
<td>8.2</td>
<td>6,240</td>
<td>0.58</td>
<td>0.41</td>
<td>1.32</td>
<td>3.19</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>779</td>
<td>249</td>
<td>0.2</td>
<td>8,760</td>
<td>0.09</td>
<td>0.03</td>
<td>0.02</td>
<td>0.86</td>
</tr>
<tr>
<td>Organic basic chemicals</td>
<td>4,173</td>
<td>3,901</td>
<td>1.8</td>
<td>8,760</td>
<td>0.48</td>
<td>0.45</td>
<td>0.21</td>
<td>0.47</td>
</tr>
<tr>
<td>Inorganic basic chemicals</td>
<td>1,878</td>
<td>1,718</td>
<td>0.3</td>
<td>8,760</td>
<td>0.21</td>
<td>0.20</td>
<td>0.03</td>
<td>0.16</td>
</tr>
<tr>
<td>Other basic chemicals</td>
<td>3,108</td>
<td>1,812</td>
<td>3.1</td>
<td>8,760</td>
<td>0.35</td>
<td>0.21</td>
<td>0.35</td>
<td>1.69</td>
</tr>
<tr>
<td>Chemical products</td>
<td>1,271</td>
<td>1,014</td>
<td>3.5</td>
<td>6,240</td>
<td>0.20</td>
<td>0.16</td>
<td>0.57</td>
<td>3.50</td>
</tr>
<tr>
<td>Building materials</td>
<td>1,619</td>
<td>1,560</td>
<td>2.8</td>
<td>6,240</td>
<td>0.26</td>
<td>0.25</td>
<td>0.44</td>
<td>1.78</td>
</tr>
<tr>
<td>Basic metals</td>
<td>8,428</td>
<td>8,218</td>
<td>1.7</td>
<td>8,760</td>
<td>0.96</td>
<td>0.94</td>
<td>0.20</td>
<td>0.21</td>
</tr>
<tr>
<td>Metal products</td>
<td>4,625</td>
<td>4,622</td>
<td>5.1</td>
<td>6,240</td>
<td>0.74</td>
<td>0.74</td>
<td>0.81</td>
<td>1.10</td>
</tr>
<tr>
<td>Rubber and plastic products, and non-classified industry</td>
<td>2,437</td>
<td>2,426</td>
<td>22.6</td>
<td>6,240</td>
<td>0.39</td>
<td>0.39</td>
<td>3.63</td>
<td>9.33</td>
</tr>
<tr>
<td>Construction</td>
<td>917</td>
<td>750</td>
<td>24.8</td>
<td>2,600</td>
<td>0.35</td>
<td>0.29</td>
<td>9.54</td>
<td>33.06</td>
</tr>
<tr>
<td>Transport</td>
<td>1,577</td>
<td>1,577</td>
<td>19.6</td>
<td>3,650</td>
<td>0.43</td>
<td>0.43</td>
<td>5.37</td>
<td>12.42</td>
</tr>
<tr>
<td>Services</td>
<td>27,028</td>
<td>24,944</td>
<td>198.1</td>
<td>2,860</td>
<td>9.45</td>
<td>8.72</td>
<td>69.28</td>
<td>7.94</td>
</tr>
<tr>
<td>Government</td>
<td>3,167</td>
<td>2,389</td>
<td>80.0</td>
<td>3,374</td>
<td>0.94</td>
<td>0.71</td>
<td>23.73</td>
<td>33.50</td>
</tr>
<tr>
<td>Total (excl. energy sector and households)</td>
<td>75,620</td>
<td>66,558</td>
<td>397.3</td>
<td>-</td>
<td>15.71</td>
<td>13.98</td>
<td>106.82</td>
<td>5.97</td>
</tr>
<tr>
<td>Households</td>
<td>22,100</td>
<td>22,100</td>
<td>362</td>
<td>3,386</td>
<td>6.53</td>
<td>6.53</td>
<td>106.92</td>
<td>16.38</td>
</tr>
<tr>
<td>Total (excl. energy sector and incl. households)</td>
<td>97,720</td>
<td>88,658</td>
<td>782.2</td>
<td>-</td>
<td>22.24</td>
<td>20.50</td>
<td>213.74</td>
<td>8.82</td>
</tr>
</tbody>
</table>

Note A: For the energy sector per delivered kWh.

Source: Energy Balances of the Netherlands Central Bureau of Statistics (CBS), supplemented with figures from the Netherlands Bureau for Economic Policy Analysis (CPB). The hours in which each sector is active are the authors’ estimates.
The fifth column shows the hours during which each sector is active. To estimate the active hours for each sector, we distinguished the following types of firms:

- Firms that produce round the clock, 7 days a week: \(365 \times 24 = 8760\) hours per year.
- Firms that produce round the clock, 5 days per week: \(52 \times 5 \times 24 = 6240\) hours per year.
- Firms that produce for 10 hours per day, 7 days per week: \(52 \times 7 \times 10 = 3650\) hours per year.
- Firms that produce for 10 hours per day, 6 days per week: \(52 \times 6 \times 10 = 3120\) hours per year.
- Firms that produce for 10 hours per day, 5 days per week: \(52 \times 5 \times 10 = 2600\) hours per year.

It is assumed that each sector comprises firms of one type only, the services sector and the government excepted. Half of the firms in the services sector (i.e. offices) work for 5 days per week, the other half (i.e. shops) for 6 days. The assumption that the services sector is not active on Sundays or between 18:00 and 08:00 Monday to Saturday is a simplification of reality. Indeed, some shops as well as recreation firms and restaurants are active at those times. However, most of the services sector’s value added is generated during the hours between 08:00 and 18:00, which justifies this simplifying assumption. Some 10 per cent of the government’s work is done round the clock, 75 per cent is done 5 days a week, and 15 per cent is done 7 days a week. Total manufacturing is an unweighted average of the sub-sectors.

The contents of the remaining columns follow directly from the ones already discussed.

**Sensitivity analysis**

The following assumptions were used for the sensitivity analysis presented in the main text. It was assumed that in the construction and transport sectors, 95 per cent of the companies operate during office hours on workdays and that 5 per cent of the activities in these sectors are carried out round the clock, seven days per week. It was assumed for the services and government sectors that 70 per cent of the activities take place for 10 hours a day, 5 days per week, and that 20 per cent are carried out seven days per week during office hours (i.e. 10 hours a day). The remaining 10 per cent are carried out round the clock, seven days per week.
4 Optimal Blackouts: Empirical results on reducing the social cost of electricity outages through efficient regional rationing. *

Abstract: The demand and supply of electricity must always balance. If supply falls short of demand, then price increases or voluntary demand reductions might help to maintain the balance in the system. Should these prove insufficient, then rationing is necessary. Rationing means interrupting the electricity delivery to certain areas or specific electricity users in order to preserve system stability. Since the cost of an interruption differs among electricity users, the social cost of different rationing mechanisms varies. This paper explores the cost difference between efficient regional rationing (minimizing social costs by rationing regions with low costs first) and random rationing (not taking into account social costs). For this the value of lost load calculations of De Nooij et al. (2007; included here as chapter 3) are refined. For the Netherlands, it is shown that efficient rationing can reduce social costs by 42 to 93 percent.

Keywords: electricity supply security, value of lost load (VOLL), electricity outages, power supply, social costs

JEL Classification: Q40, Q41, D61, H4, L94, R10


* We would like to thank Bert Pheiffer (†) and two anonymous referees for useful comments. All remaining errors are ours. This article is based on research commissioned by TenneT, the Dutch Transmission System Operator. Responsibility for the contents remains with the authors.
4.1 Introduction

When electricity supply falls short of demand, and spot prices, interruptible loads and load management programs cannot yield sufficient demand reduction, a black-out is unavoidable. A blackout is usually costly: production and leisure are lost and material damage is inevitable. Policy makers can respond to black-outs by improving the market such that rationing is less frequently needed, and policy makers and energy suppliers can improve rationing such that the welfare costs of rationing decrease. This paper focuses on the latter policy objective.

California is probably the most notable example; when power production fell short of demand in 2000; rolling blackouts were used to “solve” the problem. Otherwise, the Californian Independent System Operator would not have been able to maintain stability in the rest of the grid, and larger and uncontrolled blackouts would have been inevitable (see Weare, 2003a). In Europe in 2003, due to a hot and dry summer, demand seriously threatened to exceed supply in several countries. Rolling blackouts were implemented in Italy (see Meier, 2005). Another example is the interruption on Saturday November 4th 2006 in the German grid which led to electricity outages in several European Countries (UCTE, 2006). The interrupted areas were (pre)programmed by the (local) grid operators.

Black-outing a whole region is technically easier and faster than rationing individual users or economic sectors. In the Netherlands, system operators choose rolling blackouts in an unclear order without taking the differences between regions in terms of economic and social consequences of a blackout into account. An approach with lower social cost is efficient rationing. We define efficient rationing as reducing electricity use by interrupting regions having the lowest welfare costs, given a total reduction

33 A decree forbidding electricity use by certain sectors may be issued, but has serious drawbacks. First, it might not be quick enough since communication takes time. Second, a decree needs to be enforced, which is hard for many users. Most users do not yet have hourly meters, and their use is hard to detect in other ways. For example the use of household appliances (like refrigerators) can only be detected by entering each house.
necessary to maintain system stability.\textsuperscript{34} This will minimize total welfare costs. In theory it has already been shown that efficient rationing can improve welfare compared to random rationing (see for example Crew et al., 1995). Rose and Benavides (1999) present an illustrative model simulation in which efficient rationing implies substantial cost savings for firms. The present paper contributes to the literature by showing empirically how large this welfare effect can be, including welfare costs for households.

The better the electricity market is equipped with price-based approaches to rationing electricity during shortages, the less rationing will be needed (see for example Rose et al., 1997). The clearest response to a shortage is a price increase reducing demand and stimulating supply. However, this might for several reasons not work completely. For example, most electricity markets clear a day ahead.\textsuperscript{35} Another reason is that the price elasticity is often low.\textsuperscript{36} Grid operators have several options to reduce demand in a more or less market-based manner after the closure of the market (e.g. priority service, real time pricing, etc.; see Crew et al., 1995). Since market based solutions are unlikely to prevent all black-outs, improving black-out schedules may increase welfare. Other

\textsuperscript{34} Rationing less than needed for system stability will cause electricity users to be interrupted in an uncontrolled way because the system will shut down. This is highly unlikely to be welfare maximizing. Interrupting more than necessary will not create more benefits but will increase the social cost. This can therefore also not be a welfare optimum.

\textsuperscript{35} A day ahead market is often complemented with an unbalance market. Differences between the ‘purchased and or produced quantity of electricity’ and the ‘expected use and sale of electricity’ can often be traded up to one or two hours in advance. However these markets are rather thin and are not real time either.

\textsuperscript{36} Households and small companies are often not confronted with the real time price and therefore cannot react to sudden scarcity and high prices of electricity (this might change after the introduction of newer electricity meters). However, also the elasticity for price changes lasting years is low. For example Boonekamp (2007) studied the price elasticity in the Netherlands taking a response time of 10 years into account. For a doubling of the price he found a price elasticity of -0.07.

\textsuperscript{37} More or less refers to the fact that not all users of electricity participate in these approaches, e.g. because transaction costs are too high for small users.
black-outs are the result of technical difficulties, requiring a very fast reaction, reducing the possibility of a reaction via the market.

Efficient regional rationing requires information on the economic and social effects of supply interruptions at the geographical level upon which the network operator takes its decisions. These effects depend strongly on the number of people in each area, and on the type of production in the area. Two challenges are involved. The first is to value supply interruptions for different sectors of the economy and for households. This is difficult because power outages have no market price. The second is to provide this information at the geographical level at which the network operator can switch on and off areas.

Section 4.2 shortly discusses valuing electricity outages; more details and references can be found in an earlier paper in this journal (De Nooij et al., 2007; included here as chapter 3). Section 4.3 presents empirical results: to what extent can efficient regional rationing reduce the social costs of outages? Finally, section 4.4 concludes.

### 4.2 Valuing supply interruptions

The social cost of electricity rationing is minimized when those users are cut off which have the lowest costs per unit of undelivered electricity. This cost per unit of undelivered electricity is called the value of lost load (VOLL; see e.g. Munasinghe and Gellerson 1979, Sanghvi 1982, Tishler 1993, De Nooij et al. 2007). In order to calculate the VOLL, the damage caused by an electricity outage must be estimated.

The social costs of a supply interruption are determined by several factors: who is affected (e.g. manufacturing plants, offices, public services such as hospitals, and private households), the moment the interruption occurs (season, day of the week, time of day), the duration of the interruption, possible precautionary measures taken (such as

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38 See De Nooij et al. (2007) for an extended discussion of the theory and practice of valuing the damage to firms, valuing leisure, the electricity dependence of leisure activities and the possibilities of substituting non-electricity-dependent for electricity-dependent activities.
back-up facilities), and whether a notification prior to the interruption was given. Here, the focus is on who is struck (sectors), where (municipalities) and when (time-of-day). Since there is no market (price) for outages, economists have developed several methods to value supply interruptions. This study uses the production-function approach, which like any other method has its advantages and disadvantages (see De Nooij et al., 2007). The production function approach assumes that the damage a firm faces because of an interruption is equal to the full value added it would have created during the interruption. This implies a linear relation between the duration of the interruption and the damage. This might be an overestimate if some productive activities remain possible during the interruption, or if firms can adapt to the situation in other ways, such as increased production after the outage (although this will mostly be at higher cost). The scope for resilience will depend on many factors, including whether the blackout is announced or unexpected. On the other hand, the time needed to start up again and lost goods are not included in our estimates.

Apart from the effects on the firms which experience an outage, there may be wider economic effects, such as multiplier effects on other sectors (suppliers and customers) and general equilibrium effects. The type and size of wider economic effects will also depend on many factors, especially the geographical scale and the duration of the blackout. Rose et al. (2004) include many types of adaptive behaviour in a sectoral general equilibrium model. They show that the wider economic effects may be more than offset by adaptation. To reflect the uncertainties in our damage estimates, we carry out a sensitivity analysis.

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39 Other aspects are less important for most western countries. For example, back-up facilities are rare since the low number of outages makes these economically uninteresting to most electricity users.

40 Some large, industrial electricity users have interruptible contracts, which allow the electricity supplier to switch off supply at certain times. In turn, these users get price discounts. However, this pertains only to a small number of users; therefore interruptible contracts cannot be used to determine the cost of electricity interruptions for the whole society.
For households, a similar approach is followed, based on the ‘household production function’ developed by Becker (1965). It is assumed that the amount of lost leisure time is equal to the duration of the outage.\textsuperscript{41} This leads to an overestimation of the damage when, during the outage, people are still able to use their leisure time without using electricity. However, surveys show that most leisure-time activities depend on electricity, such as watching television and surfing the Internet. On the other hand, this method may imply underestimation of the damage because it assumes that the marginal hour of leisure time is lost, whereas actually a random hour is lost. Furthermore, anxiety – for instance about the duration of the interruption - and people stuck in traffic may increase the costs.\textsuperscript{42} For a more extensive discussion and figures supporting these assumptions see De Nooij et al (2007). Therefore, lost leisure has been valued as the average net hourly wage in the Netherlands for working people and as half that value for non-working persons.\textsuperscript{43} This method is assumed to provide a first approximation of the total damages. The sensitivity analysis mentioned above includes the damages for households.

The areas over which the network operator makes its decisions are, in the Netherlands, generally about ten by ten kilometres in size, which roughly corresponds to the size of an average municipality. Therefore the costs of an electricity outage are calculated at the municipality level and for different times (working hours, evening, weekend).

Unfortunately energy use and value added per sector are not known at the municipal level. This is not a typically Dutch problem: in other countries similar data challenges exist. Therefore, we estimated value added and energy use by disaggregating regional data (see Appendix to this chapter for details).

\textsuperscript{41} Interrupted housekeeping activities are carried out later, crowding out leisure.

\textsuperscript{42} Also, as for firms, the damage of lost goods (mostly in defrosted refrigerators) is not taken into account.

\textsuperscript{43} On average, non-working people would earn lower wages if they would get a job (e.g unemployed people, retired people, housewives). Also, leisure time is often less scarce for non-working persons (e.g. retired, unemployed and disabled persons) and has therefore a lower marginal value.
Table 4.1 Economic and energy characteristics per sector of the Netherlands economy, 2002*.

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Electricity demand (gWh)</th>
<th>Value added and value of leisure (billion €)</th>
<th>Hours per year</th>
<th>Explanation of hours per year</th>
<th>Value added (or value of leisure) per kWh electricity demand (VOLL) (£/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>2,800</td>
<td>10.1</td>
<td>8,760</td>
<td>Continuous</td>
<td>3.62</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>34,484</td>
<td>59.8</td>
<td>6,649</td>
<td>Average of the subsectors</td>
<td>1.73</td>
</tr>
<tr>
<td>Construction</td>
<td>750</td>
<td>24.3</td>
<td>2,600</td>
<td>10 hours per working day</td>
<td>32.44</td>
</tr>
<tr>
<td>Transport</td>
<td>1,556</td>
<td>17.8</td>
<td>3,650</td>
<td>7 days a week, 10 hours per day</td>
<td>11.47</td>
</tr>
<tr>
<td>Services</td>
<td>24,733</td>
<td>197.8</td>
<td>2,860</td>
<td>50 percent 5 days a week, the</td>
<td>8.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>other half 6 days a week.</td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td>2,397</td>
<td>82.1</td>
<td>3,374</td>
<td>10 percent continuous, 75%</td>
<td>34.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8 hours per working day and 15%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8 hours per day during seven</td>
<td></td>
</tr>
<tr>
<td>Total (excl. Households)</td>
<td>66,720</td>
<td>409.8</td>
<td>6,14</td>
<td></td>
<td>6.14</td>
</tr>
<tr>
<td>Households</td>
<td>22,800</td>
<td>373.6</td>
<td>3,386</td>
<td>An interruption during the</td>
<td>16.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>daytime leads to a loss of</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>leisure time in 35 percent of</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>the households. For the evenings</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>and for the weekend during the</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>daytime, these figures are</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>assumed to be 80 percent and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60 percent, respectively.</td>
<td></td>
</tr>
<tr>
<td>Total (incl. households)</td>
<td>89,520</td>
<td>783.4</td>
<td>8.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Excluding the energy sector.

1: See De Nooij et al. (2007) for more detail.

Note: The second column contains the net electricity demand from firms and households. This is the amount they take from the grid. The third column shows the value added for firms and the value of leisure for households.

Source: Netherlands Central Bureau of Statistics (CBS) and Netherlands Bureau for Economic Policy Analysis (CPB). The hours in which each sector is active are estimates of the authors.
Table 4.1 summarizes the data for the Netherlands as a whole. The first three columns depict electricity demand (the quantity households and companies use, minus what they generate themselves), ‘welfare’ (value added, and for households the value of leisure), and the hours a sector operates each year. The fourth column contains our estimates of hours worked per year. The timing of electricity supply interruptions determines the social costs. Differences between sectors can be large. For example, a substantial part of manufacturing operates round the clock, while many services close around five. Because the composition of sectors that operate at a specific moment varies, the VOLL will vary. Here, nine periods covering the whole week (workdays, Saturdays and Sundays, all divided into day, evening and night) are distinguished. The firms within a sector are assumed to operate at more or less similar times.

The fifth column of table 4.1 shows the value of lost load (VOLL), indicating the direct damage per kilowatt-hour (kWh) not supplied. Manufacturing, agriculture and energy companies have a low VOLL. Construction and the government have the highest VOLL. Households’ VOLL lies in-between. The service sector VOLL is lower than that of households, but higher than that of manufacturing.

4.3 **Results: Efficient blackouts versus random rationing**

The system operator can choose between several rationing methods. Here, we contrast the two main methods (if solutions using a market fail):

- **Efficient regional rationing.** Municipalities with the lowest VOLL are rationed first. The social costs per unit of electricity saved are thus kept as small as possible.
- **Random rationing.** The system operator does not take into account differences between municipalities in terms of economic and social consequences of a blackout. In this case, it is not clear which municipalities will be rationed. The expected VOLL of random rationing therefore equals the VOLL for the Netherlands as a whole. The average number of municipalities that have to be rationed is calculated using the average size of Dutch municipalities.
The VOLL for each municipality is determined by the sectoral structure per municipality. Municipalities with many activities with a low VOLL (i.e. manufacturing) have a low VOLL on average. In the Netherlands the ten municipalities with the lowest VOLL have an average VOLL of 2.4 €/kWh. When efficient rationing is applied these municipalities are rationed first. This way the social costs per unit of electricity saved are thus kept as small as possible. With random rationing the system operator does not take into account differences between municipalities in terms of economic and social consequences of a blackout. In this case, it is not clear which municipalities will be rationed. The expected VOLL of random rationing therefore equals the VOLL for the Netherlands as a whole (8.75 €/kWh). The expected number of municipalities that have to be rationed is calculated using the average size of Dutch municipalities. The highest VOLLs are found in cities that specialize in services, and in agricultural areas. The ten municipalities with the highest VOLL have an average VOLL of 15.1 €/kWh.

Table 4.2 shows the social costs of efficient regional rationing and of random rationing for a 1 gW shortage which lasts 4 hours. Note that 1 gW is about 6 percent of Dutch peak demand. The results show that social costs are substantially lower if efficient rationing is applied, than when rationing is done randomly. Depending on the day and time, efficient regional rationing might reduce the social costs of the blackout by 62 to 93 percent compared to random rationing. The savings of efficient rationing are between 10 and 34 million euros, depending on the timing.

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44 Rationing does not have to be random; the results pertain to all situations in which rationing is uncorrelated with the economic consequences. There can be other reasons not to black out certain areas. For example: not to black out the ministry governing the system operator, or not to black out areas with companies that are good at lobbying with politicians.
Table 4.2 Efficient rationing versus random rationing: A supply shortage of 1 GW during 4 hours

<table>
<thead>
<tr>
<th></th>
<th>Efficient rationing (municipalities ordered based on the VOLL)</th>
<th>Random rationing</th>
<th>Damage remaining after efficient rationing compared to the damage of random rationing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Social costs (x1000 euro)</td>
<td>Number of interrupted municipalities</td>
<td>Social costs (x1000 euro)</td>
</tr>
<tr>
<td><strong>Weekdays</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day</td>
<td>3,141</td>
<td>3</td>
<td>34,669</td>
</tr>
<tr>
<td>evening</td>
<td>3,886</td>
<td>5</td>
<td>38,866</td>
</tr>
<tr>
<td>night</td>
<td>947</td>
<td>6</td>
<td>13,215</td>
</tr>
<tr>
<td><strong>Saturdays</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day</td>
<td>13,655</td>
<td>13</td>
<td>37,195</td>
</tr>
<tr>
<td>evening</td>
<td>30,575</td>
<td>49</td>
<td>52,616</td>
</tr>
<tr>
<td>night</td>
<td>10,131</td>
<td>87</td>
<td>20,116</td>
</tr>
<tr>
<td><strong>Sundays</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day</td>
<td>14,383</td>
<td>22</td>
<td>44,124</td>
</tr>
<tr>
<td>evening</td>
<td>30,575</td>
<td>49</td>
<td>52,616</td>
</tr>
<tr>
<td>night</td>
<td>10,131</td>
<td>87</td>
<td>20,116</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>4,097</td>
<td>6</td>
<td>34,008</td>
</tr>
</tbody>
</table>

Note: Since the assumptions of the timing of activities might be important, the same table has been calculated using assumptions of the sensitivity analysis in De Nooij et al. (2007). The results differ from the table above only marginally and have therefore not been reproduced here.

Note: days are 08.00-18.00; evenings are 18.00-24.00 and nights are 24.00-08.00

45 Calculated using electricity demand from the grid. The results based on the VOLL calculated with total electricity use demand coincide almost completely with the results presented in the table, and are therefore omitted. For the purposes of a system operator who needs to reduce the electricity demand from his system, electricity demand from the grid is more relevant than total electricity use.
In these calculations the costs for the manufacturing sector might be underestimated. In this sector blackouts may lead to damaged machinery or equipment. These costs weren’t taken into account in the calculations. Therefore a sensitivity analysis is conducted with a 50% higher damage in the manufacturing sector (table 4.3, part A). Compared to table 4.1, the relative cost savings (last column) decrease, but only by a small amount.

On the other hand the calculations don’t take the fact into account that people can still be partly productive during a blackout. Especially in the service sector people may still be able to work at home or have meetings. Therefore a sensitivity analysis is also conducted with 50% lower damages to this sector (table 4.3, part B). This sector is mainly active during weekdays and Saturdays, therefore the total costs only decline at these times. The damage after efficient rationing as a fraction of random rationing increases only a little. This implies that the large cost difference between efficient and random rationing remains.

One might argue that we overestimate the costs of households, because we assume that the value of leisure time is reduced to zero during a power supply interruption. Although this assumption might reflect anxiety, lost goods (refrigerators) and other costs, it is plausible that the leisure time is not completely lost. Therefore also a sensitivity analysis with a 50 percent lower VOLL for households is presented (table 4.3, part C). This lowers the estimated cost of supply interruptions substantially, especially in the evenings when most households are active. Again, the relative costs savings attained by efficient rationing change only slightly compared to table 4.1.
<table>
<thead>
<tr>
<th>Week days</th>
<th>Efficiency Rationing</th>
<th>Random Rationing</th>
<th>Excess Damage of Random Rationing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>Social costs (x1000 euro)</td>
<td>Number of interrupted municipalities</td>
<td>Social costs (x1000 euro)</td>
</tr>
<tr>
<td></td>
<td>3,297</td>
<td>35,709</td>
<td>32,412</td>
</tr>
<tr>
<td></td>
<td>4,155</td>
<td>40,371</td>
<td>36,216</td>
</tr>
<tr>
<td></td>
<td>1,246</td>
<td>16,167</td>
<td>14,922</td>
</tr>
<tr>
<td>Evening</td>
<td>14,137</td>
<td>37,740</td>
<td>23,603</td>
</tr>
<tr>
<td>Night</td>
<td>11,963</td>
<td>22,496</td>
<td>10,532</td>
</tr>
<tr>
<td>Day</td>
<td>15,155</td>
<td>45,267</td>
<td>30,112</td>
</tr>
<tr>
<td>Evening</td>
<td>31,378</td>
<td>53,294</td>
<td>21,916</td>
</tr>
<tr>
<td>Night</td>
<td>11,963</td>
<td>22,496</td>
<td>10,532</td>
</tr>
<tr>
<td>Saturday</td>
<td>Day</td>
<td>10,948</td>
<td>29,123</td>
</tr>
<tr>
<td></td>
<td>Evening</td>
<td>30,575</td>
<td>52,616</td>
</tr>
<tr>
<td></td>
<td>Night</td>
<td>10,131</td>
<td>20,116</td>
</tr>
<tr>
<td>Day</td>
<td>14,383</td>
<td>44,124</td>
<td>29,741</td>
</tr>
<tr>
<td>Evening</td>
<td>30,575</td>
<td>52,616</td>
<td>22,041</td>
</tr>
<tr>
<td>Night</td>
<td>10,131</td>
<td>20,116</td>
<td>9,985</td>
</tr>
<tr>
<td>Sunday</td>
<td>Day</td>
<td>2,648</td>
<td>30,280</td>
</tr>
<tr>
<td></td>
<td>Evening</td>
<td>2,249</td>
<td>21,731</td>
</tr>
<tr>
<td></td>
<td>Night</td>
<td>829</td>
<td>11,115</td>
</tr>
<tr>
<td>Day</td>
<td>10,335</td>
<td>28,734</td>
<td>18,381</td>
</tr>
<tr>
<td>Evening</td>
<td>16,812</td>
<td>27,937</td>
<td>11,125</td>
</tr>
<tr>
<td>Night</td>
<td>8,278</td>
<td>15,780</td>
<td>7,503</td>
</tr>
<tr>
<td>Day</td>
<td>8,951</td>
<td>26,387</td>
<td>17,437</td>
</tr>
<tr>
<td>Evening</td>
<td>16,812</td>
<td>27,937</td>
<td>11,125</td>
</tr>
<tr>
<td>Night</td>
<td>8,278</td>
<td>15,780</td>
<td>7,503</td>
</tr>
</tbody>
</table>

Note: days are 08.00-18.00; evenings are 18.00-24.00 and nights are 24.00-08.00
From a social point of view, it might be less desirable for one group of electricity users to be interrupted for a very long time, for example, because of equity considerations or because the damage will increase after a while because stocks and material in process will deteriorate. For example in the Californian electricity crisis, the blackouts in each region lasted for a couple of hours, after which power was restored and another area was blacked out. Therefore, regional rationing might include a rule limiting the time the same area might be rationed. If the shortage lasts longer, then the municipalities with a VOLL just exceeding the VOLL of the initially blacked-out municipalities are rationed.

Table 4.4 shows the trade-off between efficient and random blackouts if after one hour the power has to be restored to an interrupted municipality. In this case the social costs are reduced by 41 percent and the welfare gain now varies between 2.6 and 14.2 million euros. This shows that constrained efficient rationing is substantially less efficient than unconstrained efficient rationing, but still represents a welfare gain compared to random rationing.
Table 4.4 Efficient rationing versus random rationing: the effect of limiting the duration of the outage per municipality

<table>
<thead>
<tr>
<th></th>
<th>Efficient rationing (municipalities ordered based on the VOLL)</th>
<th>Random rationing</th>
<th>Damage remaining after efficient rationing compared to the damage of random rationing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Social costs (x1000 euro)</td>
<td>Number of interrupted municipalities</td>
<td>Social costs (x1000 euro)</td>
</tr>
<tr>
<td><strong>Weekdays</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day</td>
<td>20,436</td>
<td>87</td>
<td>34,669</td>
</tr>
<tr>
<td>evening</td>
<td>25,902</td>
<td>102</td>
<td>38,866</td>
</tr>
<tr>
<td>night</td>
<td>10,571</td>
<td>251</td>
<td>13,215</td>
</tr>
<tr>
<td><strong>Saturdays</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day</td>
<td>29,942</td>
<td>67</td>
<td>37,195</td>
</tr>
<tr>
<td>evening</td>
<td>47,697</td>
<td>263</td>
<td>52,616</td>
</tr>
<tr>
<td>night</td>
<td>12,613</td>
<td>496</td>
<td>20,116</td>
</tr>
<tr>
<td><strong>Sundays</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>day</td>
<td>36,507</td>
<td>225</td>
<td>44,124</td>
</tr>
<tr>
<td>evening</td>
<td>47,697</td>
<td>263</td>
<td>52,616</td>
</tr>
<tr>
<td>night</td>
<td>12,613</td>
<td>496</td>
<td>20,116</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>23,837</td>
<td>127</td>
<td>34,008</td>
</tr>
</tbody>
</table>

Note: days are 08.00-18.00; evenings are 18.00-24.00 and nights are 24.00-08.00

---

Calculated using electricity demand from the grid. The results based on the VOLL calculated with total electricity use demand coincide almost completely with the results presented in the table, and are therefore omitted. For the purposes of a system operator who needs to reduce the electricity demand from his system, electricity demand from the grid is more relevant than total electricity use.
4.4 Discussion

This paper shows that the social costs of electricity outages can be reduced substantially through efficient rationing: blacking out those municipalities where social costs are relatively low. Such an efficient policy would imply switching off manufacturing locations with electricity-intensive production first, to the benefit of offices and private households. The cost of efficient rationing can be up to 93 percent lower than the social cost of random rationing. A sensitivity analysis demonstrated that this conclusion is robust to fairly large changes in the VOLL of the largest sectors which have a low VOLL (manufacturing) or a high VOLL (services and households).

Efficient rationing is welfare improving compared to other types of rationing, but might, without additional measures, be considered unfair since customers in municipalities with a low VOLL will be interrupted more often than other customers. It is possible to make efficient rationing more equitable by compensating areas which are blacked-out more frequently, for example by giving the interrupted customers a rebate on their electricity bill.

Some questions for future research remain. The first is the size of the differences in terms of electricity intensity between municipalities. The estimates of municipal production used here are based on an assumption of homogeneity of sectors among municipalities within regions. Therefore, these estimates may undervalue the differences. Better data could reduce this limitation. The second question pertains to the size of the social costs in relation to the duration of the outage. The simple linear relation assumed here is too restrictive. Survey research into the damage of outages of different durations yields more information in this respect. This type of research could help to determine the optimal duration each municipality should be interrupted in a rolling blackout. Thirdly, in rationing electricity we would expect priority treatment for sectors such as emergency services, and health care. It would be interesting to see whether this improves welfare. This would imply taking account of effects on other
sectors and loss of life as well as the effect on investments in back-up facilities. Finally, improving rationing will reduce the benefit of investments in reserve capacity (which reduces the chance and size of supply shortages). The interesting question is to determine the new, optimal level of investment in reserve capacity.

\[47\] Giving emergency services a preferential treatment might reduce their incentive to invest in back-up generators. In that case their electricity supply does not become much more reliable by the preferential treatment. However the social cost of rationing may increase.
Appendix Estimation of municipal data

De Nooij et al. (2007) studied the consequences of supply interruptions for 40 regions within the Netherlands. A region consists, on average, of 12.4 municipalities. The VOLL for each of the regions was calculated with figures on value added per sector and region and on energy use per sector. Unfortunately energy use and value added per sector are not known at the municipal level. There are, however, two other variables available at the municipality level: employment per sector and the number of branches (establishments) per sector. These can be used to estimate value added and energy use. From a theoretical point of view, disaggregation based on employment seems most suitable, because the variation within a sector of the valued added per worker is likely to be smaller than the variation of value added per branch. Unfortunately, employment figures are not given for all municipalities. Therefore, a two-step approach is used. First, for the municipalities \( i \) for which the employment in that sector is known, the value added of a sector \((VA)\) is calculated according to equation (4.1).

\[
VA_i = VA_R \times \frac{E_i}{E_R}
\]  

(4.1)

The value added of a sector in a municipality \((VA_i)\) equals the value added of that sector in that region \((VA_R)\) multiplied by the share of municipality \( i \) in the employment in that sector in that region \((E_i/E_R)\).

For municipalities \( j \) for which the employment in a sector is not known, the value added \((VA_j)\) is calculated according to equation (4.2):

\[
VA_j = (VA_R - \sum_i VA_i) \times \frac{B_j}{\sum_j B_j}
\]  

(4.2)

That is, the value added for a sector in a region that is not yet assigned to a municipality, \((VA_R - \sum_i VA_i)\), is assigned to the municipalities for which no employment is known, based on their share in the number of branches in municipalities for which employment figures were unavailable for that sector \((B_j/\sum B_j)\).
For households a different methodology is used. For each municipality, the total number of inhabitants is known as well as the number of workers and non-workers. Taking the average hourly wage in the Netherlands and using figures on how much leisure Dutch working and non-working people have, this study calculated the value of leisure for each municipality.

The electricity intensity in a sector in a municipality is assumed to equal the electricity intensity of that sector in the Netherlands as a whole (households are also seen as a sector). Using this assumption, the study calculates the electricity demand per sector per municipality. Aggregating over sectors gives the value added and the electricity demand per municipality. Dividing the former by the latter yields the VOLL for each municipality.

To this method we applied one refinement. A few companies are known for their large electricity consumption. These companies are aluminum and zinc smelters, chemical companies, and paper and pulp plants. In the Netherlands there are nine such companies which account for 8 percent of total electricity use. Given the size of their electricity consumption, failure to take into account these large electricity consumers would lead to an underestimation of electricity demand in the municipalities in which these companies are situated. To correct for these large users, the above calculation was enriched by a step prior to the calculation. First, the electricity use of these large users was assigned to their municipality. Next, we computed the industrial electricity use in that region minus the electricity use of the large electricity consumer(s). This adjusted electricity use was assigned to municipalities according to the procedure described above.

---

48 The electricity use of the largest three was derived from their annual reports. For the other six the use was estimated at 500 gWh per year.
5 Development and application of a cost-benefit framework for energy reliability. Using probabilistic methods in network planning and regulation to enhance social welfare: the N-1 rule

Abstract: Although electricity is crucial to many activities in developed societies, guaranteeing a maximum reliability of supply to end-users is extremely costly. This situation gives rise to a trade-off between the costs and benefits of reliability. The Dutch government has responded to this trade-off by changing the rule stipulating that electricity networks must be able to maintain supply even if one component fails (known as the N-1 rule), even in maintenance situations. This rule was changed by adding the phrase “unless the costs exceed the benefits.” We have developed a cost-benefit framework for the implementation and application of this new rule. The framework requires input on failure probability, the cost of supply interruptions to end-users and the cost of investments. A case study of the Dutch grid shows that the method is indeed practicable and that it is highly unlikely that N-1 during maintenance will enhance welfare in the Netherlands. Therefore, including the limitation “unless the costs exceed the benefits” in the rule has been a sensible policy for the Netherlands, and would also be a sensible policy for other countries.

Keywords: valuing supply interruption; cost-benefit analysis; reliability of electricity supply.


* This article is based on commissioned research by KEMA and SEO Economic Research for the four regional high voltage grid operators in the Netherlands (Liander, Delta Netwerkbedrijf, Stedin, Enexis) and TenneT, the Dutch TSO. We thank two anonymous reviewers. As usual, the authors are fully responsible for the contents of the article.
5.1 Introduction

Most papers on the reliability of electricity supply begin with the observation that electricity is crucial to most human activities. However, reliability comes at a price, and the costs of the distribution and transmission system are substantial. Therefore, maximum supply security may very well be undesirable from a social perspective. This paper applies this notion to a specific type of rule governing the transmission system. Electricity grids often have to satisfy rules of the N-k type: electricity supply to end-users must be uninterrupted if k components of the grid, e.g., a transformer or line, fail. Variations of this rule are N-1, N-2, or N-1 during maintenance. The latter variation applies to the Dutch grids of 220 kV and above. Until January 2005, the grids of 110 kV and above (but less than 220 kV) had to satisfy this rule as well. The Ministry of Economic Affairs (MEA, 2005) relaxed the regulation for these grids by including an economic criterion in the technical condition. Currently, the grids are to be designed and operated in such a way that N-1 during maintenance holds unless the costs of investing in this high level of reliability exceed the benefits. To apply this new rule, the benefits of better reliability need to be evaluated. Moreover, a probabilistic way of dealing with possible outages is necessary. This paper is the first to develop a cost-benefit framework to implement and apply this new rule. We find that adding the economic criteria to the N-1 during maintenance rule will slightly reduce reliability, but will substantially enhance welfare.

Several types of reliability metrics can be used for investments in transmission grids (Blumsack et al., 2007). Here, we merely look into variations of the N-k criterion. The transmission grid in England and Wales is designed to the relatively strict N-2 standard, and, in general, maintenance is also planned to the N-2 standard. Following the London blackout of 2003, the Trade and Industry Committee of the House of Commons (2004, pp. 14-16) investigated the reliability of the grid. According to this qualitative study, tightening the standard for areas where supply interruptions have significant consequences (such as the N-3 for London) was not worth the amount of investment needed. The Dutch constraint studied here is less stringent than the constraint implemented in the UK, but it is more stringent than in other countries.
Neudorf et al. (1995) compare investing in a new transmission line with investing in new local generation capacity. In their cost-benefit analysis they include capital costs, operating costs and the cost of undelivered electricity, and find that investing in new generation capacity is the cheapest solution.

In network planning, deterministic rules such as the “N-1 during maintenance criterion” are often used (Joskow and Tirole, 2005, p. 254). Such rules prescribe criteria with which the network must comply, irrespective of the probability of an outage. Deterministic rules do not take the costs and benefits of complying with the rule into account, but they are easy to apply and compliance is relatively easy for the regulator to check. Probabilistic network planning criteria take the probabilities for specific events, such as a supply interruption (IEA, 2005, pp.127-135), into account. When using the criterion “N-1 during maintenance, unless the costs exceed the benefits,” all expected social costs and benefits are also compared. Probabilistic criteria are more likely to maximize the welfare. Probabilistic planning criteria require complex calculations and more inputs, such as failure rates and component repair times, consequences of component failures for the network, and outage costs. This paper develops a probabilistic but non-complex method that can be applied to different cases. Probabilistic measures are not new (i.e., Nippert, 1997; Chowdhury and Koval, 2001). However, these applications do not always involve the cost of supply interruptions to the end-user. Our application also differs from earlier studies described in Blumsack et al. (2007) since we have studied investments for reliability reasons without taking congestion into account. This is because the Dutch grids under 220 kV serve local demand exclusively and face no transport constraints.  

We discuss investment in the grid as a social planner’s problem. Although Transmission System Operators (TSOs) do not typically fit the profile of a social planner, they do have incentives to operate efficiently. First of all, the clients of TSOs, the distribution

49 Kirschen and Stribac (2004) analyze a system that must follow the N-1 rule and therefore must reduce its transport capacity. They study the opportunity costs of the capacity left idle for reliability reasons, rather than the benefits of having more reliability. In the case at hand, reliability requires additional lines and cannot be achieved by reducing transmission capacity.
companies, have an incentive to put pressure on the TSOs tariffs. After all, the often applied system of yardstick competition promotes the efficient operation of distribution companies. Moreover, regulators usually have to give their consent on large investments. If the grid operator can convince the regulator that the investment satisfies the regulation, the grid operator is allowed to include the investment in its capital base, over which the regulator allows it to earn a fair return. That is the Dutch situation, since the TSO is an independent company whose turnover is regulated under price-cap (cpi-x) regulation. Since one of the regulators’ tasks is to make sure customers don’t pay too much, the regulator also has an incentive to put pressure on the TSO to operate and invest efficiently. On the other hand, the new rule does not exclude the possibility of overinvestment by the TSO. If the TSO chooses not to invest, resources will have to be spent on a cost-benefit analysis to convince the regulator. Moreover, overinvestment may be a safe strategy, whereas “not investing” may be a risky strategy for not-for-profit monopolists, like TSOs. Decreased reliability could lead to bad press and to political pressures. In this respect Dutch price-cap regulation lags behind and should be adjusted to better fit the new rules. Currently, if the Dutch TSO invests without showing that the costs exceed the benefits, it can include the capital cost in the capital stock used to determine the new x for the next three-year regulation period used in the cpi-x regulation.

The rest of this paper is organized as follows: Section 5.2.1 describes the rules in more detail. Sections 5.2.2 to 5.2.4 derive the information necessary to apply this rule. Section 5.3 presents a case study, and section 5.4 concludes.
5.2  N-1 during maintenance unless costs exceed the benefit

5.2.1  Discussion of the rule

In 2005, the Dutch Ministry of Economic Affairs changed the rule for the design of electricity grids:

[...] by law a grid with a voltage of 220 kV or more must be designed and operated in such a way that a single interruption has no impact on the transport of electricity. This rule also applies to the grids with a voltage between 110 kV and 220 kV, however the rule may be ignored if the costs exceed the benefits (MEA 2005, art 13; authors’ translation and italics).

The words in italics were added to existing rules. Even in maintenance situations, the electricity network must be able to maintain supply if one component fails. This is why we refer to the new rule as the “N-1 during maintenance, unless the costs exceed the benefits” criterion. By the word “benefits” the minister did not only refer to the private benefits for the network operator, but also to the social benefits of a more reliable electricity grid. Deviation from the N-1 during maintenance criterion is only allowed if the grid operator performs a social cost-benefit analysis. N-1 during maintenance is welfare enhancing if the Net Present Value of the benefits of more reliability ($B$) minus the costs ($C$) is positive for each investment. If the benefits of investing to satisfy N-1 during maintenance are decomposed, we have:

\[
NPV = \sum_{t=0}^{N} \frac{\Delta_t D(\text{outage}) \times cost(\text{outage}_t) - C_t}{(1 + d)^t} > 0
\]

In equation 5.1 the subscript $t$ denotes the different years. Future benefits are discounted with discount rate $d$, and $cost(\text{outage}_t)$ is the cost to society if the electricity supply is interrupted in year $t$. Further, $\Delta_t D(\text{outage})$ denotes the change in year $t$ of the expected duration of supply interruption due to an investment in the grid. This duration may increase over time if the electricity use in an area is growing. Otherwise, it may decrease if another grid investment is realized.
The change in the expected duration of supply interruptions is the difference in the frequency without investment \((F_{W,t})\) times the expected duration of those interruptions \((D_{W,t})\) minus the frequency with investment \((F_{I,t})\) times the expected duration of those interruptions \((D_{I,t})\). Frequency is defined on an annual basis.

\[
\Delta_t D(\text{outage}) = F_{w,t} \times D_{w,t} - F_{i,t} \times D_{i,t}
\]  

(5.2)

It is possible to include the change in maintenance costs, but omitting it does not have a large impact.\(^{50}\) In equation 5.1 the change in the outage probability and the costs and benefits are measured by comparing the situation after investment to the situation without investment. From time to time the TSO should also look at other situations, for example one in which investment is postponed for 5 or 10 years.

Section 5.2.2 describes the expected probability of a supply interruption with and without N-1 during maintenance. Section 5.2.3 describes the consequences to society if there is a supply interruption. Section 5.2.4 describes the cost of investing in the grid.

In the calculations we use a 5.5 percent real discount rate. This is the current Dutch government discount rate for cost-benefit analysis. Alternatively, one could use the weighted average cost of capital (WACC) used in the cpi-x regulation of the energy companies. For the period 2008-2010 the Dutch Energy Regulator estimated this to be between 4.7 and 6.3 before taxes and inflation, and uses an average WACC of 5.5 percent.

\(^{50}\) Redundancy simplifies maintenance, since weekend work and maintenance with the system under power can be avoided. This lowers the maintenance cost. However, investment results in a greater number of parts that need maintenance and increases the maintenance cost. The net effect is not clear. As a rule of thumb, Dutch grid operators calculate that annual maintenance and operational costs are 1 percent of investment costs. Using a 5.5-percent discount rate, 50 years’ maintenance costs would increase the cost by 17.1 percent.
5.2.2 Expected probability of failure with and without N-1 during maintenance

To determine the change in the expected duration of a supply interruption with and without N-1 during maintenance (equation 5.2) two cases need to be calculated\(^\text{51}\)\(^\text{52}\):

1. Interruption due to the failure of one component while another component is out of operation for maintenance. The frequency of this is:

\[
F_i = F_m \times D_m \times F_f
\]  
(5.3)

Where \(F\) denotes the frequency per year, \(D\) the duration (in hours), the subscript \(i\) the interruption of supply, \(m\) maintenance, and \(f\) the failure of a component. \(F_f\) depends on the frequency and duration of maintenance, as well as on the frequency of failure of the components that are not in maintenance.

Here “maintenance” means only regular, planned maintenance, not the repair of a failed component. The expected duration of the interruption (see equation 5.4) equals (i) the repair time of the failed component, if that is shorter than the time it takes to abort or finish maintenance of the other component; or (ii) the time needed to abort the maintenance minus a correction for the fact that the remaining maintenance time might be shorter than the time needed to abort at the moment the component fails.

\[
E(D) \text{ equals } D_r \text{ if } D_r < \min(D_a, D_m)
\]

\[
E(D) \text{ equals } \left(1 - \frac{1}{2} \frac{D_a}{D_m}\right)D_a \text{ if } D_r > \min(D_a, D_m)
\]  
(5.4)

\(^{51}\) Failure or maintenance of only one component is not relevant since it will not lead to an outage in both situations (with and without N-1 during maintenance). Failure or maintenance of more than two components is not relevant since it will lead to an outage irrespective of whether the N-1 during maintenance criterion is in place. Dutch statistics show that the simultaneous failure of more than two components is extremely rare. Also, most commonly caused events are already included in the statistics used here. For example, line failure when a series of masts breaks down is included in the frequency of interruption and the average duration.

\(^{52}\) In these calculations we assume that a failure is independent of whether another component fails or is being maintained.
$D_a$ denotes the time needed to abort maintenance. $D_r$ is the necessary repair time for the failed component.

2. Interruption due to the failure of two components.

$$F_i = F_f \times D_f \times F_f$$

$$E(D) \text{ equals } \frac{1}{2} D_{r1} \text{ if } D_{r1} < D_{r2}$$

$$E(D) \text{ equals } \left(1 - \frac{1}{2} \frac{D_{r2}}{D_{r1}}\right) D_{r2} \text{ if } D_{r1} > D_{r2}$$

(5.5)

Subscripts 1 and 2 denote respectively the component that fails first and successively. The expected duration is either (i) half the repair duration if repairing component 1 takes less time than repairing component 2 or – if repairing component 1 takes more time than repairing component 2 – ; or (ii) the repair time of component 2 minus a correction factor for the fact that the repair of component 1 has begun before component 2 fails and might be completed earlier than the repair of component 2.

Table 5.1 shows both the interruption frequency and the interruption duration. The first two columns show the unexpected out-of-use period for the main components. For example, a cable fails 0.0083 times per year per kilometer (about once every 120 years) and it takes 31 hours to repair the defect. Columns three to five show how often each component needs maintenance, how long the maintenance normally takes, and how long it takes to abort maintenance and use the component again. Normally, maintenance of a busbar takes 8 hours. If needed, maintenance can be aborted and the busbar can be used within 4 hours.
Table 5.1 Component interruption figures

<table>
<thead>
<tr>
<th></th>
<th>Unexpected out-of-use</th>
<th>Expected out-of-use (maintenance)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fail frequency /year</td>
<td>Repair time (hours)</td>
</tr>
<tr>
<td>Line circuit</td>
<td>0.0083/km (9)</td>
<td>1</td>
</tr>
<tr>
<td>Cable circuit</td>
<td>0.0083/km (31)</td>
<td>0.5</td>
</tr>
<tr>
<td>Transformer</td>
<td>0.0428 (63)</td>
<td>0.25</td>
</tr>
<tr>
<td>Busbar</td>
<td>0.0124 (26)</td>
<td>0.166</td>
</tr>
</tbody>
</table>

Note: Fail frequency and repair time are based on the official Dutch data on the total interruptions of the electricity grid, specified by location, impact and cause (the NESTOR database). Data for the grids of 50 kV, 110 kV, and 150 kV are included in the table. Figures are averages for all voltage levels. Maintenance figures are based on the experience of all grid operators.

5.2.3 The cost of an electricity outage: the social benefit of the investments

The social benefit of the investments made to comply with the N-1 rule is the value of the supply interruptions prevented. Since no existing market price reflects the costs of a supply interruption, several methods to calculate the effects of a supply interruption have been developed.\textsuperscript{53} Baarsma and Hop (2009), Beenstock et al. (1998), Day and Reese (1992), Hartman et al. (1991), and KEMA (2004) use surveys (stated preferences) to value outages.\textsuperscript{54} Munasinghe and Gellerson (1979), de Nooij et al. (2007), and Tishler (1993) estimate the consequences of outages in terms of lost production for firms and lost time for households (production-function approach).

\textsuperscript{53} For a description see Ajodhia et al. (2002) and Billinton et al. (1993).

\textsuperscript{54} Examples of stated preference methods are contingent valuation and conjoint analysis.
Caves et al. (1992) and Sanghvi (1982) use market data (revealed preferences). Both expenditures on back-up facilities and the use of interruptible contracts can provide information on how households or industries assess interruptions in the power supply. Corwin and Miles (1978) and Serra and Fierro (1997) list and evaluate all effects of an actual interruption.

Each of these methods has its advantages and disadvantages. This study combines three different Dutch studies: KEMA (2004) is based on the contingent valuation method; Baarsma and Hop (2009) use the conjoint method; De Nooij et al. (2007) apply the production function method. Table 5.2 summarizes the findings of these studies. The damage of supply interruptions can be expressed in damage per hour (in an area, or for a specific user) or as the damage per unit of electricity that is not supplied (the Value of Lost Load, VoLL) measured in €/kWh. Survey-based studies often report the damage per hour, because data on electricity use are hard to obtain (most respondents do not know). Valuation studies based on the production function approach can calculate both. Calculating the VoLL based on damage per hour as estimated in questionnaires is possible if the research describes a full sector and is sufficiently representative of that sector. Although the study of Baarsma and Hop (2009) is based on surveys, in table 5.2 we also calculate the VoLL.  

\footnote{55 The damage per hour for SME differs substantially between Baarsma and Hop (2009) and KEMA (2004). This is due to the use of different stated preference methods. KEMA used contingent valuation and asked directly for willingness to pay and accept, which has probably resulted in strategic and self-selection bias. Furthermore, the definition of SME probably explains the difference, at least in part.}

\footnote{56 Calculating the VoLL for KEMA required too many assumptions.}
Table 5.2  Summary of cost of supply interruptions

<table>
<thead>
<tr>
<th></th>
<th>Damage per hour (€/h)</th>
<th>VoLL (€/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KEMA (2004)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large electricity users</td>
<td>± 140.000 (^{57})</td>
<td></td>
</tr>
<tr>
<td>SME</td>
<td>± 3.500 (^{57})</td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>no willingness to pay (0)</td>
<td>willingness to accept = 10</td>
</tr>
<tr>
<td><strong>De Nooij et al. (2007)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Construction and government</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Services</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>2.67</td>
<td>16.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>89 million</td>
<td>8.6</td>
</tr>
<tr>
<td><strong>Baarsma and Hop (2009)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>SME</td>
<td>34.30</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>96 million (excluding large energy users)</td>
<td>9.5(^{58})</td>
</tr>
</tbody>
</table>

Note: Additional calculations by the authors. Baarsma and Hop (2009) found a non-linear relation between the damage from and the duration of the outage. Since the other two studies did not find this we have assumed linearity.

Based on these studies we conclude the following: first, a proportional relation between the duration of and the damage from a supply interruption is sufficiently realistic.\(^{59}\)

\(^{57}\) KEMA reported damage per category. The number in the table is the weighted average of the midpoints of each category.

\(^{58}\) Calculated on an annual electricity use of 88,658 GWh (2001; excluding own production).

\(^{59}\) This assumption gives too much weight to long outages. However, since most outages, for which the calculations here are relevant, are not very long this effect would seem to be limited. Moreover, if it produces biased results, this bias will be politically desirable. After all,
Second, the damage of a supply interruption of one hour for the Netherlands as a whole is estimated to be €90 million or 9 €/kWh for electricity not supplied.\textsuperscript{60}

\textbf{5.2.4 Cost}

To calculate equation 5.1 for a concrete project, the investment costs must be clear. Once a final decision is made, these costs are calculated in detail. However, during the tradeoff between making the investment or not, calculations are merely based on stylized cost figures. The average cost of the main components in the case discussed in section 5.3, including installation costs, is calculated using data for the five participating grid operators. KEMA tested these cost figures against an international benchmark. Table 5.3 summarizes the main cost components.

\textsuperscript{60} It would be an improvement to use regional data on the cost of supply interruptions. However, this is difficult for Baarsma and Hop (2009) and KEMA (2004), because it would require a representative questionnaire in each region. Adding extra assumptions, the method used by De Nooij et al. (2007) could be used to calculate the damage of a supply interruption at regional and local levels. De Nooij et al. (2009) show that the VoLL may differ by a factor of three between regions. In our case study, this would not matter, though it might be relevant to other cases.
Table 5.3  Cost per component

<table>
<thead>
<tr>
<th>Field</th>
<th>Cost (€ per unit, for connections €/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>380 kV</td>
<td>GIS 5,000,000</td>
</tr>
<tr>
<td></td>
<td>AIS 2,500,000</td>
</tr>
<tr>
<td>150 kV</td>
<td>GIS 1,500,000</td>
</tr>
<tr>
<td></td>
<td>AIS 1,000,000</td>
</tr>
<tr>
<td>110 kV</td>
<td>GIS 1,250,000</td>
</tr>
<tr>
<td></td>
<td>AIS 750,000</td>
</tr>
<tr>
<td>50 kV</td>
<td>GIS 500,000</td>
</tr>
<tr>
<td></td>
<td>AIS 350,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transformer</th>
<th>Cost (€ per unit, for connections €/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>380 kV</td>
<td>150 or 110 kV</td>
</tr>
<tr>
<td>150 kV</td>
<td>50, 20 or 10 kV</td>
</tr>
<tr>
<td>110 kV</td>
<td>20 or 10 kV</td>
</tr>
<tr>
<td>50 kV</td>
<td>20 or 10 kV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connection</th>
<th>Cost (€ per unit, for connections €/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>380 kV</td>
<td>double line 1,000,000</td>
</tr>
<tr>
<td></td>
<td>single cable 3,000,000</td>
</tr>
<tr>
<td></td>
<td>double cable 5,000,000</td>
</tr>
<tr>
<td>150 kV</td>
<td>double line 500,000</td>
</tr>
<tr>
<td></td>
<td>single cable 900,000</td>
</tr>
<tr>
<td></td>
<td>double cable 1,500,000</td>
</tr>
<tr>
<td>110 kV</td>
<td>double line 400,000</td>
</tr>
<tr>
<td></td>
<td>single cable 750,000</td>
</tr>
<tr>
<td></td>
<td>double cable 1,000,000</td>
</tr>
<tr>
<td>50 kV</td>
<td>double line n.a.</td>
</tr>
<tr>
<td></td>
<td>single cable 300,000</td>
</tr>
<tr>
<td></td>
<td>double cable 450,000</td>
</tr>
</tbody>
</table>

Note: GIS is gas insulated switchgear, AIS is air insulated switchgear. 50kV lines are built less often in the Netherlands due to the small cost difference compared to cable at this voltage level.
5.3 Application of the cost-benefit framework in a case study

The method described in section 5.2 can be used to analyze all situations that do not satisfy N-1 during maintenance, i.e., in the case of “tails.” A tail is a connection between the main grids and a demand center, which is only connected to one part of the grid. If that connection is lost, the demand cannot be served. This is opposite to ring structures, which are connected to the main grid at both ends. In the Netherlands there are about 77 tails. In this section, we apply the method to a specific, existing case. This case was selected by one of the distribution network operators, Enexis. In the case at hand Enexis had to invest, unless it could prove investment was socially undesirable.

Figure 5.1 illustrates the grid in the vicinity of Zwolle. The names refer to stations that connect the high voltage grid to the medium voltage grid. Demand is depicted under the name of the station. The number of lines between two stations corresponds to the number of lines in reality. The connections between Vollenhoven and Zwartsluis and between Frankhuis and Kampen have a singular configuration. During maintenance of one of these lines, power may be supplied via the other line and a third line, Kampen-Vollenhoven. Note that supply is interrupted if one of these lines fails while the other is in maintenance. Consequently, this configuration does not satisfy N-1 during maintenance. Kampen-Frankhuis is an 11.6 km long line, and Vollenhoven-Zwartsluis is a 14.6 km long cable. If an interruption occurs during maintenance the following stations are also interrupted (the demand in MW is shown between parentheses): Vollenhoven (15.8), NOP Voorsterweg (14.2), Emmeloord (57.9), Kampen (35.8). Therefore, a total of 123.7 MW of demand would be interrupted.

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61 We do not use the term “spur” to avoid confusion. In the Netherlands, tails have double lines and therefore satisfy N-1 for the lines. However, there are no double masts.

62 Ultimately, Enexis decided to invest, although the analysis below shows that the costs of investing exceed the benefits. The lower rules included in the grid code were not yet (and still are not) adapted according to the ministerial ruling discussed in section 2. Enexis decided it could not take the risk by breaking the grid codes.
The solution to satisfying N-1 during maintenance is to add a cable between Zwartsluis and Vollenhoven.\textsuperscript{63} Since a cable and a line between the same stations do not interact, one of the Frankhuis-Kampen and Zwartsluis-Vollenhoven lines can be taken out of service for maintenance and the other may fail without decreasing reliability.

In the current configuration, four situations could cause an interruption. All other combinations are not relevant. After all, the probability of an outage is the same for situations where the grid is designed according to N-1 compared to situations where the grid is designed according to N-1 during maintenance (the 1 and 2 in the numbering corresponds to the numbering in section 5.2.2):

1a. Maintenance of Zwartsluis-Vollenhoven and failure of Kampen-Frankhuis.

Zwartsluis-Vollenhoven is a cable and requires maintenance once every two

\textsuperscript{63} We have studied Zwartsluis-Vollenhoven only. Adding a connection between Kampen and Frankhuis instead would have the same effect for users, but would be more expensive to construct due to its longer distance.
years, which takes 8 hours. During this time the Kampen-Frankhuis line might fail: the expected frequency of this combination is: $0.5 \times \frac{8}{8760} \times 11.6 \text{ km} \times 0.0083 \text{ yr/km} = 4.396 \times 10^{-5} \text{/yr}$. If this happens the expected duration is $(\frac{8-2}{8}) \times 2 + (\frac{2}{8}) \times 1 = 1.75 \text{h}$. The expected electricity not supplied equals: $123.7 \text{ MW} \times 1.75 \times 4.396 \times 10^{-5} = 9.52 \text{ kWh/yr}$.

1b. Maintenance of Kampen-Frankhuis and failure of Zwartsluis-Vollenhoven. Due to the different distances, and since Kampen-Frankhuis is a line and not a cable, the results differ: the expected interruption frequency is $2.3\times11.6 \times 14.6 \times 0.0083 = 3.691 \times 10^{-4} \text{/yr}$. The maintenance of Kampen-Frankhuis takes $11.3 \text{km} \times 2.3 \text{h/km} = 26.68 \text{h}$. This is done in three shifts of 8 hours and one shift of 2.26 hours. The expected duration of the interruption is the weighted average of a failure during the three 8-hour shifts and the 2.26-hour shift: $\frac{(3\times8)}{26.68}((\frac{8-2}{8}) \times 2 + (\frac{2}{8}) \times 1) + (\frac{2.68}{26.68})(\frac{2.68-2}{8} + 2\times\frac{2.26}{2.68}) = 1.67 \text{h}$. The expected electricity not supplied is $76.32 \text{ kWh/yr}$.

2a. Failure of Kampen-Frankhuis followed by failure of Zwartsluis-Vollenhoven. The expected frequency $14.6 \times 0.0083 \times 1/\text{yr} \times 31/8760 \times 11.6 \times 0.0083 \times 1/\text{yr} = 4.129 \times 10^{-5} \text{/yr}$. The expected duration of this outage is $0.5 \times 9 = 4.5 \text{h}$. Expected electricity not supplied is $22.98 \text{ kWh/yr}$.

2b. Failure of Zwartsluis-Vollenhoven followed by failure of Kampen-Frankhuis. The expected frequency is $14.6 \times 0.0083 \times 1/\text{yr} \times 9/8760 \times 11.6 \times 0.0083 \times 1/\text{yr} = 1.199 \times 10^{-5} \text{/yr}$. The expected duration of this outage is $(\frac{31-9}{31}) \times 9 + (\frac{9}{31}) \times 9 \times 0.5 = 7.69 \text{h}$. Expected electricity not supplied is $11.41 \text{ kWh/yr}$.

Aggregation over these four cases shows that the higher expected frequency for an outage for a grid that does not satisfy N-1 during maintenance compared to a grid that does satisfy N-1 during maintenance is $4.663 \times 10^{-4} \text{/yr}$, or once every 2144 years. Expected electricity not supplied is $120.23 \text{ kWh/yr}$.

64 Ideally, the calculation should also include the four busbars on each end of the line or cable which might fail as well. Given the low probabilities of failure of a busbar compared to the failure of a line or cable, the effect of exclusion of failing busbars is negligible. Engineering practice is to ignore these low probabilities, and we have followed that practice.
Using the costs presented in table 5.3, the total investment costs are presented in table 5.4.

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 kV bay including compatible current transformer</td>
<td>2</td>
<td>750,000 / unit</td>
</tr>
<tr>
<td>Cable, single circuit, 110 kV</td>
<td>11.6 km</td>
<td>750,000 / km</td>
</tr>
<tr>
<td>Total costs</td>
<td></td>
<td>9,450,000</td>
</tr>
</tbody>
</table>

We compare two alternatives: doing nothing, or the addition of a new circuit between Zwartsluis-Vollenhoven. The investment costs of the investment alternative amount to €9.45 million. The benefits to society of prevented supply interruptions amount to $120.23 \text{kWh} \times 9 \text{€/kWh} = 1,082 \text{€/yr}$. Assuming a lifetime of 50 years per circuit, the present value of the benefits is €18,321 (using a 5.5 percent real discount rate). The NPV summing up the whole project is then $-€9.432 million$. Note that postponing the investment for 20 years will not alter the negative social welfare result.

In some circumstances, especially when demand is growing, the number of outages or the energy not supplied during an outage will increase markedly if the investment is not made. In such cases, the benefits will increase over time. Taking this into account in the Enexis example and assuming a lifetime of 50 years of the investment and an annual outage growth of 5 percent without investment, the present value of the benefits will increase to €48,044. This is more than a doubling, so a likely growth in outages should definitely be taken into consideration. However, the NPV of costs and benefits remains negative, i.e., $-€9.40 million$.

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65 This holds if the probability of an outage is positively related to the capacity of the line used at that moment.
5.4 Conclusion and reflection

This paper shows that complementing historically based engineering rules with economic rules that take total social costs and benefits into account, is a sensible policy from a social welfare perspective. Our case study shows that N-1 during maintenance as a design criterion for grids of 50 to 220 kV is not a welfare-maximizing rule. In other cases, N-1 during maintenance may generate higher benefits and lower costs, depending on grid configuration and local circumstances. The case studied in section 5.3 is representative of the Dutch grid, therefore it is unlikely that in other cases the benefits would exceed the costs.

From an economic perspective, technically based rules governing the electricity system do not generally guarantee optimal results. The framework developed in this paper can also be applied in other countries and to other rules. However, simply transferring the conclusion of the Enexis case is problematic for three reasons. First, the Netherlands has relatively few electricity outages. On average households endure less than 30 minutes of outages per year. Of this total, only 5 minutes are due to problems in the high voltage grid, and the rest is caused by interruption in the low or medium voltage distribution grids. In countries with more minutes of supply interruptions this rule will have a higher score.\(^66\) Second, the value of lost loads may vary between countries. This is related to the first reason, since the valuation of outage costs probably depends on the current level of outages. Third, the design of the grid in each country differs, and therefore N-1 during maintenance may be sensible for the 220 kV grid in some countries, while in others it might better suit grids of 110 kV and higher.

\(^66\) Note that in case of longer and more frequent outages, an alternative with improved maintenance may score higher compared to an alternative that includes more investments in infrastructure. Such maintenance alternatives can also be evaluated using the method developed and applied in this paper.
6 Divide and rule# The economic and legal implications of the proposed ownership unbundling of distribution- and supply companies in the Dutch electricity sector.

Abstract: In Machiavelli’s theory of power, the concept of ‘Divide and rule’ forms the main theme: the ruler has absolute power and to maintain and increase such power all means are justified. When viewed against the background of this theory, the current debate in the Netherlands on the unbundling of energy (electricity, gas) companies can be observed as an example of ‘divide and rule’, in which the Dutch Minister of Economic Affairs plays a central role. Yet, contrary to Machiavelli in his time, the Dutch government does, in fact, aim principally at the greater welfare of the Dutch people. It is therefore noteworthy that, while important steps in the decision to unbundled have been taken, there is no evidence that the Dutch people will indeed benefit from the envisaged unbundling.

Keywords: unbundling; cost-benefit analysis; legal aspects, electricity sector, principle of proportionality.

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* This article is based on a report written by the authors advising the Provincial States of the Province of Zeeland about the unbundling of existing energy companies (see Baarsma et al., 2004). We thank two anonymous referees for their comments on an earlier draft of the paper. The authors remain fully responsible for the contents of the article.
6.1 Introduction

In March of 2004, Mr. Brinkhorst, the Dutch Minister for Economic Affairs, announced his plans to divide the Dutch energy companies (both gas and electricity companies) into two entities: a network company (managing the network) and a company accommodating all other activities (generation and supply (‘sale’) of energy, as well as other activities such as cable TV and water supply). Figure 6.1 illustrates this proposal. Company A (with the grey boxes) owns generation, distribution and supply in region X. Company B (shaded boxes), which generates electricity and is active in supply, wants to sell in region X. Prior to unbundling, company B has to use the distribution company of company A, which therefore has a potential incentive to hinder B. After the unbundling (shown by a change from a grey to a dotted box with rounded corners), this incentive can no longer hinder competition in supply (and thus generation).

At present, the transmission system (see the dotted boxes) is already managed by a separate, state-owned company (called TenneT). The three major generation companies (Essent, Electrabel, Nuon) are private and have a market share of about 20 percent each. Several smaller producers (Delta being the largest), of which many are co-generators of heat and power, have a combined market share of 20 percent. Furthermore, about 20 percent of the Dutch electricity use is imported. The Dutch distribution market consists of about a dozen distribution companies. The largest three (Continuon (‘Nuon’), Essent, and Eneco) serve more than 90 percent of all households. While some fifty large users are connected directly to the transmission grid, the others (companies as well as households) are connected to the grids of the distribution companies. At the end of the column supply companies sell electricity to end users (households and companies). Historically, these supply companies belonged to the same group as the distribution companies. Since the market opened in July 2004, all end-users are free to choose their supplier, and some new supply companies have entered the market (of which Oxxio is the largest with a market share of about 5 percent). At present there is substantial vertical integration. Nuon and Essent are active in production, distribution and retail. While Eneco is only active in distribution and retail (its production capacity is negligible), Electrabel is predominantly active in generation (it sells directly to large electricity users, not to small consumers). Electricity trade between generators on the
one hand and supply companies and large users on the other hand is organised on two markets: the day ahead market (the APX market) and futures market (Endex). Most electricity (over 80 percent) is, however, traded over the counter and in-house. Still, compared to other Western European countries the Dutch market is relatively competitive in terms of market concentration, but in other markets (like Nordpool) liquidity is larger.

Figure 6.1 The market structure before and after unbundling

The idea of ownership unbundling was introduced in 2004. In August 2005 a draft bill implementing ownership unbundling was presented to Parliament. Pursuant to this bill the unbundling should become effective two years after the date on which the new legislation is put on the Dutch statute books (which period has subsequently been extended to two and a half years).

This paper discusses the economic and legal advantages and disadvantages of the unbundling proposal. Although this paper focuses on the electricity market, the analysis can to a large extent also be applied to the gas market. The lack of an all-encompassing cost-benefit analysis makes it impossible to conclude whether or not unbundling would
increase welfare. Given the potential large and irreversible effects associated with unbundling we feel, however, that it is essential to know the net welfare effect.

Before addressing the economic and legal aspects of unbundling (in sections 2 and 3, respectively), we will first briefly elaborate on the different forms of unbundling.

**Unbundling**

The Dutch debate revolves around *ownership* unbundling, which should be distinguished from two other types of unbundling. There are thus three types of unbundling:

- **Administrative unbundling** (‘Chinese walls’): all parties involved keep separate accounts for network management, on the one hand, and for commercial activities in the sphere of supply and production, on the other.
- **Legal unbundling**: network management and commercial activities are placed in separate legal bodies.
- **Ownership unbundling**: a different company than the one managing the commercial activities owns the shares in the network manager— and thus controls the network management.

Of these three options, *administrative unbundling* is the least, and *ownership unbundling* the most far-reaching. In line with the second European Electricity Directive, the current situation in the Netherlands is that of *legal unbundling*. The Directive explicitly states that ownership unbundling is not required.\(^67\) Given the European tendency to further strengthen the independence of the networks, ownership unbundling may, however, represent a future step in Europe. Being ahead of any such

\(^67\) Directive 2003/54/eg of the European Parliament and Council of 26 June 2003, referring to the common rules for the internal electricity market and pertaining to withdrawal of the Directive 96/92/EG, Article 15 Unbundling of distribution-network management, sub 1: Where the distribution system operator is part of a vertically integrated undertaking, it shall be independent at least in terms of its legal form, organisation and decision making from other activities not relating to distribution. These rules shall not create an obligation to separate the ownership of assets of the distribution system operator from the vertically integrated undertaking.
future development, the Netherlands is now already prepared to take this step. In the current debate, the term ‘unbundling’, where used in this paper, therefore refers to the transition from legal to ownership unbundling.

**Outline of the paper**

Section 6.2 discusses the economic advantages and disadvantages of the envisaged ownership unbundling. Section 6.3 addresses the legal aspects. Section 6.4 concludes.

### 6.2 The economics of unbundling

Below we will address the economic arguments for and against unbundling (subsections 6.2.1 and 6.2.2, respectively). The analysis presented here is based chiefly on the economic literature and various policy reports. \(^{68}\) Subsection 6.2.3 summarises our arguments.

#### 6.2.1 Advantages

Unbundling has several (potential) advantages, it: (i) stimulates competition and thus increases efficiency, (ii) simplifies market and company structures, (iii) allows privatisation (iv) advances the security of supply. Below each of these advantages will be discussed.

The most important potential advantage of unbundling is the creation of a level playing field for supply companies. Because ownership of the network qualifies as an ‘essential facility’, an integrated electricity company could in principle give (undue) preference to its own supply company. It could hinder the access of other suppliers to the network by setting the tariffs too high (raising rivals’ costs), and by using commercially sensitive information— information the competitor has to make available to the integrated network manager— to the advantage of its own supply company. Furthermore, the integrated energy company may support its own supply company through cross-

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\(^{68}\) Martin (2001), Perry (1989), Tirole (1988), OECD (2003), and letters from the Dutch Minister of Economic Affairs to the Dutch Lower Chamber.
subsidisation— for instance, by attracting advantageous (group) financing by using the network as collateral, or by carrying the same or a similar name— an advantage, from a marketing point of view. This would all be discouraged by unbundling. At present, due to the absence of a level playing field within the Dutch market, competition between the supply companies that are active in this market is not as intense as it could be. As a consequence, there is insufficient incentive to operate efficiently.

The actual effect that unbundling will have on competition (and thus on efficiency) will depend on the distortion of competition due to the existence of an uneven playing field, on the way in which unbundling will address this distortion, and on other less-far-reaching alternatives that are available. It should be noted that some forms of favouritism are hard to realise— if they can be realised at all. For example, network companies are not allowed to favour their own supply company by charging a tariff that is below the tariff charged to competitors. Yet, some other forms of favouritism may occur, such as integrated companies using the network as collateral for (group) financing. This advantage has recently been restricted (see section 6.3). However, large foreign companies seeking to enter the Dutch market may still use their networks as collateral, whereas the Dutch companies cannot. Unbundling thus creates a level playing field on a national level, but not on a European level.69

69 The effect of dividing up the playing field thus depends on delineation of the relevant market. The Minister views the Netherlands as the relevant market, whereas the energy companies consider the relevant market to include at least large parts of Europe. The right decision requires a well-founded delineation of the market, but until now such delineation is, unfortunately, not in evidence. In 2002, the NMa (the Netherlands Competition Authority) issued a memorandum on concentrations in the energy sector— for the present limiting delineation of the market to the Dutch market. This delineation now dates back four years, which, in the rapidly changing electricity market, may be too long. Furthermore, this memorandum focused mostly on production, and paid little heed to the networks (as these are regional monopolies where no competition is possible). The delineation, which was not made to address the unbundling issue, is therefore ineffectual. The NMa also insisted on this narrow delineation in their evaluation of the Nuon-Reliant takeover case (NMa, 2005).
Alternatives to achieve a level playing field are also important. Cross-subsidies, for example, and passing on commercial information, are already prohibited under the current law. Furthermore, the possibilities for cross-subsidisation are dramatically reduced by the system of price regulation for the networks, since cross-subsidisation is only possible if transport services are priced too high. Prices for transport services have strongly decreased, however, over the past few years due to price regulation. Distribution tariffs for electricity have been reduced by €200 million (Nillissen and Pollit, 2004). It would also seem that, contrary to the experience in countries as Germany and Spain, existing laws and regulations in the Netherlands already sufficiently ensure access to gas and electricity networks.

Nevertheless, competition can still be increased and a level playing field can be achieved through other means than unbundling. This is shown by an advisory note by DTe to the Minister of Economic Affairs in respect of the legal tasks of network managers after the implementation of the unbundling (DTe, 2005). DTe observes that network managers should perform more tasks themselves, instead of outsourcing such tasks to others, and thus changing from “lean” to “fat”. DTe indicates that such a change would be desirable, even if the unbundling were not to be realised.

Another important point is that unbundling does not necessarily lead to an increase in competition (Aalbers and Baarsma, 2005). It is likely that unbundling will lead to the sale of a number of supply companies. As a consequence, vertical integration of generation and supply companies will increase. Since independent suppliers will have difficulties to hedge on the futures market, new entrants may only be able to enter the market if they themselves are vertically integrated too. Such increased entrance barriers will have a detrimental effect on competition.

A second advantage is that unbundling will lead to a simplification of the market structure and the company structure. Market parties would better be able to estimate the profitability of their plans, and supervision would be easier for regulators, since the network manager would no longer have a motive for favouring a supply company.

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70 The DTe (2004) estimates this reduction to be much higher: namely, at €1.4 billion.
Consequently, supervision by the energy regulator and/or the competition authority and the quality of the regulation would probably improve, since the information backlog of the regulator compared to market parties would decrease. It is not clear, however, to what extent the regulator will be able to catch up with this backlog.

Moreover, unbundling may also complicate the market relations between the competing- and the monopolistic market segments (Gómez-Ibáñes, 2003). In addition, the government will have to prevent (regulate and supervise) vertical re-integration or mergers of the de-merged companies. On balance, however, there will still probably be an advantage.

A third advantage of unbundling, is that it will allow the provincial and municipal governments to withdraw from the commercial supply activities, and to dispose of financial means that are now tied up in the energy companies. Withdrawal from the commercial activities would be the sensible thing to do for the local governments, as these activities entail market risks that, according to the Fido Act (the law pertaining to the financial involvement of lower governments), governments may no longer enter into. It is worth questioning whether the Minister is running ahead of future privatisation possibilities by stressing the advantage of financial means becoming available. The provinces and municipalities will be allowed to sell the supply companies, they are also expected to be allowed to replace part of their equity in the network companies through debt (‘re-capitalisation’).

To understand this argument, it is crucial to realise that municipalities are currently not allowed to privatise the network companies due to the vetoing power of the Minister of Economic Affairs. The Minister has indicated, however, that once the unbundling occurs he will consider allowing the privatisation of a network company. Finally, the Minister assumes that unbundling will be advantageous for security of supply, since it will avoid under-investment in the networks which may occur due to the fact that unsuccessful commercial investments leave insufficient money to invest in the networks. Two observations are in order here. First, no one knows as yet whether an increased aggregate duration of power interruptions means that the situation has
deteriorated. The aggregate duration of power interruptions is currently short (on average less than 30 minutes per year), whereas substantial amounts of money are spent on network management. The aim should be the optimal level of security of supply (being that level of interruptions where the marginal social benefits at a lower aggregate duration of interruptions equal the marginal costs for the network company to reach this level), rather than the greatest possible security of supply.\textsuperscript{71}

Second, on 1 January 2005 (backdated to 1 January 2004), DTe (2004) introduced quality regulations to the effect that network managers with more interruptions than the norm set by DTe have to charge their customers lower prices. When a network manager scores better than the norm, it will be allowed to charge higher prices. The extent of the tariff adjustments is based on the damages suffered by the customers in the case of an interruption. By internalising the external effect (the power interruption), the quality regulation makes it in the interest of the network company to strive for the socially optimal level of interruptions. Underinvestment is an unattractive option, because it would result in lower profits. It is not clear why companies would not react to the stimuli of quality regulation and therefore would not achieve the desired result. Moreover, if the desired result would not be achieved, it is not clear why the system of quality regulation could not be improved. Unbundling should therefore merely be regarded a second-best option.

6.2.2 Disadvantages

Apart from the advantages, unbundling has several (potential) disadvantages. It: (i) causes direct cost, (ii) reduces synergy, (iii) increases transaction cost, (iv) facilitates acquisitions by foreign companies, (v) creates regulatory uncertainty and (vi) may lead to double marginalisation. These disadvantages will be discussed here below.

\textsuperscript{71} The social costs of the current level of interruptions are roughly between 50 and 100 million Euro (see Baarsma \textit{et al.}, 2005; and De Nooij \textit{et al.}, 2005). When compared to the total annual costs of the electricity network of about €2 billion, these social costs are relatively low. It may therefore be feasible for us to content ourselves with a somewhat lower quality level and a lower electricity bill.
A first major disadvantage of unbundling is the cost involved (e.g., expenditures for the services of lawyers, notary-publics and accountants). For example, market leader Essent estimates the costs of unbundling at €100 million in the first year, and at €75 million for the following years. Non-recurring expenses would thus amount to €25 million. The second largest Dutch player, Nuon, estimates the costs of unbundling at €1 billion.\(^72\) In addition, the decreasing creditworthiness of the commercial companies may lead to higher capital costs.

The changed ownership structure may impact the existing cross-border leases of the networks. In the past many energy companies have entered into lease-and-lease-back constructions with American investors in respect of their networks and production facilities. Through these transactions the American investors obtained a considerable tax advantage, which was shared with the energy companies. The companies now estimate that the envisaged unbundling may potentially lead to substantial damages under these lease transactions (up to a few billion Euro). The Dutch government, however, feels that it will not be that bad at all. At this moment it is impossible to say who will be right.

A second potential disadvantage is the loss of synergy (‘economies of scope’). These economies of scope, come about when the ‘incremental’ costs for a second service provided are less when a first service is already on offer. Whether or not this disadvantage is actually present is still unclear. The same applies to the extent of these synergy effects of vertical integration in the electricity market. Opinions vary greatly.

Essent and Nuon assert that the unbundling involves high structural costs,\(^73\) by which they mean partly the loss of synergy advantages. Van Damme and Kanning (2004) also predict a loss of synergy advantages as a result of the unbundling. The Ministry, on the other hand, does not expect great losses of synergy advantages, seeing that these are

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\(^{72}\) Actually, Nuon estimates the costs of unbundling at €1.5 billion, of which €500 million is to be spent on re-negotiating cross-border leases (quoted in Nillissen and Polit, 2004).

\(^{73}\) Statements by Mr. Broersma, Chair of the Essent Management Board, during the extra meeting of the State Commission for Economics, Education and International Affairs (EOI) and Finance and General Affairs (FAZ) on 7 September 2004 with regard to Essent’s privatisation.
already limited by the current regulations regarding the independence of the network companies. Other researchers see only few synergy advantages, since the sale of electricity and the management and maintenance of the networks are entirely different business processes. It should be noted that often no clear distinction is made between the costs and the loss of synergies. This may lead to double counting.

A third disadvantage of the unbundling—related to the loss of synergy— is the possibly higher transaction costs as a result of the unbundling. For example, the costs of finding a suitable salesperson, acquisition costs, and the costs of drawing up contracts may all increase. In the case of vertical integration, these transaction costs will be replaced by lower internal transaction costs. Unbundling would then lead to higher transaction costs (Perry, 1989). This disadvantage seems to be limited, as the networks and the supply are already placed in separate companies of the same holding.

A fourth potential disadvantage is that unbundling facilitates foreign takeovers of the Dutch companies. Integrated companies are larger and financially stronger (the network constitutes a stable source of income). In politics, this argument is often presented as an economic argument; it is, however, more of a political argument. In all likelihood, Dutch companies will be taken over by foreign parties as a result of the implementation of ownership unbundling. Whether this should be avoided is debateable. Such acquisitions may have consequences for the security of supply, for the companies themselves, and for the employees. A number of considerations are thus relevant.

It has been stated that foreign take-overs may cause a deterioration of the security of supply in the Netherlands. Because of their foreign roots, foreign companies may consider Dutch interests from the point of view of their profit-and-loss accounts, instead of from the perspective of Dutch supply security. A foreign-owned network may therefore involve some risks. This is based, however, on the (remarkable) assumption that foreign companies behave like rational companies (and Dutch companies do not), and that there are no adequate incentives to aim for the optimal level of interruptions. If these assumptions were correct, then security of supply may indeed deteriorate. However we do not believe this to be reasonable.
It may also be argued that foreign acquisitions have a negative effect on the employment situation in Dutch energy companies. The underlying idea being that the Dutch economy will benefit from having prosperous Dutch energy companies. In this respect it should be noted that stimulating a specific sector has proven to be unsuccessful in the past. Sectoral policy is therefore no longer regarded as acceptable.

A fifth disadvantage is that the unbundling proposal goes beyond the obligations defined in the European directives.\(^74\) Unbundling therefore goes against the general Dutch policy that the implementation of EU directives should not exceed what is required.\(^75\) A deviation from this policy line shall be to the detriment of the entire Dutch business community. Insecurity in respect of government intervention will increase, having a negative impact on investment decisions.

A sixth disadvantage is that a great deal of uncertainty has arisen frequently postponed debate on privatization. Furthermore, given the fact that the energy sector has faced a large number of institutional changes since the end of the 1990s— the end of which is not to be expected any time in the near future— it has had hardly any opportunity to adequately react to the incentives available. As a result, private parties continue to be restrained in their investment behavior (the ‘hold-up problem’).\(^76\)

\(^74\) The Ministry of Economic Affairs confirms this. However, the Minister indicates that, during talks with various European decision-makers, he received support for his proposals to take the Dutch unbundling beyond the obligations as set forth in the European perspective. The Minister notes that in other countries (notably in the UK) the unbundling has also taken place (although not to the same extent). The Dutch electricity companies reject this comparison: the unbundling in the UK was voluntary, whereas here it will be mandatory.

\(^75\) This standpoint predates publication of the Minister of EA’s Industry Letter (6 October 2004c; translation from the Dutch text): In order to prevent extra administrative and observance costs, the Cabinet will in principle adopt new EU directives on a one-on-one basis. The Cabinet will not top this with a ‘national head’, unless a specific Dutch problem requires that we do so.

\(^76\) For a pronouncement concerning the unbundling proposal, see Dixit (1996).
Finally, double marginalisation constitutes a seventh disadvantage of unbundling. This will occur where there is market power\textsuperscript{77}, when the two companies that will exist after the unbundling will both charge a margin (a profit surcharge) and the price will be too high. Production will be below the socially optimal level, and the turnover, the producer surplus and the consumer surplus will be lower. Since the three major players in the supply market (Nuon, Essent, and Eneco) have a total market share of 85\% in the market for supply to private consumers, double marginalisation constitutes a risk that may materialise. However, because network tariffs are regulated, this effect is expected to be rather small.

6.2.3 Synthesis: Is unbundling likely to increase welfare?

As with other policy plans, unbundling has a number of advantages and disadvantages. In this respect, it is common practice to provide an overview of costs and benefits of the envisaged policy (see table 6.1).\textsuperscript{78} A policy is attractive if the balance is positive.

<table>
<thead>
<tr>
<th>Advantage (Profit = +)</th>
<th>Value</th>
<th>Disadvantage (Cost = −)</th>
<th>Effect</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better competition through the creation of a level playing field</td>
<td>Netherlands + International −</td>
<td>Execution of unbundling</td>
<td>−</td>
<td></td>
</tr>
<tr>
<td>Simpler markets and business structures</td>
<td>+</td>
<td>Loss of synergy advantages</td>
<td>−</td>
<td></td>
</tr>
<tr>
<td>Privatisation</td>
<td>?</td>
<td>Foreign take-overs</td>
<td>− / ?</td>
<td></td>
</tr>
<tr>
<td>Security of supply</td>
<td>?</td>
<td>General insecurity regarding government intervention</td>
<td>−</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>? / +</td>
<td>Total</td>
<td>−</td>
<td></td>
</tr>
</tbody>
</table>

Unbundling leads to improved competition and facilitates supervision. There is a price to be paid, however—a price that may well be too high. Ultimately, the debate on

\textsuperscript{77} Companies do not have to be monopolists to do so. Market power from an oligopolistic market suffices (Economides and Salop, 1992).

\textsuperscript{78} For infrastructure, for example, such an overview and the estimation of main cost and benefits has been structured and standardized in the Netherlands (cf. Eijgenraam et al. 2000).
unbundling should not focus on the protection of competitors or competition, but should address the benefits of unbundling for the consumer (including benefits that result from increased competition). In the end all costs will be borne by the consumers: costs charged to the de-merged network companies will lead to higher distribution costs, whereas costs charged to the supply companies will partly, depending on the degree of competition in the supply market, be charged to the consumer. Costs that can not be passed on to the consumers will reduce either the dividend received by the local and provincial governments (as shareholders) or the purchase prices they receive upon a divestment, consequently resulting in an increase of local taxes or a lower level of local services. Ultimately, therefore, the costs of unbundling are borne by the people.

Although many studies have been performed in connection with the envisaged unbundling, we do not know of any substantive research containing a cost benefit analysis and establishing that, in the end, the consumer will benefit from the envisaged unbundling. Such a survey would require a study of several policy alternatives, thereby focusing on, among other things, the costs and benefits of an unchanged policy, of improved supervision, of additions to the regulation, and of ownership unbundling. The choice of possible alternatives plays a major role in this respect (Eijgenraam et al. 2000).

Such a comprehensive study would also have to elaborate on individual effects. The level playing field, for instance, is currently regarded an advantage as well as a

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79 Adam Smith (1776) formulated this as follows: “Consumption is the sole end and purpose of all production, and the interest of the producer ought to be attended to only so far as it may be necessary for promoting that of the consumer”.

80 In March 2006 the CPB a government economic think thank performed a rough cost-benefit analysis. However, they quantified the economic effects of unbundling vis a vis the current legal unbundling, while they in the same report acknowledge that there are two ways in which the regulation can be improved without unbundling. Noted that the first quantification of the cost and benefit was made two years after the minister announced his decision and the parliament discussed about it and most parties decided on their opinion.
disadvantage of unbundling. This is the result of, among other things, the lack of consistent market delineation.

Another important input in such an analysis will be an international comparison with other countries where unbundling is required by law. Until now, only New Zealand has implemented such mandatory requirement (unbundling in UK was voluntary). In New Zealand ownership unbundling did not have the desired result as prices did not decrease, switching rates did not increase and residual margins increased. Moreover, unbundling did indeed lead to the sale of supply companies to generators (as referred to in section 6.2.1) and, consequently, the number of players in the market decreased. At present, independent supply companies no longer exist in New Zealand.

The lack of an all-encompassing cost-benefit analysis makes it impossible to conclude whether or not unbundling would increase welfare. Such a cost-benefit analysis is, however necessary, since the potential effects associated with unbundling are substantial.

### 6.3 The legal controversy

From a legal perspective, the envisaged unbundling offers the advantage of preventing creditors of energy production-, trade- and supply companies from enforcing security rights against the networks. However, due to the ‘loan prohibition’, which is already incorporated in the Electricity Act 1998 as of July 2004, this advantage is rather limited. Moreover, if the enforcement of security rights would result in changes in ownership of the network, or in ownership of the shares in a network manager, the same would already under current legislation require the Minister’s approval.

A disadvantage is that the Dutch unbundling plans may well impose limitations that are incompatible with the freedom of capital and establishment or with the European

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82 A network for which a network manager has been appointed cannot be made available as collateral for attracting financial means, except if this happens in aid of network management.
Convention on Human Rights. In this context, it is important to realise that the European directive on electricity is not intended to interfere with ownership relations, but acknowledges that network managers do not have to own the networks that they manage.

Before addressing possible conflicts with European law, we will first briefly discuss the present Dutch legal framework.

### 6.3.1 Legislation concerning the Dutch electricity market

The position of the Dutch electricity networks and of the electricity network managers is regulated through the Dutch Electricity Act 1998, which implements the 1996 EU Directive and, as of July 2004, also the new European electricity directive. Upon the implementation of the latter directive through the ‘Implementation and Intervention Act’ (I&I), the Electricity Act 1998 was substantially amended. Supervision of the network management was expanded, which meant that measures were taken to guarantee the quality level of the networks. Furthermore, this Act contained additional powers for the DTe, as well as a number of provisions on security of supply. In many

Furthermore, no rights (that are based on the future incomes from a network for which a network manager has been appointed) can be established in favour of third parties, except if this happens in favour of the network management. All of the above holds for deals closed after the Implementation and Intervention (I&I) Act became effective.

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84 Consideration (10) of EU Directive No. 2003/54/EG, of 26 July 2003: While this Directive does not address ownership issues, it is recalled that in case of an undertaking performing transmission or distribution that is separated in its legal form from those undertakings performing generation and/or supply activities, the designated system operators may be the same undertaking owning the infrastructure.

85 Consideration (8) of EU Directive No. 2003/54/EG, of 26 July 2003: […] It is also appropriate that the transmission and distribution system operators have effective decision-making rights with respect to assets necessary to maintain, operate and develop networks when the assets in question are owned and operated by vertically integrated undertakings. […]

86 EU Directive 96/92/EG of 19 December 1996.

respects, the I&I Act goes beyond the requirements laid down in the European electricity directives. One important difference is that the I&I Act requires network managers to have the ‘economic ownership’ of their networks.\(^{88}\) Although this requirement of economic ownership has not yet become effective, the Minister has indicated that it will come into effect simultaneously with the unbundling legislation. Consequently, regardless of the fact that—through the I&I Act—regulation with respect to the networks has recently been expanded substantially, and the fact that the European electricity directives do not require ownership unbundling, a number of interventions in the ownership situation with respect to networks are currently under discussion.

### 6.3.2 Ownership rights under Article 295 of the EU Treaty

Although Article 295 of the EU Treaty stipulates that the Treaty does not interfere with the regulation of ownership rights by Member States, this does not mean that Member States are completely free in their regulation of such rights. According to jurisprudence of the EC Court of Justice, the execution of ownership rights should comply with fundamental rules of the Treaty.\(^{89}\) Examples of such fundamental rules are the non-discrimination principle, the freedom of establishment, the principle of free movement of capital, as well as the competition provisions under articles 81 and 82 of the EU Treaty.\(^{90}\) A Member State is consequently not required to privatise if this is felt to be

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\(^{88}\) However, the network manager is not required to own the network in a legal sense, although there is an additional requirement that, in such cases, the ‘lawful’ owner should ‘in principle’ be the relevant network manager’s holding company.

\(^{89}\) EU Court of Justice, 6 November 1984, *Fearon*, (C-182/83, Jurisprudence, p.3677), sub 7: “Consequently, although article 222 of the treaty does not call in question the member states’ right to establish a system of compulsory acquisition by public bodies, such a system remains subject to the fundamental rule of non-discrimination which underlies the chapter of the Treaty relating to the right of establishment.”

\(^{90}\) EU Court of Justice, 23 September 2003, case C-452/01, *Margarethe Ospelt*, sub 24: “First, it should be borne in mind that, although Article 222 of the EC Treaty (now Article 295 EC) does not call into question the Member States’ right to establish a system for the acquisition of immovable property which lays down measures specific to transactions relating to agricultural
undesirable. However, when privatisation is decided upon, the ‘golden share’ rules, described below, apply.

6.3.3 The ‘Golden-Share’ decisions after 4 June 2002

On 4 June 2002, the EC Court of Justice rendered three decisions with respect to ‘golden shares’. As a result of these decisions, the principle of free movement of capital can be restricted by national legislation only if such legislation is justified by compelling reasons of public interest, and if it is applicable to all individuals and companies.

The landmark decision is the decision in case C-503/99, Commission vs. Belgium. This decision shows that the possibilities to restrict the principle of free movement of capital are subject to strict requirements. In the case of Belgium, the State possessed ‘golden shares’ in the National Grid Company and Distrigaz. Under these golden-share arrangements, the Minister would have to be notified of a share transfer prior to the transfer, thereby enabling the Minister to prevent the transfer if it would impair national interests in the field of energy.

The EU Court of Justice determined that the legislation involved should be suitable (in order to ensure that its objectives were met), and should not go beyond what would be necessary to achieve such objectives (the ‘principle of proportionality’). It should therefore always be considered whether—in case of a real, serious threat to the supply of energy—the restrictions warrant a certain minimal supply. Whether this is indeed the case should be subject to a restrictive interpretation.

and forestry plots, such a system remains subject to the fundamental rules of Community law, including those of non-discrimination, freedom of establishment and free movement of capital […] In particular, the Court has held that the scope of the national measures governing the acquisition of immovable property should be assessed in the light of those provisions of the Treaty which relate to the movement of capital.”
It should be noted that, unlike in the Netherlands, in the case of the Commission vs. Belgium there had been no prior approval of the share transfer.\textsuperscript{91} The Belgian regulation involved an ex post measure, which is generally considered to be more acceptable than an ex ante measure.

All other decisions rendered on 4 June 2002 (as well as thereafter) concern situations of prior approval. In all of these decisions, it was found that such prior approval was contrary to the principle of free movement of capital.\textsuperscript{92}

In short, only in the case of compelling reasons of public interest will restrictions to the principle of free movement of capital be allowed. Since safeguarding the security of energy supply can be considered a legitimate public interest, restricting the transferability of shares in supply and network companies will in principle be allowed. Such restrictions must, however, be non-discriminatory; they must be suitable for achieving their objectives and cannot go beyond what is absolutely necessary.

\textbf{6.3.4 Arguments based on the European Convention on Human Rights}

Based on Article 1 of the First Protocol of the European Convention on Human Rights, enterprises are entitled to the undisturbed use of their assets.\textsuperscript{93} National governments are

\textsuperscript{91} Article 93 of the Electricity Act stipulates that every change regarding the ownership of a network or of the shares in a network manager requires the Minister’s approval.

\textsuperscript{92} In the case C-493/99 of the EU Court of Justice of 4 June 2002, the Commission vs. France, the Court ruled that, although in the case at hand there were compelling reasons of public interest, the limitation of the principle of free movement of capital was disproportional. In its decision, however, the Court did not completely preclude the compatibility between a system of prior approval and the principle of free movement of capital. In the case C-367/98, the Commission vs. Portugal, the Court ruled that this case did not involve any compelling reasons of public interest that could justify an exception to the principle of free movement of capital.

\textsuperscript{93} Article 1 of the First Protocol of the European Convention on Human Rights, on the protection of ownership (in translation): every natural and legal person has a right to the undisturbed use of his property. Ownership will be taken from no body, except in the public interest and under the conditions laid down in the law and in the general principles of
not allowed to interfere with this right. It may well be a matter of concern whether this right is respected by the current plans for unbundling, since the energy companies are being forced to demerge, making them lose the undisturbed use of their assets or at least of a major part of their assets (namely, the networks). It should thus be noted that in some cases, these networks constitute between 70 and 80 percent of the balance-sheet value of the companies.

Restrictions to the undisturbed use of assets, as described above, are allowed only on three conditions. The restriction must be in the public interest, it must be proportional (ownership interference must be proportional to the objective set) and it must have a legal basis. As to the proportionality requirement, a State has a wide ‘margin of appreciation’.\(^{94}\) However, also in this respect is it questionable whether—in the case of the envisaged unbundling—such far-reaching interference with the undisturbed use of the networks is proportional to the objectives at which the measures aim.

6.3.5 The Council of State on the networks of RWE

The arguments expressed in the section above have been confirmed by the Dutch Council of State. Already in 2002 the Council concluded (in the context of the privatisation of regional distribution company Obragas) that with respect to any transfer of shares in Obragas after its privatisation, an approval requirement as incorporated in the Gas Act and the Electricity Act 1998\(^{95}\) was contrary to the principle of free movement of capital.\(^{96}\) The Council stressed that upon the privatisation of Obragas, RWE had become the owner of the shares. In principle, therefore, no further restrictions could be imposed affecting the transferability of Obragas shares. Consequently,


\(^{95}\) Article 85 of the Gas Act, and Article 93 of the Electricity Act.

\(^{96}\) Lower Chamber 2001-2002, No. 28323, A.
Minister Brinkman’s unbundling plans should, in principle, not affect the networks that have already been privatised, like Obragas. This would constitute expropriation.

6.3.6 Unbundling scenarios incompatible with European law

In view of the above, we cannot rule out the possibility that the new legislation will be contrary to fundamental provisions in the EU Treaty or the European Convention on Human Rights. Deviations would be possible only in case of compelling reasons of public interest applicable to all individuals and companies— and even then, only to the extent that such deviations are justified. The relevant measures must be both effective (in order to ensure that the set objective is realised) and proportional. In this respect, it should be determined whether the measures guarantee a minimal supply of energy in the event of a real and serious threat— and whether they are restricted to what is really necessary. With respect to the proposed unbundling, there can be real doubts as to the latter.

It should be noted that the unbundling plans were announced even before the recent amendments of the Electricity Act 1998 (through which the I&I Act became effective)— and thus before any experience could be obtained with the new legislation. It should also be noted that the envisaged unbundling is much more than a mere legal prohibition to own shares in both network managers and commercial energy companies simultaneously. As a consequence of this prohibition, the transferability of shares in commercial energy companies— and possibly of shares in privatised network managers— will be restricted. The question is whether such measures are in the public interest, and whether they are necessary and proportional.

6.4 Conclusions

Unbundling has a number of advantages (e.g., it increases competition and facilitates supervision), as well as a number of disadvantages (e.g., implementation costs). The ratio between the costs and the benefits is not clear, however, and it is uncertain whether the Dutch society as a whole will benefit. There are also some disadvantages from a legal point of view. The Bill on unbundling may well be in violation of fundamental
stipulations in the EU Treaty, since, for example, it is questionable whether the envisaged unbundling can be considered to be in the public interest. Whether this measure is necessary and proportional is also doubtful. The absence of an all-encompassing cost-benefit analysis makes it impossible to conclude whether or not unbundling would increase welfare. However, the potential effects are substantial and irreversible. The fact that important steps towards the implementation of the draft bill on unbundling have already been taken without knowing whether this will indeed increase the welfare leads us to conclude that the political process has dominated economic rationality. This makes unbundling at this point in time (without a more profound basis) an unattractive measure, and raises the question why unbundling is nevertheless being pursued. In view thereof it should be noted that the development of regulation can be explained with the help of two theories. According to the public-interest theory regulation arises from the public’s request to solve the failure of the market (Posner 1974). The private-interest theory, or the interest-group theory, states that government regulation emerges as a result of interest-group interference. In all of this, there is a risk that the regulator protects the interests of the regulated parties, instead of the public interest (‘regulatory capture’; see Stigler 1971 and 1974). Neither of these two theories supports the envisaged unbundling proposal, however, because an understanding of the effect on welfare is as yet missing. Moreover, the unbundling proposal seems to conflict with the interests of the interest groups. The latter may be intentional, since during the last few years the energy companies have forcefully and sometimes successfully objected against new regulation (e.g. the price regulation). It may therefore be concluded that the unbundling proposal in the Netherlands complies with the private interest theory— only ‘inversely’ so.

Our conclusion is that— at least for the time being— it would not be wise to proceed with ownership unbundling without further and more detailed information on the effect on welfare. This view is based on economic and legal arguments that deserve to be heard in an integral and balanced assessment of the advantages and disadvantages of unbundling. Without an explicit cost-benefit analysis, any unbundling beyond what is required under European law would be ill advised.
7 Divorce comes at a price: An ex ante welfare analysis of ownership unbundling of the distribution and commercial companies in the Dutch energy sector#

Abstract: Vertical unbundling in the electricity sector is a hot political topic in the European Union. The European Commission has decided that the ownership unbundling of transmission networks from other stages in the value chain is the most effective way to ensure fair network access and infrastructure investment. While this European unbundling debate has not ended yet and most countries still do not have an independent Transmission System Operator (TSO), the Dutch government has already taken one step further. In 2008 it decided that distribution companies should be completely separated from commercial activities that are part of the same holding (generation, trade and supply). This governmental decision has been fiercely debated. Although the goal is to improve competition as well as security of supply, these benefits are uncertain. Nevertheless, it is certain that ownership unbundling comes at a cost. In this paper we present an ex ante cost-benefit analysis of the Dutch unbundling act. We conclude that it is unlikely that this act is welfare enhancing: divorce comes at a price.

JEL codes: D61, L42, L94, L95

Keywords: unbundling; cost-benefit analysis; electricity; gas.


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7.1 Introduction

When talking about unbundling in the electricity sector most people think of creating a Transmission System Operator (TSO), that is, separating transmission networks from electricity companies. In the Netherlands a TSO (TenneT) was already established in 1998. The Electricity Act of 1998 appointed TenneT as the independent administrator of the national high-voltage grid of 220 kV and above. Consequently, in the Netherlands unbundling is associated with the separation of distribution networks from commercial companies in the same holding. In line with the second European Electricity Directive, the situation in the Netherlands is that of legal unbundling. The Directive explicitly states that ownership unbundling is not required (EU 2003, Article 15 sub 1). However, the Dutch government is convinced that legal unbundling incurs too many competition problems and has taken unbundling a step further, requiring ownership unbundling.

In 2008 the Dutch government decided that Dutch energy companies must be unbundled before 2010, such that the distribution companies are no longer part of holdings with commercial interests in the energy sector (such as production or supply). Box 1 tells the story of how the unbundling proposal became legislation. In Dutch, the legislation is called the Wet Onafhankelijk Netbeheer (WON; Independent Grid Administration Act). In the same legislative package, the TSO was also made responsible for all 110 kV grids and above. Nevertheless, the WON was still referred to as the unbundling law, because unbundling is the most controversial part of it. In this paper we will solely deal with the unbundling part of the WON. Readers who are interested in the effects of the transfer of the management of all 110 kV grids and above to the Dutch TSO are referred to De Nooij and Baarsma (2007).

The Minister of Economic Affairs (MEA) who proposed this law, aimed to create a level playing field for supply and production companies and encourage commercial companies to become more efficient. Moreover, the WON was meant to make regulation of the energy sector more simple. Ownership unbundling is not a cheap solution; it requires reorganization and may involve costs associated with cross-border leases. However, the minister expects benefits to exceed costs, although the companies involved suspect the opposite. In the years preceding the formal unbundling decision,
extensive research was carried out on various aspects of unbundling. However, an all-encompassing cost-benefit analysis was lacking. Therefore, it was impossible to judge whether the proposal would increase or decrease welfare. This paper fills this gap. In Baarsma et al. (2007) we developed a cost-benefit framework for ownership unbundling of distribution networks and discussed the most important welfare effects in qualitative terms. In this paper we quantitatively assess various unbundling options.

As the effects of the unbundling proposal differ for the Dutch gas and electricity sectors and as gas production and transmission are not affected by the unbundling proposal, this paper deals with electricity generation, electricity transmission, and gas and electricity distribution and supply. Given that the impact on the electricity sector exceeds the impact on the gas sector, we often refer solely to the electricity sector. However, when relevant, all calculations include the gas sector.

In section 7.2 we will review the literature on ownership unbundling of electricity distribution networks. Section 7.3 will describe the expectations of the MEA regarding the unbundling legislation and the Dutch electricity market. In section 7.4 we will discuss two important elements of the CBA framework, namely the definition of the counterfactual and the alternatives, as well as the discount rate and economic growth scenario. The different effects of the unbundling proposal (such as the effect on competition and therefore efficiency, as well as the reorganization costs) will be discussed in section 7.5, while section 7.6 will present the results and conclusion.

The paper concludes that the Dutch unbundling act (WON) is more likely to decrease than to increase welfare: divorce comes at a cost. Given the large degree of uncertainty concerning the benefits of ownership unbundling it would have been wise for the government to wait a few more years to enable a reassessment of the potential benefits.
Box 7.1: How the unbundling proposal became legislation

The MEA introduced the idea of ownership unbundling in 2004 in two letters to the Dutch parliament (by parliament we mean the Dutch House of Representatives or the second chamber; the first is referred to as the Senate). In August 2005, the MEA presented a draft bill in parliament which would implement ownership unbundling. On 13 February 2006 the minister and parliament debated the proposed legislation. Members of parliament were not convinced of the costs and benefits of the proposal, the employment effects and the effects on cross-border leases. The minister therefore appointed a validation committee (the Kist Committee, named after its chairman; Kist 2006). The committee reviewed the reports commissioned by the minister. This committee reported on 20 March 2006 and parliament approved the proposed legislation that same month. Our research was undertaken while the Senate still had to approve this legislation. The Senate ratified the legislation, but at the same time required that ownership unbundling would only be executed under certain circumstances. This was surprising since the Senate does not have the right to change laws. The Senate named three conditions under which unbundling would have to be executed: (i) if integrated companies clearly hinder competition, (ii) if energy companies undertake possibly risky foreign activities, or (iii) if Brussels requires ownership unbundling. The new MEA decided in her first week (7 June 2007) that the proposed merger of Nuon and Essent was a sign that the companies wanted to obstruct competition (this was before the competition authority could judge the effects; the merger failed in the end) and that Delta was involved in risky foreign activities because it bought a Belgian garbage collection service 50 kilometres away (Delta is a multi-utility with a large garbage collection service already). Therefore the energy companies are required to unbundle before 1 January 2010.

7.2 Literature on ownership unbundling of electricity distribution networks

There is some literature available on ownership unbundling. However, most of this literature deals with the unbundling of transmission networks (e.g., Pollitt, 2007; Brunekreeft, 2008), or with vertical integration between generation and retail (see for example Bushnell et al., 2008). We could only find four papers that specifically address distribution companies.
The CPB Netherlands Bureau for Economic Policy Analysis was asked by the MEA to study the cost and benefit of the unbundling proposal (CPB, 2006). The CPB concluded that the effects of ownership unbundling were uncertain. At the same time it was stated that ownership unbundling could entail net-benefits of up to one billion euros. Our results differ from this CPB estimate. One important reason is that the CPB expects the gains from increased efficiency through more intensified competition to materialize without delay. However, the improvements in procedures, the organizational changes and the investments that are necessary to increase efficiency take time to implement. This implies that the efficiency gains were overestimated compared to our results. A second reason for the difference in results originates from the difference in the alternatives we compare. One of the alternatives not studied by the CPB turned out to be the most attractive according to our study. Ultimately, we were unable to reproduce the outcomes of the CPB study. We produced a negative net present value using their values, while the CPB concluded that the benefits exceed the costs.

Another Dutch study was performed by Künneke and Fens (2007). This paper compared several institutional regimes and did not provide a welfare analysis. Künneke and Fens developed a framework that enabled the classification of different institutional regimes according to the public utility model and the commodity model. They concluded that ownership unbundling is strongly related to further privatization: while it is possible to keep the network predominantly in public hands (institutionally structured according to the public utility model), applying ownership unbundling allows the commercial activities to be sold to private investors (the commodity model).

Thus far only New Zealand has required ownership unbundling of distribution companies (from April 1999). The reason for this unbundling was a concern that integrated companies could damage competition, due to monopoly rents and cross-subsidies between network and commercial activities, and restrict access to competing commercial companies (a PWC 2006 report described in Nillesen and Pollitt, 2008). The PWC found that unbundling did not have the intended effects: the prices fell only

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97 This policy report is also published as Mulder and Shestalova (2006).
98 In the UK, ownership unbundling is voluntary.
temporarily following unbundling and subsequently increased to the pre-unbundling level, switching rates initially increased but stagnated after two years and residual margins in the sector increased, which led to the sell-off of retailers to generators, reducing the number of players in the market. Unbundling resulted in substantial one-off restructuring costs of approximately €100 million for the distribution sector, which amounted to around 20 percent of the distribution revenues in 1998. The one-off cost for the retail companies could not be quantified, due to a lack of data; however, the operating costs only fell temporarily after unbundling. The PWC concluded that the financial costs outweighed the financial benefits. There were no non-financial benefits (such as a more reliable network) which could compensate for this.

In another study, Fraquelli et al. (2005) investigated the cost efficiency of vertical integration strategies. They used a dataset of 25 Italian local electricity utilities (of which 14 operated in both generation and distribution and 11 were pure distributors) which they observed during the period 1994-2000. They found that – especially for larger firms – there are significant economies of vertical integration and multi-stage scale. Moreover, they found that fully integrated firms enjoy higher cost synergies. Their conclusion was that these efficiency losses could render unbundling unprofitable from a welfare perspective. Since they did not investigate the benefits of unbundling, a definitive welfare statement could not be made. One possible ingredient of the Dutch unbundling proposal was to allow for privatization (cf. section 7.4). Newbery and Pollitt (1997) showed that the privatization of electricity networks has unambiguous effects on consumers. They performed a cost-benefit analysis of the privatization and restructuring of the Central Electricity Generating Board, which generated and transmitted all public electricity in England and Wales until 1990. The main benefits came from generator efficiency gains, switching from nuclear power and lower emissions, while costs increased as a result of the higher prices of imported French electricity, the cost of restructuring and premature investment in a gas-fired generating plant. Overall, restructuring led to a permanent cost reduction of 5 percent per year. This cost reduction was not equally distributed: consumers and the government lost out, while producers gained more than the cost reduction. Newbery and Pollitt is an ex post study, while the current paper provided an ex ante analysis.
7.3 The Dutch energy market and the unbundling proposal

The unbundling legislation actually consists of two related proposals: ownership unbundling of distribution companies and extension of the grid that is operated by the TSO. This section provides further details on the unbundling law (cf. MEA, 2004a, 2004b, 2006a, 2006b), while section 7.5 will discuss the effects in detail.

Figure 7.1 illustrates the effects of unbundling on the energy market. Company A (grey boxes) owns generation, distribution and supply in region X. Company B (shaded boxes), which generates electricity and is active on the supply side, wants to sell in region X. Prior to unbundling, company B cannot supply its electricity without the use of Company A’s distribution network. The latter, therefore, has an incentive to put obstacles in B’s path. After unbundling (shown by a change from a grey to a dotted box), this incentive no longer exists. Ownership unbundling creates a market structure which will permanently remove the incentives that encourage integrated distribution and retail companies to place obstacles in the path of competing retailers and generators in order to increase the profits of the holding.

As stated above, the transmission system (the dotted boxes) is already managed by a separate, state-owned company (TenneT). The three major generation companies (Essent, Electrabel and Nuon) have a market share of about 20 percent each. Several smaller producers (Delta being the largest), of which many are co-generators of heat and power, have a combined market share of 20 percent. Furthermore, about 20 percent of the electricity used in the Netherlands is imported. In 2007, the Dutch distribution market consisted of about a dozen distribution companies. The three major players (Continuon ['Nuon'], Essent and Eneco) served more than 90 percent of all households. While some fifty large users were connected directly to the transmission grid, the remaining users (business and domestic) were connected to the networks of the distribution companies. At the end of the chain, supply companies could sell electricity to end-users (domestic and business). Historically, these supply companies belonged to the same group as the distribution companies. However, when the market was opened up in July 2004, all end-users were free to choose their supplier, and some new supply companies entered the market (of which Oxxio is the largest, with a market share of...
approximately 5 percent). At present there is substantial vertical integration. Nuon and Essent are active in production, distribution and retail. While Eneco is only active in distribution and retail (its production capacity was negligible in 2007), Electrabel is predominantly active in generation. Electricity trade between generators on the one hand and supply companies and large users on the other is organized into two markets: the day-ahead market (the APX market) and the futures market (Endex). Most electricity (over 80 percent) is, however, traded over the counter and in-house. Nevertheless, compared to other Western European countries the Dutch market is relatively competitive in terms of market concentration, although other markets (such as Nordpool) have a greater liquidity.

Figure 7.1  The market structure before and after unbundling

Source: Baarsma et al. (2007)

The gas market bears a strong resemblance to the electricity sector. Distribution and supply are roughly controlled by the same market players with the same market shares as in the electricity sector. This is not surprising since, historically, gas and electricity distribution and supply were mostly undertaken by integrated regional monopolies. Gas
is already transmitted by a separate company and, therefore, the WON does not
influence this. Most gas production is not integrated with supply and has a different
market structure. Gas is produced in the Groningen Field in the Netherlands, as well as
Norway and Russia. Gas production is not affected by the WON, which renders gas
supply independent from gas distribution, thereby creating efficiency gains. Thus, both
gas transmission and production are not affected by the WON, while in the electricity
sector production and transmission are affected.

The Dutch unbundling debate centres on the question of whether changing from legal to
ownership unbundling will entail sufficient benefits compared to the costs of full
separation (different holdings with separate ownership). An important reason why the
MEA thinks that ownership unbundling is necessary is that legal unbundling requires
too much regulatory supervision that may – in the end – not be effective. Strengthening
the current process of legal unbundling through additional regulation and provision of
instruments to the regulator might reduce companies’ options for frustrating the
competition, but not their incentive to do so. The minister is convinced that integrated
companies could use several tricks that the regulator would not detect. An integrated
company could use part of its revenues from distribution activities to cross-subsidize its
retail or generation business (with the risk of running down the network) or use its
network as collateral for cheap loans to cover investment in retail or generation
(essentially, the distribution company would bear the risk of the commercial activities).
Moreover, within an integrated electricity firm, commercially sensitive data could be
exchanged between the distribution company and the retailer, and the distribution firm
is also more likely to provide technical assistance to its own retailer than assistance to
competing retailers (e.g., in the switching process).

A related problem is that of outsourcing tasks from the regulated distribution company
to commercial parties within the holding. This can be profitable for the holding, with the
relatively high cost of outsourced activities being included in the tariffs paid by
consumers for distribution services. In other words, the current, legally separated
distribution companies are considered too lean, meaning that they do not perform
enough tasks themselves for independent distribution management to be possible. Under
the proposed law, the distribution companies will be obliged to perform strategic tasks themselves, and thus turn into so-called fat distribution companies. For example, shared service centres are no longer allowed and infrastructure activities will no longer be part of the commercial companies. The distribution companies will only be allowed to outsource physical activities such as physical investments, maintenance and repair. However, the trade-off between these activities and the process of scheduling them has to be made by the network company. This is in contrast to the current situation in which some distributors are lean, that is, they have a postal address and a few employees who outsource all activities (including strategic planning) to other companies in their holding (MEA, 2006a, p. 21–22).

Finally, the minister expects unbundling to make company structures more transparent, which will help companies to make better decisions (taking only their core business into consideration).

The second part of the unbundling act concerns the extension of the grid operated by the TSO (TenneT), such that it covers all grids of 110 kV and above. The grid will remain the property of the current owners: primarily Nuon, Eneco and Essent. Currently all grids of 220 kV and above are operated by TenneT. This part of the act should optimize the investment in and operation of the grids, resulting in higher levels of reliability and lower costs. Reliability is expected to improve because, after integration, less time will be needed for communication in the case of an emergency, and also because investment in the grid will be better coordinated. However, the effect of this may be relatively small because the coordination between grid and production investment remains weak, and because a state-owned enterprise (such as TenneT) is not necessarily better at investing than commercial companies that bear the risks of investment themselves.

Furthermore, the transfer of management should stimulate competition and thus efficiency in the generation and retail sectors by ensuring producers have equal access to the wholesale market. TenneT also takes the effect of grid investments on market power into account, while a holding company which also benefits from market power in retail or production will not do this. Because of this effect on market power, the rules
for the independence of the grid are often more effective than those for the distribution grid. This is also clear from the requirements that must be met by the TSOs and distribution companies in Europe (see Jamasb and Pollitt, 2005, for an overview of achievements in various European countries).

In this paper we merely address the effects of ownership unbundling and omit the effects of the second part of the WON – the transfer of the management of all 110 kV grids and above to the Dutch TSO. Because the creation of a fat distributor is automatically linked to ownership unbundling, we will analyse the costs and benefits of both of these changes.

7.4 The CBA framework: counterfactual, policy alternatives, discount rate and growth

A cost-benefit analysis (CBA) analyses all of the effects of a plan or policy vis-a-vis a counterfactual. A CBA quantifies and expresses the effects in a common unit (usually monetary units) so they can be compared. In addition, a Net Present Value (NPV) of all effects can be calculated such that effects can be compared at different moments in time. The outcome (the aggregate of all effects) can then be seen in terms of an increase or decrease in welfare.

To assess the welfare implications of a policy proposal, it should be compared to a realistic counterfactual. The effects (either costs or benefits) are assessed as the differences between the policy options and the counterfactual. Furthermore, it is important to include all other policy options available, to see whether a better policy might be possible.

The counterfactual in our study assumes no ownership unbundling (but does assume legal unbundling) and no introduction of a fat distribution company, but it is not the same as the situation in 2007. Small changes (fine-tuning) to the legislation and the rules instituted by the regulator are possible in the counterfactual, for example when the supplier of last resort rule does not work properly or when behaviour that discourages competition occurs. Finally, the counterfactual also takes into account regulations that
were accepted before 2007. Most importantly, in 2004 the Electricity Act of 1998 was substantially amended by the Implementation and Intervention Act (I&I). Supervision of network management was expanded, which meant that measures were taken to guarantee quality levels in the networks. Furthermore, this Act gave additional powers to the energy regulator, as well as including a number of provisions on security of supply. Consequently, in the counterfactual, we also take into account the effects of the I&I Act.

In the original study we provided a complete overview and distinguished nine different alternatives. Table 7.1 presents seven of these alternatives. Each alternative consists of three potential elements: (i) ownership unbundling, (ii) introduction of fat distributors, (iii) transfer of the management of the 110 kV grids to TenneT, and (iv) privatization of production and supply companies and up to 49 percent of network companies. Unbundling was first pursued to enable the privatization of commercial activities without privatizing the monopoly of the grid. However, not all of the current owners – municipal and provincial authorities – want to privatize. Also, parliament now doubts the desirability of privatization and has asked the minister to convince the current owners not to do so. Therefore, whether privatization would take place and the timing of this were unclear at the time the law was being discussed.

Here we only analyse alternative D. In this alternative no privatization occurs and the management of the high voltage grid is not transferred to the TSO. Due to considerations of space we want to focus on the effects of ownership unbundling (compared to legal unbundling), as this is relevant to the focus in current European policy discussions. As stated earlier, ownership unbundling is not possible without the fattening of lean distributors. That is why the creation of a fat distributor is included in

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99 De Nooij and Baarsma (2007) also considered two alternatives, including the Agreement of March 2005 that the four major energy companies had been negotiating with the Ministry and the Energy regulator. Because the Agreement was rejected by the minister – who thereby overruled his officials – and because the alternatives, which included the Agreement, did not provide additional information regarding our main conclusion (i.e., it is likely that the WON is welfare decreasing), both alternatives are not discussed here.
the one alternative we present here. All nine alternatives are discussed in De Nooij and Baarsma (2007).

Table 7.1 Counterfactual (0) and seven policy alternatives (A–G)

<table>
<thead>
<tr>
<th></th>
<th>Introduction of fat distributors</th>
<th>Transfer of the management of the 110 kV grids to TenneT</th>
<th>Ownership unbundling</th>
<th>Privatization of the production and supply companies and up to 49 percent of the network companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>A</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>B</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>C</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>D</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>E</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>F</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>G</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

All the effects are assumed to exist for up to 100 years. The effects in the distant future are relatively small due to the use of a real discount rate of 7 percent. At the time the legislative package was discussed, this was the official discount rate used by the government for projects with a standard risk and without inflation. Since then it has been lowered to 5.5 percent (without affecting our conclusion). All calculations are in euros from 2006, such that inflation does not influence the results.

Both the economy and energy use will grow in the coming decades. We make the following assumptions: (i) most benefits will grow with economic growth. We use 1.7 percent as the annual economic growth rate as this is the average economic growth rate in the four official scenarios for the Netherlands between 2002 and 2040; (ii) the benefit of more efficient production and supply and the permanent reorganization cost will increase with the annual growth of the economy, minus an assumed annual increase in energy efficiency of 1 percent, this gives a total of 0.7 percent growth; (iii) due to the regulation of the distribution grid, costs currently fall about 2 percent annually.
Therefore the benefit of better-focused and more efficient distribution decreases by 0.3 percent per year.

### 7.5 Effects of unbundling

This section analyses the differences between the counterfactual of legal unbundling and the project alternative of ownership unbundling. The costs and benefits of ownership unbundling that could be expressed in monetary terms are presented in table 7.2. The effects on the environment, employment, share values and the competitiveness of large energy users are omitted from the table, as are the costs of taxation and the increased insecurity regarding future government intervention due to the unbundling act running counter to the general Dutch policy concerning the implementation of EU directives, that is, not to exceed what is required. As discussed in De Nooij and Baarsma (2007) these effects are small and do not affect the conclusion. Nevertheless, in our original study, we evaluated all the effects that play a role in the policy discussion in order to prevent small effects from being overemphasized.

Here we focus on the largest – and thus most important – benefits and costs. Interested readers are referred to De Nooij and Baarsma (2007) for an evaluation and discussion of all of the effects. The most important benefits are increased competition and more efficiency (section 7.5.1.1) and more efficient distribution companies (section 7.5.1.2). The most important costs are the one-off and permanent reorganization costs (section 7.5.2). In table 7.2 we give a short explanation of the benefits and costs that are not discussed in the main text. When presenting the results of the cost-benefit analysis, all effects in table 7.2 are included.

We included uncertainty of the effects in our analysis by using three scenarios: (i) a probable scenario, (ii) a positive scenario (with low costs and high benefits) and (iii) a negative scenario (with high costs and low benefits). The negative and positive scenarios represent reasonable lower and upper limits.
For quantification and monetary valuation of all effects we relied as much as possible on published studies. Where needed – due to a lack of specific studies – we made our own calculations. A drawback of this kind of study is that assumptions are inevitable. However, an ex ante policy evaluation is not possible without assumptions. Here they are easily recognizable. This may lead to more criticism, compared to an evaluation with more hidden assumptions. Most main effects were studied in reports for the Dutch Ministry of Economic Affairs. Some of these studies are contradictory. Therefore, we will describe these data sources in as much detail and as critically as possible.
Table 7.2  Summary of costs and benefits of ownership unbundling

<table>
<thead>
<tr>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Costs of reorganization and loss of economies of scope (one-off and permanent costs)</td>
</tr>
<tr>
<td>2. Costs related to Cross Border Leases</td>
</tr>
</tbody>
</table>
| Explanation: There are two kinds of costs associated with CBLs. The first is potential damage claims by American investors. The energy companies sold (or leased for a very long period) their grids and some of their generation plants to American investors in order to lease them back for a much shorter period. This created a tax benefit for the American investor, which it shared with the Dutch companies. Unbundling might affect the collateral of these contracts or the form of the contract, and the American investors might claim damages. Since these costs are highly controversial, they are Not Monetized and denoted below by ‘-NM’.
| Apart from these potential damages, some of the CBLs have to be adjusted. In the probable scenario, the costs of the unbundling alternatives are estimated to be €2.25 million annually, plus a one-off cost of €5 million. In the negative and the positive scenario the costs are 50 percent higher and lower respectively. |
| 3. Costs of finance                                                  |
| Explanation: Integrated companies might have an advantage when it comes to attracting money on the international credit market. MEA (2006a) expects these costs to be between €50 million and €100 million per year. This financial advantage is limited (otherwise big companies would have such a large competitive advantage that most sectors would be dominated by one company, which is not the case). Therefore, the loss of synergy has been valued at zero in the probable and positive scenarios. In the negative scenario the costs are estimated at €100 million in the first year and are assumed to disappear in 10 years (linear progression). |
| 4. Costs of legal cases                                              |
| Explanation: Unbundling will possibly interfere with ownership rights, the fundamental European right of free movement of capital and the European Convention on Human Rights, which states that enterprises are entitled to the undisturbed use of their assets (see Baarsma et al., 2007). The energy companies (or their owners) could challenge the law using costly legal procedures (if the government would have to compensate the energy companies for damages, this would be a transfer of wealth not a change in the national wealth). We estimate the costs to be €20 million for the private parties plus the same amount to be incurred by the legal system. In the positive scenario no costs are included, while in the negative case these costs... |
5. One-off costs and annual benefits of implementing and enforcing legislation and regulations

Explanation: Implementing the project alternative will entail one-off legislation and regulation costs. The reason for this is that the WON also includes transferring the management of the 110 kV grids and above to TenneT. Our project alternative does not include this management transfer. Rewriting the legislation will take around 10 man-years of work by civil servants and external consultants and lawyers, at a cost of €1 million a year. The energy sector and politicians will spend time on the new drafts, and their effort and costs are assumed to be similar to those of the MEA. Total costs add up to €2 million a year.

After unbundling, fewer amendments to the regulations will be required to counter anti-competitive behaviour and minor incidents (less fine-tuning). This involves a decrease in the workload for civil servants of about 15 man-years of work per year (€1.5 million).

In the negative scenario, the costs and benefits are 50 percent higher, in the positive scenario they are 50 percent lower.

Benefits

1. Increased wholesale and retail competition (or: less obstruction of competition by integrated firms) and higher efficiency in both generation and supply and possibly an extra effect from small-scale generation by independent players

2. Better focus and thus more efficient distribution companies

3. Simpler market structure and thus cheaper regulatory oversight

Explanation: Unbundling makes life easier for the regulator because the companies have less complex organizational structures and need less control, as the distribution companies have fewer incentives to frustrate competition. This allows the regulator to cut its costs, which also results in the cost for the companies of cooperating with its investigations being reduced.

Unbundling will reduce the cost of the regulator by 20 percent (€0.9 million annually). In the negative scenario the costs are 50 percent higher, in the positive scenario they are 50 percent lower. The costs of regulation will change immediately after the law is passed.

4. Effect on security of supply

Explanation: The proposed law could affect the security of the electricity market by (i) affecting investment in and maintenance of the networks, and (ii) affecting investment in
generation. On average, Dutch households experience around 25 minutes of supply interruption each year, caused by disruptions in the medium and low voltage grids. In the probable scenario this will fall by 2.5 percent and in the negative and the positive scenario by 0 and 5 percent respectively. Each minute of supply interruption costs €1.5 million (De Nooij et al., 2007). These benefits will be realized gradually over two regulatory periods (in total, six years).

7.5.1 The most important benefits

7.5.1.1 Increased competition and more efficiency

The benefits originate from the assumption that ownership unbundling creates a more equal playing field than does legal unbundling. Another effect may be that ownership unbundling increases competition simply by removing the presumption that integrated competitors obstruct competition. This presumption might make companies reluctant to enter a market or to compete aggressively. As competition increases, companies are forced to improve their efficiency. In addition, the illegal exchange of information within an integrated company could hinder competition. However, competing suppliers can also obtain the majority of the relevant data, since consumers have an interest in revealing their true electricity consumption and usage patterns to prevent them being taken advantage of.

We estimate the effects to be as follows (cf. second row, table 7.3). In the negative scenario there are no benefits from increased competition (but no negative effects either). The probable scenario follows the estimate of the CPB (2006). The benefits

100 The CPB (2006) bases the benefits of more competition on Newbery and Pollitt (1997). These authors find that the liberalization of the English energy market reduced costs by five percent. The CPB estimates the efficiency gain in the Netherlands to be only one-third of this (€100 million). In relation to generation, a quarter of this will be realized anyhow, and the other three-quarters only if small-scale generation does indeed take off as a result of unbundling. Several studies indicate that the amount of €100 million may be an overestimation. In a study comparable to Newbery and Pollitt, Pollitt found for Scotland in 1999 that the efficiency gains were negligible (cited in Newbery, 2005, p. 52). Furthermore, Newbery and Pollitt (1997)
of more efficient generation are equivalent to a quarter of this effect, since in the probable scenario no benefits resulting from more distributed generation are taken into account (see the following section). In the positive scenario the benefits of increased competition are 50 percent higher than in the probable scenario, and the benefits of more small-scale generation by independent parties are also taken into account.

Ownership unbundling will cause the largest possible reduction in the incentives and possibilities which hindered competition, with efficiency increasing by 1.5 percent. Consequently, ownership unbundling can stimulate competition and therefore efficiency.

Enhancing efficiency usually requires organizational change or investment, both of which take time. Supply is assumed to become more efficient over five years, generation over ten, with each year showing 20 percent and 10 percent respectively of the ultimate effect. Effects related to generation need more time to materialize, since it requires more investment and modification of plants. These percentages are multiplied by the total annual cost of energy supply (about €300 million) or the total annual cost of electricity production (€5.9 billion) (CPB, 2006).

**The effect of small-scale generation**

If unbundling led to an increase in small-scale generation by independent producers this would be an additional benefit. Unbundling might lower entry barriers, resulting in a rise in distributed, generally small-scale, generation operated by parties independent of the current generators. This would stimulate competition and thus overall efficiency (CPB, 2006). Below we discuss two conditions that must hold for this relationship.

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explain part of the cost reduction as due to a rapid switch to gas-fired plants. This is not possible in the Netherlands, given the high proportion of gas-fired generation.

The CPB uses two scenarios: one in which distributed generation is stimulated by unbundling and one in which distributed generation is unaffected. Other uncertainties are not explicitly taken into account in the calculations.
Firstly, benefits can only arise if small-scale generation capacity in the hands of independent producers increases. This is questionable. Currently, the level of investment in small-scale generation in the Netherlands is already high compared to other countries, thus there is relatively little room for extra initiatives. Unbundling is not critical for investment in small-scale generation, since current small-scale generation was established without unbundling. In addition, the level of competition will increase after unbundling. The large, integrated energy companies have argued that an increase in competition will reduce the electricity price, making distributed generation less profitable (EEND, 2006). Profitability would only be possible if government subsidies were increased.\textsuperscript{102} Finally, small-scale generation in horticultural greenhouses and in homes seems to have growth potential, while the growth in distributed generation in manufacturing has ground to a halt.

Secondly, small-scale generation must affect price-setting. A significant proportion of small-scale generation currently does not set prices or respond to the energy price. Wind energy is produced when there is sufficient wind and combined heat and power production usually occurs when manufacturing plants need heat. However, this might change. Mante (2006) described how horticultural producers using greenhouses are currently joining forces to increase their responsiveness to prices, and they expect to double their capacity from the current figure of 1,000 MW to 2,000 MW in 2020, though increasing energy efficiency in greenhouse horticulture might threaten this projection. Newer small-scale generation will be more flexible and has a larger relative share of electricity in its output, increasing the impact of small-scale generation on price-setting. However, this will occur in both the alternative and the counterfactual.

Treating the effect of an increase in distributed generation on competition and thus efficiency as uncertain and only including it in the positive scenario is warranted. The reason is that currently around 35 percent of installed capacity is already distributed generation. Moreover, this capacity is – for a large part – operated by the incumbents.

\textsuperscript{102} Currently, the government subsidizes distributed generation, since on its own it is not cost-effective. This subsidy depends on the electricity price and the CO\textsubscript{2} tradable permit price and is motivated by beneficial environmental effects (MEA, 2006a, p. 14).
Thus an increase in distributed generation could well be the result of investments by the incumbents, and this would not help competition. Another reason to only take this benefit into account in the positive scenario is that increased investment in small-scale generation might also increase the social cost, since these investments are costly. Table 7.3 summarizes these efficiency gains.

<table>
<thead>
<tr>
<th>Efficiency gain</th>
<th>Negative</th>
<th>Probable</th>
<th>Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>0.0</td>
<td>4.5</td>
<td>6.8</td>
</tr>
<tr>
<td>Generation (excluding small-scale generation)</td>
<td>0.0</td>
<td>22.1</td>
<td>33.22</td>
</tr>
<tr>
<td>Generation: small-scale generation</td>
<td>0.0</td>
<td>0.0</td>
<td>66.4</td>
</tr>
</tbody>
</table>

7.5.1.2 More efficient distribution companies

Unbundling may result in more efficient distribution companies for two reasons. Firstly, independent distributors may focus more effectively on their core business without being distracted or limited by the commercial activities within the same holding (MEA, 2006a, p. 5). There are no studies available on the effect of an increased focus on efficiency. The companies in the UK which unbundled voluntarily apparently did not find this positive effect significant enough to prevent some of them from re-integrating, even though the network and supply often did not overlap geographically. Of course, in reality, there might be other strategic reasons for reintegration, meaning that reintegration in the UK case is not proof but merely an indication that the benefit of a greater focus by distribution companies after unbundling may not be very high. Here the effect of better-focused management after ownership unbundling is estimated to be 1 percent of the annual network cost of maintenance (€3 billion; CPB, 2006).

Secondly, the energy regulator gains better insight into the activities of the energy companies, since unbundling will simplify their accounting. Therefore, the regulator can work more effectively, which gives the distributors a more powerful incentive to be more efficient. Again no national or international studies on this effect are available. A rough estimate is that this effect has the same dimensions as the effect described above.
Thus, the welfare gain is €60 million, that is, €30 million for better-focused management and €30 million for better-informed regulation. In the negative scenario the benefits are 50 percent lower, while they are 50 percent higher in the positive scenario. Becoming more efficient takes time. Here it is assumed that two regulatory periods of 3 years each are required before the full effect is felt. Each year the effect will grow by one-sixth of the final effect.

7.5.2 The most important costs: costs of reorganization and loss of economies of scope

The creation of fat distributors and the introduction of unbundling will require changes in the organizations involved. These changes relate to the IT systems, names, contracts with suppliers and buyers, location and buildings, and staff employment contracts (MEA, 2004b, p. 11). The total costs faced by the energy companies amount to €3,250 million, with the costs of activities of the holding amounting to €890 million and the rest being due to operational activities (Deloitte, 2005, p. 24). Operational costs will barely be affected by ownership unbundling.

Two kinds of reorganization costs are distinguished: one-off and permanent costs. Deloitte calculated that the one-off reorganization cost will come to between €70 million and €100 million after unbundling. This is mainly made up of ICT, personnel, programme management, location, organization, changing contracts, financial and legal costs.

Deloitte estimated the permanent cost by estimating the scale effects for each cost category (they distinguish 26 categories) that is lost after ownership unbundling. Table 7.4 presents the initial estimate by Deloitte. From this table, they took the ten largest items (responsible for 80 percent of the initial estimate) and looked at these in detail. Subsequently, they re-estimated the total annual costs. All the synergy losses added up

103 Nillesen and Pollitt (2008) report that the total one-off cost of reorganization after ownership unbundling amounted to NZD 210.6 million (1999 prices). Currently, one New Zealand dollar is a little less than half a euro. Moreover, real costs have increased due to inflation. This indicates significantly higher one-off costs than are estimated in this paper.
to a total of between €350 and €460 million, which would mainly be the result of changes to ICT, support, the board, finance, personnel and organizational structure. Ownership unbundling would create permanent reorganization costs of €5 million. The majority of the costs result from the transformation into fat distributors, which is inextricably bound up with ownership unbundling.

Roland Berger (2005) confirmed these estimates and calculated what would happen if mergers and foreign or local takeovers occurred after unbundling. Taking into account the likely cost savings that the merging firms would realize (MEA, 2006a, p. 32), the permanent reorganization cost would be between 285 million and €400 million annually after five years. For the period thereafter, Roland Berger made no predictions, given the uncertainties about how the market would develop. Both the CPB (2006) and the current paper use one value for the reorganization cost and assume this to be constant over time.

The MEA (see Parliament, 2006) argued that the permanent reorganization costs would only be 55 percent of the €285 million estimated by Roland Berger. The reason is that the billing system in the Dutch energy market would be substantially simplified by charging the customers a capacity-based network fee (currently they pay for the network on the basis of their usage). This will reduce and simplify contact and billing between distributors and suppliers. No detailed breakdown or underpinning of the 55 percent figure is publicly available. The commission set up by the government and parliament to validate the research commissioned by the MEA confirmed this estimate (Kist, p. 11, p. 22). However, Roland Berger (2006, p. 17, 19) has stated that this reduction in the estimate is unrealistic.
<table>
<thead>
<tr>
<th>Items</th>
<th>Sub items</th>
<th>Costs 2005 (A)</th>
<th>Extent of synergy (B)</th>
<th>Reorganization costs (A*B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td>Strategic policy</td>
<td>55</td>
<td>75%</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Communication and marketing</td>
<td>40</td>
<td>25%</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Capital and risk management</td>
<td>25</td>
<td>100%</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Corporate governance</td>
<td>20</td>
<td>75%</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Business performance management</td>
<td>20</td>
<td>75%</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Relation with regulator</td>
<td>15</td>
<td>25%</td>
<td>4</td>
</tr>
<tr>
<td>P&amp;O</td>
<td>Security and health</td>
<td>20</td>
<td>25%</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Personnel and organization</td>
<td>20</td>
<td>75%</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Remuneration, assessment, development</td>
<td>15</td>
<td>25%</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Personnel administration</td>
<td>10</td>
<td>75%</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Recruitment</td>
<td>10</td>
<td>75%</td>
<td>8</td>
</tr>
<tr>
<td>ICT</td>
<td>ICT products and services</td>
<td>90</td>
<td>100%</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>ICT planning and control</td>
<td>50</td>
<td>75%</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Control ICT structure</td>
<td>45</td>
<td>100%</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Customer support</td>
<td>20</td>
<td>100%</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>ICT policy, architecture, standards</td>
<td>15</td>
<td>75%</td>
<td>11</td>
</tr>
<tr>
<td>Financial</td>
<td>Reports and analysis</td>
<td>80</td>
<td>50%</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Consolidation</td>
<td>25</td>
<td>50%</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Taxes</td>
<td>20</td>
<td>100%</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Financial policy</td>
<td>15</td>
<td>75%</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Financial administration</td>
<td>10</td>
<td>75%</td>
<td>8</td>
</tr>
<tr>
<td>Support</td>
<td>Customer service and billing</td>
<td>105</td>
<td>75%</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>Facilities</td>
<td>55</td>
<td>100%</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Accommodation</td>
<td>70</td>
<td>50%</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Purchase</td>
<td>20</td>
<td>75%</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Legal affairs</td>
<td>20</td>
<td>50%</td>
<td>10</td>
</tr>
<tr>
<td>Initial estimate of total annual cost</td>
<td></td>
<td>890</td>
<td></td>
<td>640</td>
</tr>
<tr>
<td>Final estimate of total annual cost</td>
<td></td>
<td>890</td>
<td></td>
<td>350–460</td>
</tr>
</tbody>
</table>

Source: Deloitte (2005, p. 27)
The CPB (2006) criticized the results of the studies by both Deloitte and Roland Berger. Deloitte (2005) found that the synergy effects in most costs shared by the distributor and the commercial companies in the same holding generally exceeded 50 percent and in some cases were as high as 75-100 percent. The CPB remarked that such significant synergy effects are uncommon and that if they do exist they can be realized by purchasing the goods and services from specialist companies. Therefore, the CPB (2006) estimated the cost of creating a fat distributor to be €80 million annually, with ownership unbundling adding €20 million. In this CBA, we follow the CPB and estimate the one-off costs to be €80 million for the fat distributor, with an additional €20 million for ownership unbundling. In the negative scenario the costs are 50 percent higher, while in the positive scenario the costs are 50 percent lower. The first row in Table 7.5 shows the one-off costs.

A wide range of estimates of permanent reorganization costs have been produced. Note that all the research, including the high cost estimates, was commissioned by the MEA. Also note that the MEA had an interest in producing low estimates because he wanted to make ownership unbundling compulsory. The MEA estimates are used for the probable scenario. The positive estimates are the CPB figures, while the low estimates by Roland Berger are used in the negative scenario. The second row in table 5 shows the permanent reorganization costs.

<table>
<thead>
<tr>
<th></th>
<th>Negative</th>
<th>Probable</th>
<th>Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-off costs</td>
<td>-150</td>
<td>-100</td>
<td>-50</td>
</tr>
<tr>
<td>Annual costs</td>
<td>-285</td>
<td>-150</td>
<td>-100</td>
</tr>
</tbody>
</table>

### 7.6 Results and conclusions

Table 7.6 shows the main results in the form of the Net Present Value of the ownership unbundling alternative relative to the counterfactual (of legal unbundling and lean distributors). In the probable scenario, the costs exceed the benefits by around €1.4 billion. In the negative scenario – that is, low benefits and high costs – the net welfare
effect is almost minus €5 billion, whereas in the positive scenario – that is, high benefits and low costs – the effect is almost €1 billion.

Table 7.6 also gives the present value per effect for the probable scenario (centre column). The main benefits are increased efficiency in production resulting from increased competition (€272 million in the probable scenario), and more efficient distributors because of an improved focus (€691 million). The main cost is the permanent reorganization cost (€2,392 million). Table 7.6 also shows the present value per effect for the positive and negative scenarios, which indicates the margin per effect. The margin is the largest for the largest cost, that is the permanent reorganization cost. The largest margin on the benefit side is the increased efficiency of production resulting from greater competition and due to more distributed generation. In addition, the benefit of better-focused energy companies is relatively uncertain.

A sensitivity analysis (due to space limitations this is only reported in detail in the earlier study: De Nooij and Baarsma, 2007) revealed that the sign of the outcome is robust. For example, a shorter time horizon, a lower discount rate, the faster implementation of the efficiency gains, higher growth in electricity use and a change in growth of energy efficiency have no effect on the sign. The lower structural cost used by the CPB makes the net present value positive in alternative G only marginally. If distributed generation is important in all scenarios, the ownership unbundling alternative remains welfare decreasing. Subtracting costs for the CBL worsens all outcomes. Again, for more details see De Nooij and Baarsma (2007). Our conclusion is that the outcomes are remarkably robust to changes in the assumptions used.
Table 7.6  The results in the probable, negative and positive scenarios

<table>
<thead>
<tr>
<th></th>
<th>Negative</th>
<th>Probable</th>
<th>Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less obstruction of competition: more efficiency in supply</td>
<td>0</td>
<td>64</td>
<td>96</td>
</tr>
<tr>
<td>Less obstruction of competition: more efficiency in generation</td>
<td>0</td>
<td>272</td>
<td>409</td>
</tr>
<tr>
<td>More competition and thus efficiency through more distributed generation</td>
<td>0</td>
<td>0</td>
<td>817</td>
</tr>
<tr>
<td>Cheaper regulatory supervision</td>
<td>59</td>
<td>119</td>
<td>178</td>
</tr>
<tr>
<td>Better-focused and thus more efficient distribution companies</td>
<td>346</td>
<td>691</td>
<td>1,037</td>
</tr>
<tr>
<td>Security of supply</td>
<td>0</td>
<td>16</td>
<td>31</td>
</tr>
<tr>
<td><strong>Total benefits</strong></td>
<td>405</td>
<td>1,162</td>
<td>2,568</td>
</tr>
<tr>
<td>One-off reorganization cost</td>
<td>-150</td>
<td>-100</td>
<td>-50</td>
</tr>
<tr>
<td>Permanent reorganization cost</td>
<td>-4,545</td>
<td>-2,392</td>
<td>-1,595</td>
</tr>
<tr>
<td>Legal cost of amending the cross-border leases</td>
<td>-75</td>
<td>-50</td>
<td>-25</td>
</tr>
<tr>
<td>Damages to be paid on the cross-border leases</td>
<td>-NM?</td>
<td>-NM?</td>
<td>-NM?</td>
</tr>
<tr>
<td>Cost of finance</td>
<td>-476</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cost of legal cases</td>
<td>-40</td>
<td>-20</td>
<td>0</td>
</tr>
<tr>
<td>Legal and regulatory costs</td>
<td>11</td>
<td>27</td>
<td>42</td>
</tr>
<tr>
<td><strong>Total costs</strong></td>
<td>-5,275</td>
<td>-2,535</td>
<td>-1,628</td>
</tr>
<tr>
<td><strong>Total (benefits net of cost)</strong></td>
<td>-4,870</td>
<td>-1,374</td>
<td>940</td>
</tr>
</tbody>
</table>

Concluding remarks: divorce comes at a price

This paper reveals that the Dutch Act dealing with unbundling (WON) is more likely to decrease welfare than to increase welfare. This conclusion is relevant if the European debate on the unbundling of distribution grids really takes off. It can however not be used in the European debate on unbundling transmission grids, although the method is a useful addition to the European impact assessment (EU, 2007).

Our results show that uncertainty about the costs and benefits are very high. With the effects so insecure, it is wise to wait for a few years, maintaining the current situation until the magnitude of the effects becomes more apparent. Our results underestimate the
total welfare effect as we only included effects that could be given a monetary value. For example, we omitted the effects on cross-border leases, which might cost up to €4 billion. These effects increase the chances that costs exceed benefits. Moreover, we did not include alternatives that would probably outperform the ownership unbundling alternative and the other alternatives studied (table 7.1, alternatives A to G). One example of an alternative is improving the quality of legal unbundling by requiring a compliance officer (similar to the UK). Therefore, it seems safe to conclude that unbundling is likely to reduce welfare.

The fact that our cost-benefit analysis indicates that ownership unbundling is not welfare enhancing is not surprising if we recall that the effect of this alternative is relative to the current level of legal unbundling and the management tasks of TenneT. According to Jamasb and Pollitt (2005, p. 22), the Dutch transmission market at the time scored five out of five and distribution three out of five. Since then, independence has improved – in 2006 distribution scored four out of five (only the UK scores better). This means that the additional competitive benefits of ownership unbundling are modest. At the same time, the costs of unbundling are high.

Moreover, in 2007, well after the act that obliged ownership unbundling was implemented, the Dutch energy regulator concluded – based on a report by external accountants – that it was highly unlikely that illegal cross-subsidies had occurred. One of the arguments for ownership unbundling was that it could prevent illegal cross-subsidies from the network to commercial suppliers in the same holding. These cross-subsidies are rational (i.e. they increase profits) if the regulation of the networks is imperfect and allows costs to be shifted from the competitive supply company to the regulated distribution company and if the network tariffs can be increased to compensate for these ‘extra’ costs. This improves the competitiveness of the supply company and, therefore, increases its profits, while at the same time the profits of the network company are maintained. This requires that the regulator does not see the shifting of costs and that the regulation of the distribution company is at least partially cost-oriented (Brunekreeft and Van Damme, 2005). The necessity of ownership unbundling decreases if illegal cross-subsidies do not seem to occur in practice. Perhaps
it would have been better to review companies annually with respect to illegal cross-subsidization and bring the act into force only if the reviews were negative.  

Another reason to be careful with ownership unbundling is that it may well have adverse effects. Here we address two of them. Firstly, ownership unbundling might increase the vertical integration of generation and supply, which would cause competition to decrease. Consequently, it would become difficult for independent suppliers to hedge their supplies on the futures market. This means that only players who are vertically integrated would be able to enter the Dutch market. Increasing such entrance barriers would decrease competition. Secondly, ownership unbundling may lead to the sale of Dutch supply firms to foreign players. While it is prohibited in the Netherlands to sell the networks, unbundling makes the sale of separate supply companies possible. This sale increases the vertical integration of generation and supply.

A final reason why it would have been better to postpone the unbundling decision is that unbundling damages the level playing field – even at the national level – since foreign holdings are not obliged to unbundle their distribution networks. This is so because in the Netherlands many of the new suppliers (without a grid in the Netherlands) are part of a foreign holding with a grid and good access to cheap credit, an example being Oxxio, the largest new supplier, which is owned by Centrica.

Please note that the Dutch unbundling act (WON) is different from the alternative analysed in this paper. In the WON, the TSO is also made responsible for all 110 kV grids and above. In De Nooij and Baarsma (2007) we revealed that the results were similar for the WON alternative.
8  Social cost-benefit analysis of electricity interconnector investment: A critical appraisal#

Abstract: This paper examines the economic analysis (social cost-benefit analysis) underlying two decisions to build an interconnector (NorNed and the East West Interconnector) in Europe. The main conclusion is that current interconnector and transmission investment decisions in Europe are unlikely to maximize social welfare. The arguments are as follows. (i) It is unclear how much demand for transmission capacity and interconnectors actually exists, and thus the benefits of investment are unclear. (ii) Both analyses underlying the investments studied are incorrect, to the point where, in one case, even the sign may be wrong. (iii) The main criticism concerns the fact that they do not take the resulting changes in generator investment plans into account and ignore the (potential) benefits of increased competition. (iv) Several smaller issues can be improved, such as the discount rate used. (v) Decisions at the European level are taken very differently, and approval may depend on which authority grants approval. (vi) Interconnector decisions receive the most attention, although most money goes to transmission investments. Two research recommendations for future improvements are formulated.

Keywords: Project Evaluation, Infrastructures, Interconnector.

JEL codes: Q4, H43, H54


* This paper benefited from discussions at the Second Tilec Round Table on Energy, from seminar participants at Delft University, the Bremen Energy Institute, the Dutch Competition Authority, the 2009-IAEE conference in Vienna and the Market Design 2009 conference in Stockholm. Furthermore, discussions with Gert Brunekreeft, and comments on earlier versions from Eric van Damme, Robert Haffner, Jan-Paul Dijkman, David Newbery, Bert Tieben, Laura Malaguzzi Valeri, Bert Willems, and two anonymous referees greatly improved the paper. The author is grateful to the Electricity Policy Research Group of Cambridge University, and the Bremer Energie Institut at Jacobs University for the hospitality enjoyed while writing parts of this paper. The author is solely responsible for any remaining errors.
8.1 Introduction

Transmission and interconnection capacity between different markets or TSO regions should be increased and investment is insufficient according to many including the European Commission and the European TSO’s (EC 2007b, 2008b; ERGEG 2009, p. 8; ENTSO-E 2010; see also ECF 2010 and PWC 2010). This new capacity should increase trade between cheap and expensive production areas, fight the market dominance of incumbents and increase competition, connect more renewable energy sources to the grid and increase security of supply (EC, 2007b, 2008b; ERGEG 2009, p. 8) Consentec and Frontier Economics (2008, p. 7) estimate transmission investments needed to exceed €100 billion. ENTSO-E (2010, p. 126) estimates the investment required up to 2020 to cost between €57 and €64 billion for about 42,100 km of new or refurbished network routes; this is about 14 percent of the total ENTSO-E transmission network of 300,000 km. About 25% of these new network routes will be new DC links, like the two cases studied here (ENTSO-E, 2010, p. 15). Given the vast amounts of investment at stake, careful decisions are necessary. Therefore, this paper focuses at two European cost benefit analysis used to underpin actual investments, to test whether CBAs currently made are delivering efficient and adequate investments.

In a social cost-benefit analysis (CBA), costs and benefits measure all differences in society with and without a project. Not only effects for the decision maker are included

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105 EC (2007b) complained that not much investment is taking place. A similar statement holds for the US (see Joskow, 2005a). EC (2007a) gives several explanations why current low investment might mean underinvestment. However, several other explanations for low investments are possible without underinvestment: excessive investment prior to liberalisation resulting lower required levels of investment now (Brennan, 2006; Moran, 2004) and calls for more investment may come from actors with an interest in building them (White et al., 2003).

106 The absolute investments in transmission are large, but constitute only a relatively small fraction of the total cost of the electricity system (IEA 2002, p. 50). However, given the sharp rise in the cost of transmission investments, currently grid investment costs are comparable to generation assets on a rough per MW or MWh basis (see ENTSO-E 2010, p126).

but also the externalities. This is done for all potentially good project alternatives. Methodological there are two alternative methods: more limited cost-benefit calculations, and multi-criteria analysis (MCA). Sometimes, a cost-benefit calculation is made without including all of social costs and benefits; for example, in PJM the investment decision is based on reliability reasons or solely on congestion revenues in the case of market investment (see Joskow, 2005a, 2005b). This is unlikely to lead to socially optimal investment if external effects are important, or if both congestion and reliability benefit from a single investment.

In an MCA, projects are scored on various criteria, such as physical quantities, money and expert judgements. Weights are allocated to the criteria before the scores are combined into an overall rating for each project. The basis for the allocated weights is not always clear but often includes the preferences of policy makers or researchers involved. The double-counting of effects is more difficult to avoid than with a CBA because strict criteria for the inclusion of effects are lacking (Eijgenraam et al., 2000). An example of an MCA is the Baltic Energy Market Interconnection Plan (CESI, 2009). The criteria used are the benefit/cost ratio, where benefits refer only to market benefits and costs refer to investment costs, timing for the authorization and construction, and risks. Because it was impossible to determine the weights, CESI used equal weights. This has the drawback that relatively unimportant criteria or overlapping criteria (like the time required to realize a project, which is also included in the discounted value of the future benefits) are overrated.

The strength of a CBA is that all the effects need to be formulated precisely. A downside is that it is hard to determine how to use each factor in the CBA (such as the uncertainties related to quantifying the costs and benefits). MCA can deal with less strict criteria more easily. MCA and CBA both try to determine what the (physical) consequences of a specific project will be. While the MCA leaves it to the decision maker in dialogue/debate with society to make the trade off, CBA tries to infer the weights by establishing how citizens make these trade-offs by expressing all effects in monetary terms. Therefore CBA is likely to get closer to answering the question of what happens to welfare than MCA. Therefore this article focuses on CBA.
A CBA also seems to be in line with ERGEG and ENTSO-E policy. The European Regulators’ Group for Electricity and Gas (ERGEG 2010, p. 2) uses several criteria to judge the work of ENTSO-E on the desirability of new transmission capacity. ERGEG uses technical criteria (including a thermal criterion, stability criterion, voltage and reactive power criteria, short-circuit criterion) and several economic criteria to assess the social welfare arising from possible investment. The socio-economic evaluation should include a CBA, which should include investment costs, project risk analysis, change in losses, and possible synergies and dependencies between the projects. It also includes socio-economic criteria such as: the exchange of ancillary services; the value of a more integrated market, for example by managing price differentials effectively across congested areas; the improved welfare of end-customers within the European market; the risk and costs of energy and/or power shortages (security of supply); generation optimization (generation according to the merit order). How these various criteria should be weighted is not specified. ENTSO-E (2010, pp. 16-17) states that TSOs must use the following four criteria to evaluate investments in new transmission projects. (i) The investment should maintain or improve current high reliability to which end-users are accustomed. (ii) Investment should positively address social welfare. To this aim, cost-benefit analyses are undertaken by TSOs for every transmission project. (iii) New technological advances are taken into account. (iv) Grid planning should anticipate long-run perspectives beyond the following ten years. This is an analysis of CBAs as mentioned by ENTSO-E under (ii).

This paper focuses is at two large investments to increase interconnection capacity. However, capacity can also increase because of smaller measures, like changes in the operation, the allocation mechanism, congestion management\(^\text{108}\), the relaxation of reliability standards, and investment in IT systems or small investment (see Hirst 2000; Joskow 2005b, p. 14; Léautier and Thelen, 2009, p. 131; Turvey, 2006; Kirschen and Stribac, 2004). Some of the objectives of more interconnection (i.e. more competition between generators) can also be reached with other measure like favouring entry (Küpper et al., 2009), or breaking up the largest companies (Tanaka, 2009). Although

important for a CBA also to include low-cost solutions, this article does not discuss this in more detail. To illustrate its importance two examples. In 2004 capacity worth almost €50 million was not utilized on the Dutch - German border, almost half the total value of this interconnector capacity (EC, 2007a, p. 185). Under-using and misusing of the UK-France interconnector amounted to €289 million from 2002 to 2005 (Bunn and Zachmann, 2010). The importance of improving the use of existing interconnectors has been seen and improvements are underway. For example, market coupling between Belgium, the Netherlands and France reduced congestion: the percentage of time the prices between the Netherlands and France differed fell from 90 to 37 percent after market coupling in 2007 was established (see ERGEG, 2009, p. 16, Küpper et al., 2009).

In a CBA, all costs and benefits are relevant. The costs include investment costs, operational and maintenance costs, environmental impact, real options, the impact on electricity loss and other system costs (frequency control, spinning reserve and other ancillary services costs). The costs mainly follow directly from calculations made by engineers. On the benefit side, two benefits stand out: efficiency benefits and security of supply benefits (or reliability benefits).109

Efficiency benefits, including trade and competition benefits, can arise from investing in interconnection and transmission because an extended network increases the possibilities for trade and competition between generators. In the short run, this can increase allocative efficiency (the electricity goes to the consumer with the greatest willingness to pay, redistribution cannot improve welfare) and productive efficiency (the same electricity cannot be made at a lower cost by having some producers produce more and others less). Allocative and productive efficiency also include the absence of mark-ups over the marginal cost based on market power, since these mark-ups distort the optimal allocation of goods among consumers, of production among producers, and the optimal quantity produced. More competition may also reduce x-inefficiency (where

109 For a more in-depth discussion of all costs and benefits, see the next two sections, De Nooij (2010), Turvey (2006), Malaguzzi Valeri (2009).
firms could produce at a lower cost than they actually do)\(^{110}\) and it may influence dynamic efficiency (through investments in R&D and new technologies).

Increasing reliability is often the main reason behind grid investments (Joskow, 2005b). Valuing increased reliability requires (i) an estimate of the increase of reliability (e.g. the decrease in MWH of electricity not delivered due to interruptions) (ii) a valuation of increased reliability (difficult, but possible, see De Nooij et al., 2007). Often a distinction is made between investments necessary to maintain reliability (by meeting certain engineering reliability criteria) and investments to facilitate the market (including all non-reliability benefits; see for example AER, 2007). Joskow (2005b, p. 2,3) asserts that this is ‘nonsense’: reliability investments can have significant effects on trading opportunities and on the use of operating reserves.\(^{111}\) For the 42,100 km of new network routes needed in Europe ENTSO-E (2010, p. 15) gives three reasons why they are needed: connecting renewable to the grid accounts for 20,000 km, security of supply for 26,000 km and the internal energy market for 28,500 km. The sum total being larger than 42,100 km indicates that lines are built for several reasons.

This article investigates the underpinning of investment decisions in interconnectors in more detail, using CBA as a reference point. I use two case studies to shed more light on this issue. Sections 8.2 and 8.3 study the economic underpinning of two decisions to build an interconnector in Europe: NorNed between the Netherlands and Norway and the East-West Interconnector between Ireland and the UK. These cases were selected since they are published (in English) in more detail than other cases, allowing a detailed

\(^{110}\) X-inefficiency (Leibenstein, 1966) can result from workers or management putting in substandard levels of effort, from misdirected effort, imperfect rationality and from markets that are not perfectly competitive. Leibenstein argued that gains of improved x-efficiency are likely to far exceed gains from improving allocative and productive efficiency. X-inefficiency is a departure from strict neo-classical economics, and as such is subject to criticism, see Stigler (1976) and Leibenstein’s response (1978). Frantz (2007) gives an overview of studies that quantify x-inefficiency.

\(^{111}\) Related, reliability requirements impact the trading possibilities over a line (Kirschen and Strbac, 2004).
The aim of this article is to critically assess the argumentation used to support the investment decision in these two cases, using CBA as the reference point to establish the effects of the investment on economic welfare. Section 8.4 discusses the lessons for evaluating investment decisions in international interconnections in general and offers recommendations for further research.

8.2 NorNed

In 2004, the Dutch regulator approved a plan by the Dutch TSO (TenneT) to build a cable from Norway to the Netherlands (hence ‘NorNed’) and to finance it with past interconnection auction revenues. This cable has been operational since October 2008. The figures are, unless stated differently, from the energy regulator (then DTe, now EK; DTe, 2004) and TenneT (2004) and reflect the Dutch side only.

NorNed is 580 kilometres long, with a capacity of 700 MW and operates at 400kV. TenneT is not vertically integrated with production, distribution or supply, and is fully state-owned. The Dutch and Norwegian TSOs (Statnett) share costs and revenues on a 50-50 basis. The TSOs buy power on the day market in the country with the lowest price and sell it on the market in the other country. Price differences can exist because

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112 Publishing decisions in detail is not required in Europe (it is in Australia, see AER, 2007), so when it happens voluntarily it should be applauded. For example the CBA of 30 new connection by Nordel (2008) is published less detailed.

113 In the Netherlands past auction revenues are earmarked for new congestion-relieving investments (Article 6.6 of the EU regulation also allows rate reductions; EC, 2003). Two dangers are associated with this. First, if investments are made only if enough funds are available from past auctions, underinvestment may arise. Second, it may lead to overinvestment if investments are made because there are funds from past auctions. There is no indication that either occurred here.

114 The Norwegian analysis is not discussed since it has not been published (in English). Most likely the Norwegian analysis strongly resembles the Dutch analysis since TenneT’s analysis is based on studies jointly commissioned by both TSOs.

115 Direct market coupling proved to be difficult due to differing closing times of the Dutch and Norwegian power markets.
(i) the Norwegian demand pattern is flatter over the day than the Dutch; (ii) the countries use different production technologies (hydropower in Norway and thermal based in the Netherlands); (iii) unexpected shocks, such as power plants failing unexpectedly, may occur. Table 8.1 shows the main costs and benefits. The overall outcome will be discussed further on under the heading ‘the discount rate’.

To facilitate comparison with section 8.3, table 8.1 also contains the characteristics of the East-West interconnector.
Table 8.1 The NorNed and EastWest Interconnectors.

<table>
<thead>
<tr>
<th></th>
<th>NorNed (Dutch effects only)</th>
<th>East-West (Irish effects only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment cost</td>
<td>€264m (half the cost)</td>
<td>€595m (total)</td>
</tr>
<tr>
<td></td>
<td>(including €25m preparation costs, which are sunk)</td>
<td></td>
</tr>
<tr>
<td>NPV</td>
<td>€175m according to TenneT</td>
<td>€350m</td>
</tr>
<tr>
<td></td>
<td>€3m according to DTe</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>580km</td>
<td>256km, 185km under sea</td>
</tr>
<tr>
<td>Capacity</td>
<td>700 MW</td>
<td>500 MW</td>
</tr>
<tr>
<td>Trade benefits,</td>
<td>Gross trading margin</td>
<td>-</td>
</tr>
<tr>
<td>directly estimated</td>
<td>€40.9m annually</td>
<td></td>
</tr>
<tr>
<td>Trade benefits</td>
<td>-</td>
<td>€40m annually</td>
</tr>
<tr>
<td>estimated indirectly (i)</td>
<td>prevented investment in generation capacity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>€14m annually</td>
</tr>
<tr>
<td></td>
<td>reduced carbon credit payments</td>
<td></td>
</tr>
<tr>
<td>Reduced wind</td>
<td>-</td>
<td>€10m annually</td>
</tr>
<tr>
<td>curtailment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of power due</td>
<td>€3.8m annually</td>
<td>-</td>
</tr>
<tr>
<td>to heating of the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net Dutch consumer</td>
<td>€2.2m annually</td>
<td>-</td>
</tr>
<tr>
<td>&amp; producer surplus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dutch consumer</td>
<td>€52.1m annually</td>
<td>-</td>
</tr>
<tr>
<td>surplus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dutch producer</td>
<td>- €49.9m annually</td>
<td>-</td>
</tr>
<tr>
<td>surplus (loss)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other benefits:</td>
<td>€4.2m annually</td>
<td></td>
</tr>
<tr>
<td>increased revenues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>from existing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>interconnectors and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>effect on the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>contribution to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ETSO cross-border</td>
<td></td>
<td></td>
</tr>
<tr>
<td>trade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other costs:</td>
<td>- €3.3m annually</td>
<td></td>
</tr>
<tr>
<td>operational cost,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>additional cost to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>the rest of the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>grid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Security of supply:</td>
<td>€0.5m and €3.3m annually</td>
<td>€2m annually</td>
</tr>
<tr>
<td>reserve capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and reduced need</td>
<td></td>
<td></td>
</tr>
<tr>
<td>for carrying reserve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discount rate</td>
<td>9.0%</td>
<td>5.63%</td>
</tr>
<tr>
<td>Time horizon</td>
<td>40/25 years</td>
<td>30 years</td>
</tr>
<tr>
<td>Alternatives studied</td>
<td>No interconnector, 600 MW (later optimized to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>700 MW), 1200 MW</td>
<td></td>
</tr>
<tr>
<td>Effect on</td>
<td>Mentioned, Not quantified</td>
<td>Mentioned, some calculations, not included in the</td>
</tr>
<tr>
<td>competition</td>
<td></td>
<td>calculation</td>
</tr>
<tr>
<td>NorNed (Dutch effects only)</td>
<td>East-West (Irish effects only)</td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td>-------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Dynamic effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mentioned. Not quantified</td>
<td>Partially included, prevented investment in Ireland. No reaction in the UK, nor change in production mix</td>
<td></td>
</tr>
<tr>
<td><strong>Environmental effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mentioned, not quantified</td>
<td>Reduced need for wind curtailment</td>
<td></td>
</tr>
<tr>
<td>Likely to be small</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Note: The difference between the consumer and producer surplus is the change in dead weight loss. This is small (€2.0m), since the price elasticity of electricity is low. SKM (2003) used a step-wise linear demand function with differently shaped demand curves per country. NorNed: Yearly effects refer to 2008. The energy regulator did not include all small effects in the analysis. This is not discussed here. East-West: Yearly effects refer to 2011.

The decision criteria

DTe (2004, §52-54) looks at many different criteria, such as cost and benefit for TenneT and grid users, the effect on security of supply, the effect on consumer and producer prices, the possibility of materializing the benefits through market coupling, the benefit to consumers\textsuperscript{116}. These criteria partly overlap and may also partly contradict each other because it is unclear how they are weighted. Altogether, the main decision criterion seems to be a social cost-benefit analysis (§53-98). A CBA for the Netherlands and one for electricity customers were made. The last had to show that users are getting a good return from the investment.

In the Netherlands, for large-scale governmental investments, a guideline (Eijgenraam et al. 2000) and subsequent improvements are mandatory (Ministry of Transport, 2004). NorNed also involved a government decision whether to invest. It is therefore useful to discuss the investment decision in NorNed using the government CBA methodology as a point of reference. This case study shall show that the NorNed approach differs in

\textsuperscript{116} Both companies and households.
several aspects (for example with respect to the discount rate used)\footnote{Neither do other appraisal guides (like EC, 2008) seem to be used.} and concludes that the CBA analysis of NorNed can be improved to better understand the effects of this specific investment on economic welfare.

**Alternatives**

DTe compared investing in a 600MW or a 1200 MW cable versus not investing at all. Other alternatives were not considered, in part because the time available to change the plans was limited due to the expiration of a crucial environmental permit, which would have caused years of delay and serious additional costs. Another reason is that DTe was not allowed to alter the proposal significantly, for example by conditionally approving a much larger capacity. However, considering the right alternatives is an important part of achieving the correct outcome for a CBA. Also DTe did not compare the interconnector with an investment in generation. The TSO is not allowed to invest in generation; however if the TSO does not invest in the interconnector the market may decide to invest in generation.

**Calculating the welfare effects: uncertainty and the endogenous response of companies**

TenneT calculates an annual Dutch welfare gain of approximately €2 million, that is an increase in the consumer surplus of €47 million per annum and a loss for producers of €45 million per annum. DTe (§92) holds that the precise distribution between consumer and producer surpluses is particularly uncertain, partly because the models used to calculate these amounts are not specific to this and the decision to invest may change investment behaviour by market parties. However, DTe claims that the net welfare change (€2m) depends less on these assumptions, and therefore DTe uses it (§90-92). This poses two crucial questions. First, if the models are not suited to calculating consumer and producer surpluses, how can they be used to calculate the revenues from trade? All three concepts depend on the same price, marginal cost and marginal benefit curves. Second, how do the producers react to the reduction of their surplus by €45 million annually (a present value of €550 million, at 6.8% over 40 years)? Unless they
make excess profits that disappear due to the new interconnector they have to react to stop themselves from incurring losses and going bankrupt by changing investment plans (building fewer or different power plants). Changing investment plans changes the marginal cost curves used to determine the trade revenues and the welfare effects. Although DTe acknowledges that the cable may lead to different investment patterns, the impact of this on welfare has never been analysed. More investment in Norwegian hydro generation could increase the social benefits of trade, because it would allow a technology mix that was previously impossible.\footnote{Fehr and Sandbråten (1997) discussed the impact of trade between a hydro and a fossil fuel system on the investment in generation capacity. Under unrestricted trade, and with hydro power having the lowest marginal cost, overall thermal capacity is reduced and the technology mix is more centred around medium-cost technologies. Net exports from the hydro system necessitate the expansion of the energy capacity of that system (water-inflow capacity).} However, trade benefits might also decrease over time. Investment in a high-price area may reduce an interconnector’s initial trade revenues.\footnote{In 2006 TenneT and RWE published a joint study of a new interconnector that will increase import capacity in the Netherlands from Germany by up to 2000 MW (export capacity will not increase due to higher transit levels through the Dutch-Belgian border). This line would cost both of the TSOs involved about €70 million. A few years later, there is a substantial chance that the extra import capacity is not going to be used often given the Dutch investment boom in generation. See Moran (2004) for a similar observations of several Australian investment plans.} To sum up, the direction of this effect could be either positive or negative. Determining this effect requires a separate study, which was lacking.

The effect of the interconnector on competition and the efficiency of generators

Existing electricity market models only take static efficiency into account without studying long-term dynamics (dynamic efficiency). Another, rough approach would be to look at other studies that either measured or estimated increases in efficiency due to an increase in competition. This approach has been followed by CPB and SEO (see De Nooij and Baarsma, 2009) in the Dutch debate on ownership unbundling the distribution network companies. In that debate, a 0.375 percent increase in the efficiency of the generator (annual turnover €5.9 billion) amounts to a benefit of €22 million annually. A similar benefit here would provide a present value of €259 million (40 year, 6.8 percent
real discount rate). Admittedly this is a crude approach, with the risk that the competition benefits are estimated too high. The alternative is to implicitly assume that these effects are zero.

**Effect on security of supply**

DTe (2004, §97-98) took into account a positive but not quantifiable effect on security of supply. If the Netherlands should have an unexpected shortage of generation capacity, NorNed could be used to import extra electricity to solve the shortage. A shortage can exist when cooling water is scarce (as in the summer of 2003) or if power plants fail unexpectedly. A shortage will have two effects. First, power prices rise, and thus the interconnector will be used for import already. This effect is included in trading revenues. Second, if the shortage occurs at short notice, reducing demand or importing power may be the only solution. Such an outage has never occurred in the Netherlands, but assuming a shortage-of-supply-induced outage every 20 years, which only NorNed could prevent, over a period of two hours (during which time other production can be ramped up, or large users can be called off line), assuming the full capacity of the line (700 MW) and a value of lost load of €8.6/kWh (see De Nooij et al., 2007), then the expected benefits are €0.6 million annually, or a discounted €7.2 million (40 years, 6.8% real). Given that such an outage has never occurred, Norway has to be able to produce and transport more, and other preventative measures are possible (such as interruptible contracts with large users) this value seems an upper limit. Without quantification, the welfare effects of security of supply may easily get too much attention.

**The discount rate**

The discount rate used in the present value calculations was debated heavily between TenneT and the regulator (see DTe 2004, §68-71 and TenneT, 2004), but the discussion was unusual for several reasons. First, the discount rate used here differs from the standard discount rate used by the government in its CBAs. Therefore, a project’s

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120 In the reports, this discount rate is often referred to as the Weighted Average Cost of Capital (WACC). Since this discount rate is also used for future consumer surpluses the term ‘discount rate’ is used here.
approval may depend on which government’s department has to approve. For government investments, a 4 percent rate (since then lowered to 2.5 percent) plus a project-specific risk premium should be used.\textsuperscript{121} Here the discount rate would be 8.9 percent \((4 + 0.9 \times 3 + 2.2\,\text{percent inflation})\).\textsuperscript{122}

Second, TenneT corrected its calculations for corporate taxes, which is logical for a company since taxes paid are a cost. It is not correct in a CBA since for society taxes are a transfer (from a company to the government, which is part of society). TenneT proposed an after-tax discount rate of 6.31\%, which divided by 1 minus the tax rate (34.5\%) gave a pre-tax discount rate of 9.65\%. By correcting for taxes the calculated social welfare of interconnector investment will be too low.

Third, DTe does not take costs and benefits after 25 years into account. DTe chose this shorter time horizon for two reasons (DTe, 2004 §65-67). First, the technical life of the cable is uncertain; there is not enough experience with underground HVDC cables to be certain of a 40-year life. Second, economic revenues after 2020 are uncertain since the economic models are less detailed after 2020 than before that time. A higher discount rate (or taking only a share of the expected benefits into account) after 25 years seems reasonable given these uncertainties. However, an implicit discount rate of infinity seems too extreme. Furthermore, DTe increased the cost of investment by 20\% since many public investments in the Netherlands in previous years saw considerable cost overruns.

Table 8.2 illustrates the result of the different discount rates. ‘Correcting’ for the tax rate makes a big difference in NPV (compare rows 1 and 2). The difference between the government discount rate (row 5), the ‘corrected’ discount rate (row 2) and the discount rate used by DTe (row 3) is modest. However, the methods used to calculate the discount rate are very different and in the future larger differences cannot be ruled out. The 20-percent increase in investment costs and DTe’s reduction of the period to 25

\begin{itemize}
\item \textsuperscript{121} Project-specific risk should be valued at beta times 3 percent with unknown betas equal to 1 (Ministry of Transport, 2004).
\item \textsuperscript{122} 0.9 risk was estimated by TenneT. Normally Dutch CBAs are in real terms. Here inflation had to be added since TenneT and DTe increased all numbers by the rate of inflation.
\end{itemize}
years instead of 40 makes a significant difference (compare rows 3 and 4). Being more cautious than the usual Dutch standards negatively impacts on the evaluation of NorNed. Although it does not alter the final conclusion for this investment, it could make it more difficult to use these more positive but standard assumption for the next investment.

Table 8.2 Impact of different discount rates on the Net Present Value (€million, time horizon of 40 years unless otherwise noted).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
<th>Discount rate</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TenneT’s discount rate before tax</td>
<td>6.31%</td>
<td>448</td>
</tr>
<tr>
<td>2</td>
<td>TenneT’s discount rate after tax</td>
<td>9.65%</td>
<td>175</td>
</tr>
<tr>
<td>3</td>
<td>DTe’s discount rate, cost and time horizon equal to TenneT’s</td>
<td>9.00%</td>
<td>213</td>
</tr>
<tr>
<td>4</td>
<td>DTe’s actual calculations, high cost and short time horizon (as used in the decision)</td>
<td>9.00%</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Government’s discount rate (infinite horizon)</td>
<td>8.90%</td>
<td>220</td>
</tr>
</tbody>
</table>

Source: Row 2 TenneT (2004); other NPVs: author’s calculations based on DTe (2004) and TenneT (2004).

Conclusion

Overall, there are lacunas in the economic argumentation for the NorNed case. The revenues from trade, which in the short term will be realized, will not be fully realized in the long run after the producers have adjusted their generation portfolio. These benefits from trade will not disappear completely because NorNed offers the Netherlands good access to flexibility. But in total the benefit from trade are overestimated. On the other side are savings on investments and benefits from increased competition, which have been neglected.

Several lessons can be learned for future investment. First, alternative options and the counterfactual have not been studied in detail. This is partly understandable, but it also carries the risk that better options are ignored. Second, the criteria used in the decision should be clear. If seven aspects are included it should be made clear which ones will prevail or be the most decisive. The main one seems to be a CBA, but that is not certain. Third, dynamic effects should be taken into account by studying system dynamics. Producers will react to an annual decrease in producer surplus of €45 million. Fourth,
valuing effects where possible improves the analysis. Using back-of-envelope calculations may be inevitable, although more substantiated methods are preferable. Currently, the effect on security of supply seems to be overemphasized, while the effect on increased competition seems undervalued. Fifth, it is strange that the government discount rate is not used. This may create a bias in favour or against projects within the government; the discussion over the discount rate also absorbed a great deal of attention and resources. That being said, compared to other investments in the Dutch Grid, the NorNed decision stands out for being discussed and published in greater detail, even though some of these other investments exceed the costs of NorNed by far (see De Nooij 2010).

8.3 The East West interconnector from Ireland to the UK

The Irish TSO (EirGrid) is planning the construction of a new interconnector with the UK, known as the East-West interconnector. It is due for use in July 2012, will have a capacity of 500 MW and will cost €600 million. It has a total length of 256km, of which 185km are undersea. The Irish Commission for Energy Regulation (CER) has approved the project based on EirGrid’s ‘Approval to Proceed’ submission in February 2009. The Irish Government gave final approval in March 2009. It will be a regulated asset owned and operated by EirGrid. The investment will be recouped through customer Transmission Use of System charges (and congestion charges should the interconnector be congested) (SEM, 2009, p. 10). The EU contributed a €100 million grant to speed up construction (EC, 2009). The studies and discussions on whether to build this interconnector lasted 30 years (DKM, 2003, p. 4), culminating in the so-called business case in 2008. Normally a business case only includes an investor’s costs and benefits; however, EirGrid also included social benefits, making it more of a CBA than a business case. The third column in table 3.1 summarizes the business case.

Security of Supply

Security of supply has been measured through the replacement need for a peaking plant. The Generation Adequacy Report (made earlier by EirGrid) has identified the need for additional generating capacity or an interconnector over the next seven years to
maintain security of supply. At the same time, they signal significant capacity available in the UK. The UK capacity is expected to increase further, resulting in a capacity margin of 35 percent. The excess capacity in the UK enables it to trade electricity across borders.

In 2007, total installed capacity in Ireland was 7577 MW, of which 1132 MW was not fully dispatchable (mostly wind, 950 MW). Installed capacity is expected to increase to 9081 MW, of this 3076 is not fully dispatchable (wind energy accounting for 2800 MW). Since plant closures will exceed new capacity, fully dispatchable capacity will decrease from 6445 to 6005 MW. In the UK, EirGrid expects total installed capacity to increase from 78.4 GW in 2007 to 101.9 in 2013. The largest increase will come from new gas-fired generation. The growth in wind energy will add a further 9.3 GW. For the UK, EirGrid looks only at total capacity and does not distinguish between fully and not fully dispatchable capacity. This means there is greater reliance on not fully dispatchable capacity in the UK than the not fully dispatchable energy Irish capacity. This might overestimate the possibility Ireland has to import electricity and to avoid investing in a new plant.

EirGrid estimates the benefits from this capacity margin in the UK to be enough to save a peaking plant. The costs of a new peaking plant are estimated at €39.9 million annually (500 MW times €79.77/kW as the annual fixed cost of a best new entrant peaking plant). Furthermore, EirGrid notes that such a plant generally has low energy efficiency (it operates only a few hours per year and has to be ramped up and down quickly).

EirGrid (2008) assumes the UK capacity to be so generous that the Irish economy can profit over the course of 30 years. For the short term this might be correct, but for the longer term (say after 5 to 10 years) this seems too optimistic. Without the cable, the UK generators would have to make an optimal investment decision, and if capacity is so abundant, its reward would be low, and investments and capacity would be reduced. For example, if UK’s excess capacity falls after using the cable for 5 years, a new plant would be necessary from 2017 onwards. Then the security of supply benefit would
disappear and the present value of all benefits would fall to €543 million, which is €50 million less than the cost. Alternatively, if the UK generators decide to invest to cope with Irish demand over the East-West interconnector, they do so because they get paid for it: the Irish pay for the extra capacity (via the electricity price), even though it is standing in the UK and not in Ireland. So also in that case it is not a cost saving either.123

Trade is further facilitated by the fact that demand peaks and forced outages in the Republic of Ireland and the UK do not coincide (EirGrid, 2008). Ireland’s peak demand in 2005 occurred in mid December, while UK peak demand occurred towards the end of January. However, the correlation between the demand curves of Ireland and the UK was 0.89 in 2005 (Magazulli Valeri, 2009). Modest savings in required capacity are likely, but have not been quantified.

**Competition**

Lack of competition is a real problem in the Irish market, since it is highly concentrated. Furthermore, plant availability in Ireland was only 80 percent while the best practice rates available are about 90 percent, suggesting that competition is too weak to make the generators produce efficiently. The new interconnector will improve competition in the Irish market (EirGrid, 2008, p. 4 and 10). Currently the Residual Supply Index is over 1.1 for around 50 percent of the time. With the new interconnector this is expected to improve to 67 percent. According to Malaguzzi Valeri (2009), a rule of thumb for electricity markets is that the RSI should be above 1.1 for 95 percent of the time, which would require an increase in interconnection capacity of 1300 MW or more. As EirGrid (2008, p. 10) states, one of the key financial benefits associated with increasing competitiveness is increased pressure on the efficiency of generators and reduced market power, creating a downward pressure on prices. They estimate that every 1%

123 This could be a cost saving if the UK has a comparative advantage (for example because the UK can use a technology the Irish cannot use, like in the NorNed case the Norwegians use hydropower which for the Dutch is impossible). Since both countries use gas and coal technology and import part of these fossil fuels a comparative advantage for the UK seems absent.
decrease in average wholesale electricity prices creates a benefit to consumers of €20 million annually. It is unclear whether this €20 million is a transfer of wealth (through lower mark-ups) or a welfare increase (because generators become more efficient). Second, an alternative method of increasing competitiveness without a new interconnector would be to split the dominant supplier: the incumbent has an 80-percent market share. Given that it is 95 percent state-owned (Malaguzzi Valeri, 2009), this may not be so hard to do as for private companies (however political economy will make it difficult or impossible as well). EirGrid did not quantify the expected price decrease, nor how much of it would be an efficiency gain. Third, it is unclear whether the benefits of a lower price through more competition and reduced investment needs are mutually exclusive, since the capacity replaced by the line is not additional, but replaces a generator that will not be built (see also the discussion of Borenstein et al., 2000 in section 4).

Despite these questions, the competition benefits appear to be real. The fact that they are not included leads to an underestimation of the total benefits.

**Reduced wind curtailment**

Ireland plans to invest substantially in wind energy. Given the fluctuations in the amount of wind energy actually produced, wind energy will sometimes have to be curtailed if it constitutes a large fraction of the total generation capacity. A new interconnector reduces that need through pooling with the UK. IerGrid estimates this to be worth €10 million annually, but does not give details of its calculation. However, this number is partly based on the Grid Development Strategy with the 2025 target of 33 percent renewables. This raises two questions. First, how realistic is the scenario of 33 percent renewables and how fast will it be realized? (It is strange that only one scenario is used; given that wind capacity increases over time, it is more likely that the benefits would be smaller at the start and would increase gradually, which would reduce the present value of the benefits.) Second, the potential of the interconnector to prevent wind curtailment also depends on the correlation between wind conditions in the UK and in Ireland. The stronger the correlation, the less potential there will be to export
wind power from Ireland to the UK and vice versa. EirGrid does not reveal whether this has been studied.

A related effect not discussed by EirGrid is that if wind energy capacity increases, thermal plants have to ramp up and down more frequently, which could reduce their efficiency and increase their costs. An interconnector could reduce this. This effect could be a real benefit, not discussed in the decision.

Therefore it is questionable whether the benefits estimated for reduced wind curtailment are accurate.

**Reduced carbon credit payments**

Reduced carbon credit payments (i.e. CO₂ permits) are estimated to be worth €28.30 million annually. EirGrid assumes that one MWh of electricity is generated with an average of 600kg of CO₂, that the 500 MW Interconnector has a 50% load factor, and a CO₂ price of €21.57 per tonne. Given the uncertainty of whether this effect will actually materialize, EirGrid assumes a 50 percent likelihood and an expected value of €14.15 million (a current value of €203 million). However, if the interconnector is used to import energy, the UK generators have to buy CO₂ permits in the UK, which will have to be paid by the Irish importers, resulting in no savings. Real CO₂ reductions are derived only from a reduced need for wind curtailment in Ireland, or in the UK, or if more wind energy capacity is installed. The last two issues are not discussed, and the first is included in the cost-benefit analysis. Therefore, the likelihood that this benefit will materialize seems to be overestimated substantially.

**Discounting the future / valuing governments**

EirGrid uses its real pre-tax WACC of 5.63% to discount future benefits (CER, 2005). The pre-tax WACC is too high since it is used to determine how much return is necessary to compensate an investor. An investor pays the corporate tax and receives the post-tax WACC of 4.92%. The investor does not value the tax revenues of the government as a benefit. If a society as a whole is investing (which is here implicitly the case since all electricity users will pay for the investment via system charges), these tax
revenues are for society a real benefit (the government can do more or the government needs less other taxes). That means that for society-wide investments the post-tax WACC is better. Using the post-tax rate instead of the pre-tax WACC increases the present value of the benefits from €948 to €1026 million. This difference is rather small due to the low Irish tax rate.

Further remarks

The required capital costs necessary for development and construction are estimated at €595 million, including contingencies. No other costs are noted; for example, no maintenance and operational cost are included. TenneT included an annual estimate of €4 million (a present value of €57 million) for the NorNed cable. The same is true of electricity losses during transport which EirGrid does not mention.

An alternative approach to study the welfare effects of this interconnector is followed by Malaguzzi Valeri (2009) who studies trade benefits and the cost of generating electricity using the merit orders of 2005 for Ireland and the UK. This approach is comparable to the NorNed approach. Trade benefits are largely based on the fact that the price-setting generation in the UK is mostly coal-fired, while in Ireland it is gas-fired. Different CO₂ prices and different sizes of additional interconnection capacity are simulated using the 2005 data. A new 500MW interconnector is beneficial to social welfare, but is too small to integrate both markets (a price difference of less than 1.5 percent). At the margin, the capacity necessary to integrate the markets (last 500MW capacity) has more social costs than benefits. Trade revenues depend on the generation mix, which may change over time. For example, the large share of gas-fired generation in Ireland compared to the UK is strange since the Irish gas price exceeds the UK’s by 20 percent, the UK’s share of coal generation may decrease due to CO2 prices, and an increase of wind energy in Ireland makes coal plants the price-setters more often. The trade revenues and thus the social desirability of the interconnector depend on a correctly predicted mix of electricity generation. But Malaguzzi Valeri (2009) uses a static model, changes in the generation mix are not considered. This is especially important since the Irish producers face a drop in producer surplus of €143 million
annually, to which a response is to be expected. A model of system dynamics analyzing future investment decisions is lacking here, although it is necessary for a proper CBA.

Conclusion

Several lessons arise in the comparison of the business case for the Irish East-West interconnector with the CBA approach. First, the largest benefit is an increase in the security of supply, estimated in terms of avoiding the expense of a new generator, which would otherwise be needed to maintain security of supply at the same level. Imports from the UK are assumed to be always possible. However, the non-dispatchable capacity in the UK has not been taken into account, nor has the fact that UK generators will invest less to reduce abundant capacity, reducing the possibility for low-cost imports. Second, competition benefits were cited as important, but are not quantified. Third, the benefits of reduced wind curtailment are crucially dependent on new investment in wind energy and the extent to which the system can handle it, as well as the correlation between wind in Ireland and in the UK. Fourth, the business case overestimates the benefits of reduced carbon credit payments on imported electricity because now the Irish power importers will have to buy these permits in the UK instead of in Ireland. Fifth, the discounting seems to be too negative; the social benefits are calculated using the pre-tax WACC instead of the post-tax WACC. Sixth, the calculation available is less detailed than the one available for the NorNed cable. But like in the Dutch case, the interconnector investment is published in more detail than domestic investment although these latter require more money.\textsuperscript{124} The main conclusion is that EirGrid’s conclusion that the East-West Interconnector is socially attractive does not stand up to scrutiny, the true conclusion could be negative instead of positive.

8.4 Conclusion and policy and research recommendations

Investments in transmission and interconnection capacity require substantial amounts. Claims are that the coming years substantial investments are necessary to allow for more trade, to stimulate competition and to connect renewable energy to the grid. A

\textsuperscript{124} The Irish National Development Plan finds that over €1.2 billion in investment is needed for the strategic energy infrastructure (EirGrid, 2008, p. 1).
A good and thorough analysis of the costs and benefits of proposed investments is therefore important to make sure that only investments that increase welfare go ahead. This article investigates the economic arguments made for two decisions to build an interconnector in Europe, and finds that the cost-benefit analysis used can and should be improved to ensure efficient and adequate investments.

First, in a CBA, the demand for a new investment must be clear before it can be evaluated. Currently demand for new capacity is unclear: utilizing the current connections can be improved (for work on that see ERGEG, 2009) and the measures of congestion have to be further improved. Measures of interconnector scarcity are crude and often do not use economic concepts. Measuring congestion is difficult, there are several different measures each with pros and cons, see ERGEG (2009) and CWRI (2010) for a discussion of the different metrics as well as quantifications. That measuring demand for interconnectors is difficult can be illustrated by comparing two measures: the hours a line is (contractually) congested and the price paid for capacity over that line. EC (2007a, p. 172) studies the first metric and finds that many interconnectors are congested. Other indicators show for the same line no congestion. For example the interconnectors from the Netherlands to Germany were congested 62.9 percent of time and from Germany to the Netherlands congestion existed 87.9 percent of time from January until May 2004. Under this definition, a line can be congested in both directions simultaneously, even though electricity will only flow one way and it is not actually desirable for it to flow in both directions. However, the monthly auction prices showed a different picture. The price paid to export from Germany to the Netherlands was with 6.66 €/MWh substantial. The price for the reversed was a mere 0.08 €/MWh (about 0.2 percent of the wholesale price), indicating that there is hardly any congestion because market participants are unwilling to pay for capacity (see De Nooij, 2010).

Other congestion measures, such as the 10 percent of demand as a minimum required import capacity agreed upon in Barcelona in 2002 (see EC, 2007, p. 175), lack any economic rationality. It may be too little in some circumstances and too much in others (CEER, 2003). For instance, the Dutch interconnector remains congested though import capacity is 17%. Léautier and Thelen (2009, p. 140), using four different congestion metrics, show that in a three-node network the congestion costs for different sizes of a new interconnector vary widely.
Congestion within European countries is even harder to quantify than border congestion because market design is such that price differences inside European countries do not exist (with the exception of nodal pricing in the Scandinavian countries).

Second, in both CBAs the TSOs and regulators involved went to considerable lengths to make the best decisions. However, in both CBAs their argumentation is flawed. The NorNed case underestimates the social benefits of the investment, while the East-West interconnector overestimates these benefits, to the extent that the true conclusion could be negative instead of positive. Possibly regulators may try negative assumptions in their CBAs to be sure that the NPV remains positive. A drawback is that it is not clear how attractive interconnector investments are, resulting in inadequate attention. Also it is not unthinkable that a new benchmark approach is set that is unnecessarily negative for the next investment.

Third, both CBAs do not take the (long-term) reaction of producers to new interconnection capacity into account and both ignore some of the potential benefits of more competition. Short-term trade benefits are calculated in great detail. The efficiency gains in generation that are brought about through increased competition are mentioned but not quantified, leading to a potentially significant underestimate of the welfare effects of investment in interconnectors and transmission. It is unlikely that these effects can ever be calculated to the degree of detail that the current trade benefits are estimated, but the current implicit approximation of zero benefits could certainly be replaced by a crude, but more correct estimation (probably a bandwidth).

In both CBAs, dynamic effects are to be expected, but these are not included in the discussion. Generators will respond to a lower calculated producer surplus and to additional supply arriving over a new interconnector by changing their investment pattern. This may create social benefits (fewer investments lead to a lower social cost by definition) and impact trade benefits as well.

Fourth, several smaller issues can also be improved. For example, both cases discount using a pre-tax WACC which underestimates the benefits for society since it ignores tax
revenues as a benefit. In both cases, only a limited set of alternatives is examined, and a potentially better alternative is likely to be missed. Some difficult to value effects are not quantified or valued, such as security of supply in the Dutch case. A rough valuation provided here shows that this is a minor effect at best.

Fifth, both economic argumentations differ widely, leading to situations in which approval for an investment may depend on which authority or country has final approval. The development of a uniform method used for all transmission and interconnector investments in Europe, or within a particular country, (used for all government-approved CBAs) would help to reduce this. A standard method would limit some of the choices now left to the applicant (such as the choice of discount rate) to save time and costs on standard issues which could then be spent on more difficult issues (such as predicting generator responses). One guideline may also make evaluations by the regulator more predictable. For guidelines inspiration can be found in national or EU guidelines for infrastructure investments (e.g. Eijgenraam et al. 2000; EC 2008a) or in international guidelines for transmission investments (e.g. in Australia AER, 2007; In California CAISO, 2004; Awad et al., 2004). Of course a guideline still leaves a lot of aspects to be determined or quantified by the applicant and errors are still possible (Littlechild, 2004, criticized an Australian decision for taking insufficient alternatives into account).

Sixth, in both countries the interconnector decision receives more attention and a more detailed analysis of costs and benefits than the domestic grid investment even though these domestic investments require substantially more money. This may not lead to optimal investments.  

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126 Two (speculative) explanations for the relatively high interest in interconnectors: (i) Regulators may fear that the other country would benefit more from an interconnector at the cost of domestic consumers; (ii) alternatively, interconnectors may be easier to analyze and thus get more attention.
It is therefore unlikely that decisions to invest in interconnectors and transmission in Europe are currently maximizing social welfare. Both underinvestment and overinvestment can occur, and both are costly.\footnote{For discussions on whether over- or under-investments are more likely or worse see De Nooij (2010), Nordel (2008, pp. 3, 19), Brunkreeft et al. (2005, pp. 75-76) and Léautier and Thelen (2009, p. 133).}

**Research recommendations**

Some of these critics can be dealt with in new CBAs, however two effects of interconnectors deserve more research.

The first effect that deserves more researched is the dynamic effect. Connecting two grids may reduce the need for generation capacity if peak demands are not closely correlated. Changing investment is to be expected due to different price patterns, in part from lower investment in peaks and probably more in base loads, and location can change. For NorNed, this would probably lead to greater benefits, while for the East-West interconnector it would probably lead to lower benefits. The amounts involved are potentially large: if every MW of interconnector capacity leads to a 0.5 MW reduction in generation capacity the additional benefit can be in the magnitude of half the investment costs. One could argue that this effect does not need to be included because the generation mix takes a long time to change given the long lifetime of power plants. However, not all power plants need to change. If the next investment changes (type, whether it is built, location, etc.), this is already a substantial effect. Also the Californian ISO recommends that the interaction between generation investment, demand-side management, and transmission investments is taken into account (CAISO, 2004). However, only a few papers study the interdependence between transmission and generation. One exception is Sauma and Oren (2006)\footnote{Other exceptions are Keller and Wild (2004), CAISO (2005) and Ojeda et al. (2009). Fehr and Sandbråten (1997) analyze changes in investment due to interconnection.}, who show that the size of the welfare gains associated with transmission investments and the location of transmission expansions may depend on whether a generation expansion response is taken into consideration.
The second effect that deserves more research attention is the effect of interconnectors on competition between generators. In EU policy, this is an important reason for new investment, but in the CBAs studied this effect was not included. Most electricity market models estimate allocation efficiency and production efficiencies resulting from trade given the current technologies and prices.

In the theoretical literature, much emphasis is put on the reduction in market power due to interconnector investment, resulting in lower mark-ups over the price, smaller transfers from consumers to producers and a lower dead-weight loss (see for example Borenstein et al., 2000; Léautier, 2001; Tanaka, 2009). In practice, estimating the reduction in mark-ups is difficult, and it is not included in the cost-benefit analysis found, leading to a likely underestimate of the benefits (Nordic competition authorities, 2007, p. 49-51).  

Note that trade benefits and lower mark-ups may interact. Borenstein et al. (2000) model two identical markets with a monopolist. With a small interconnector, one of the monopolists could play aggressively and export the full capacity of the interconnector. For the other monopolist it would still be attractive to exercise monopoly power over the residual demand in its home country. With a larger interconnector the monopolist facing imports would find its best strategy to react aggressively and export power. From his perspective this strategy maximizes his expected profits. The result is that for symmetry reasons, both companies act as duopolists. Prices and quantities produced and sold would be similar and thus the interconnector remains idle. The counter intuitive result is that the competition effects may be greatest when the interconnector is not used. So unused capacity may appear to be overbuilt and underused, but could actually provide a useful antidote to anticompetitive behaviour.

129 For the Great Belt interconnector between East and West Denmark the Danish TSO estimated the welfare contribution of increased competition to yield up to 20 M €/year in socio-economic benefits (Nylund, 2009). Given this uncertainty they chose not to include it in the cost-benefit analysis at all, although they do suggest that a careful alternative is to include 10-20% of it.
Apart from lower mark-ups, competition can improve X-efficiency and the dynamic efficiency of generators due to stronger incentives to be efficient. Although this effect is mentioned in the policy claims that Europe needs more interconnectors and transmission capacity, it has never been included in a CBA. Ahn (2002) finds that these long run effects of more competition often exceed the short run effects. This is in line with Joskow’s (1997, pp. 124-125) expectation that competition (through market liberalization) will not lead to significant short-run cost savings. He expects more benefits from medium-run efficiency gains because competition may reduce the existing large differences in the operating performance of the existing stock of generating facilities and increase labour productivity. (The differences in operating performance exist even after controlling for age, size and fuel attributes). Joskow expects the main benefits to come from cost savings associated with long-run investments in generating capacity, where controlling for the relevant characteristics, investment costs vary widely between companies, as well as adoption speeds for new technologies. Joskow expects the most from x-efficiency and dynamic efficiency. Until x-efficiency and dynamic efficiency are included in CBAs, the welfare contribution of new investments will be underestimated, potentially resulting in too little investment.\footnote{For a further elaboration on these long run effects see De Nooij (2010).}

**In conclusion**

Given the amount of proposed transmission investments by ENTSO-E (2010) and others, further thinking about the costs and benefits of these investments seems a worthy goal, especially since each investment is decided upon separately, usually after a cost-benefit analysis is performed. Some practical and theoretical challenges exist, both for the TSOs and the regulators involved and for the academic world. This paper has endeavoured to contribute to that thinking; however, it is unlikely that a perfect CBA method which both TSOs and regulators can use will be found. Some of the issues at stake are too complicated for that. Including some of the effects with a bandwidth would seem to be the best that can be achieved. That requires careful drafting of the CBA since policy makers are not used to work with a bandwidth, and might use the
most likely average or one of the borders if that is more attractive. If the most likely outcome is used instead of the bandwidth than uncertainty might not be dealt correctly. However, not including a value (or bandwidth) for an uncertain effect requiring more research is in political decision making implicitly equal to using a value of zero.
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