University of Twente
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Investment planning for network companies

Consequences of an early replacement versus a late replacement strategy

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Preface

This is my thesis: Investment planning for the electricity distribution companies in The Netherlands: the choice between a fix and fail strategy and engineering excellence strategy.

This thesis was written because of the education Technische Bedrijfskunde at the University of Twente. This is the graduation part of the education. The research has been carried out in collaboration with the Energy&Utilities department of PricewaterhouseCoopers Advisory in Amsterdam.

I would like to take the opportunity to thank all my colleagues for their great cooperation and all the assistance I got during the research. Special thanks to my supervisor John de Croon from PricewaterhouseCoopers and my supervisors from the University of Twente Dominique Dupont and Peter Schuur. Despite their busy schedule they always took the time to give their opinion, to answer questions or to discuss new developments about the subject of my thesis.

Also I would like the opportunity to thank all the interviewees which were a great help to perform my research; Danny Ouwendijk, John Hodemaekers, Jan Wierenga, Jan Lantinga, Jack Seuren, Ype Wijnia, Paul Nillesen and Johan Huisma.

Finally I would thank the reader for his/her interest in this thesis. I wish the reader much reading pleasure.

Amsterdam, February 2007

Bart Steenbergen

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1 Management Summary

Most part of the electricity distribution networks in the Netherlands were built in the early 1950s just after the Second World War and many of these assets are approaching the end of their expected lifetime. So distribution companies are operating assets beyond their original design limits and consequently network reliability, safety and security may be at stake. Former has led to the following problem definition:

What would be a good investment strategy for the ageing infrastructures of distribution network companies and what are the consequences of this strategy?

Distribution companies are asset intensive companies and the distribution networks are rather complex. The distribution companies have not experienced any revolutionary change in the past 50 years. While there have been incremental improvements, designs installed in the 1950s still stand the test of time. The network companies have to replace their assets in the future. Based on the installed assets from 1900-1997 a replacement model has been built. Cross border leases were conducted for a large number of Dutch power plants and electricity networks. According to Moody's early termination events for the cross border leases are very limited and the risk of unscheduled early termination is rather low.

Electricity distribution is the penultimate stage in the delivery of electricity to end users. It is generally considered to include medium-voltage (less than 50 kV) power lines, electrical substations and pole-mounted transformer, low-voltage (less than 1000 V) distribution wiring and sometimes electricity meters. For the thesis electricity meters are included in the scope. Generally all levels of 110kV and higher can be defined as transmission. However high-voltage cables (110 and 150kV) are included in the scope, since the network companies are the owners of these assets.

To evaluate the asset management replacement strategies the general asset management model of Roestenberg, De Croon and others (2003) is adapted for this specific replacement problem. That model lacks a flexibility factor. The replacement model has four dimensions; financial performance, operational performance, level of risk and flexibility.

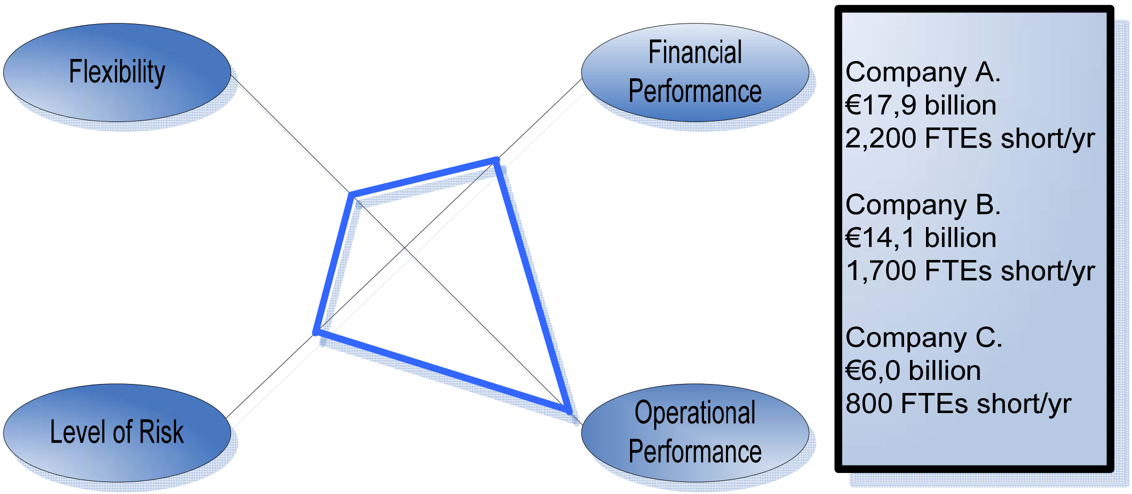
- *Financial performance*: the expenditure in euros for the given time horizon. The less or the later money is spend, the higher the financial performance is.
- *Operational performance*: the performance of the distribution network in terms of non-availability. It means that if no investments are made the performance probably deteriorates.
- *Level of risk*: the risk that necessary replacements cannot be carried out. The risk that a network company will be in a vicious circle; more and more employees are necessary to fix the failures in the network and replacements have to be carried out as well.
- *Flexibility:* the degree a company can react to changes of their environment. A higher flexibility means that a network company can make better investment decisions in the future.

A network company can adapt one of the following two extreme strategies; the early replacement strategy and the late replacement strategy. If there are no regulatory changes it doesn't matter if one company will replace their assets earlier than another network company, because each company will have to make their replacement investments in one or another regulatory period. For the electricity companies a longer regulation period would enable them to develop longer-term replacement strategies.

New technologies will lower the use of the distribution network therefore a technology factor is introduced for the replacement model. This technology factor reduces replacement investments by 20% starting from the year 2020.

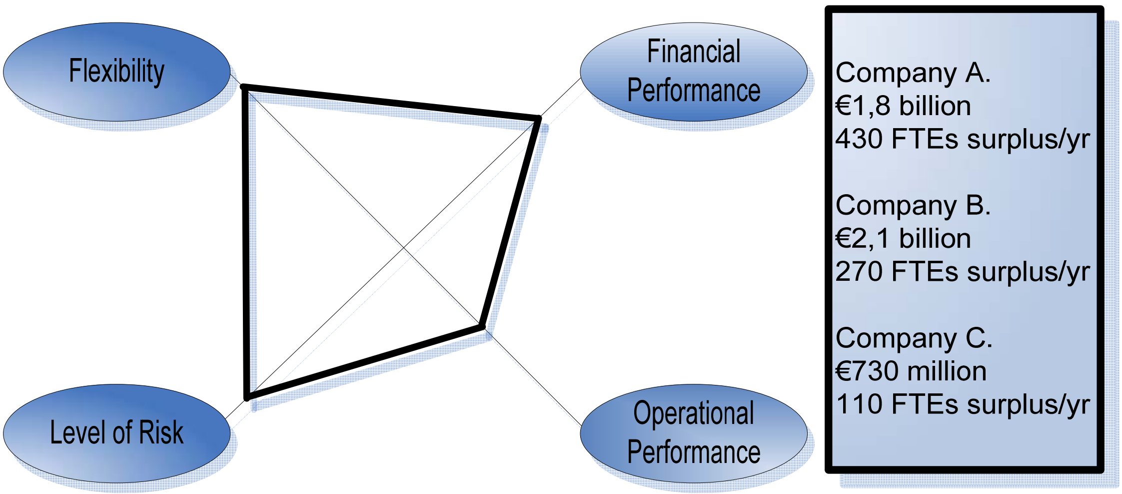
The 2007 investment prognosis from Company A and Company B themselves is about €100 million per year. Company A indicated that the total investments will double up within 30 years. The 2007 investment prognosis from Company C is about €90 million. Company C indicated that it will approximately be the same the coming years.

Early replacement strategy



If a company has a preference for operational performance it would be best to adapt the early replacement strategy. A disadvantage is that the short-term financial performance will not be high. Also a lot of FTEs are needed to perform the replacements so the average FTEs short per year is high (see figure above). From 2007 there are immediate FTE shortages for each network company. Average investments per year for Company A is €810 million, for Company B €640 million and for Company C €275 million (much higher than the network companies indicated).

Late replacement strategy



If a network company has a preference for flexibility the network company has to adapt the late replacement strategy. But the network company has to accept the accompanying delivering risks (operational performance) and the risk of a future shortage in employees. Advantages of this strategy are that the short-term financial performance will be good and that the chance of anticipating to new technologies or to new regulatory rules will be high. This strategy will lead to less replacement investments and therefore a higher short-term financial performance (see figure above). Average investments per year for Company A is €80 million, for Company B €94 million and for Company C €33 million. These figures are slightly lower than the investment prognoses form the network companies themselves.

Most likely scenario

According the most likely scenario a FTE shortage of 75 for replacements occurs for the first time in 2008 for Company C, for Company B this occurs in 2010 (144) and for Company A also in 2010 (75). For the Netherlands it means that the first labour shortage occurs in 2010 of 300 FTEs.

2007-2027	Company A	Company B	Company C	the Netherlands
Average FTE short/yr	120	160	140	430
Total FTEs short	2,700	3,500	3,050	9,500
Total investments	€5.1 billion	€4,8 billion	€2,2 billion	€13,8 billion
Average investment/yr	€230 million	€220 million	€100 million	€630 million

According to the investment forecasts the most likely scenario follows more the late replacement strategy than the early replacement strategy. Also the average investments per year follow the expectations from the network companies themselves rather well.

The sensitivity analysis of the model for the most likely scenario shows that for Company C it is for more than 80% certain that their investments will exceed €1,6 billion. For Company B it is for more than 80% certain that the investments will exceed €3,5 billion and for Company A it is for more than 80% certain that their investments will exceed €3,8 billion.

Also it is for more than 83% certain that there will be a shortage in FTEs for Company A. It is for more than 90% certain that Company B has a shortage in FTEs and for Company C it is for than 99% sure that there will be a shortage in FTEs.

Recommendations for further research:

- Research has to be carried out to the employees of the contractors. They face the same problem of their ageing human resources as the network companies. What are the intake and outflow figures from these companies and how do they try to solve these problems?

- Research has to be carried out to the work force in other countries. Are there enough employees available in other companies and are they capable to perform the tasks.

- An investigation to the asset replacement in detail to failure rates. If there is enough data to investigate when an asset will fail than there will be no unnecessary replacements. Only replacements in critical parts of the network could be carried out.

- Research in developing plans with governments and other utilities so that together with for example the sewage system and the water companies' asset management strategies could be developed so that it will be the optimal strategy for a specific city. So streets don't have to be opened as much as they do now.

- Essent and Continuon probably merge with each other according to the newspapers. Determine the regulatory consequences for this new company and for the other network companies on the investment model.

2 Introduction

Because the thesis is very extensive this introduction part will be used to clarify the structure of the report. The different chapters will be introduced briefly so that the reader can easily maintain an overview of the report.

First of all in chapter 3 the client company PricewaterhouseCoopers (PwC) and their business activities will be introduced together with the University of Twente.

The problem description and the background of the problem will be given in chapter 4. Thereafter the problem statement and the accompanying sub research questions will be outlined. Also the research method and the research phasing will be shown.

In chapter 5 a theoretic framework will be outlined to define the concept of asset management and there will be examined what is important for the research question.

The market structure for the network companies will be given in chapter 6. Readers who are familiar with the electricity market could skip this part.

As a result of the natural monopoly of network companies the government has developed a regulatory framework which is handled in chapter 7.

New technologies which will have an impact for the network companies will be outlined in chapter 8.

Chapter 9 describes the asset bases of the three network companies and the asset base for the Netherlands will be given.

In chapter 10 a replacement model will be introduced and the outcomes of the model given different scenarios; early replacement, late replacement, combined late and early replacement and a most like scenario.

In chapter 11 'Conclusions and recommendations' the most important conclusions will be summarized and recommendations will be given to optimize replacement strategies and the accompanying problems for the network companies.

3 PricewaterhouseCoopers & the University of Twente

This chapter will shortly introduce the company and the university for which the thesis is being carried out.

3.1 PricewaterhouseCoopers

At PricewaterhouseCoopers (PwC) Netherlands more than 4,300 professionals work with each other from sixteen offices proceeding in three different Lines of Service:

- Assurance
- Advisory
- Tax & HRS

The Energy&Utilities (E&U) department where the research for the thesis is within the Advisory part of PwC. PricewaterhouseCoopers has been providing professional services to energy, utilities, and mining companies for more than 100 years. PricewaterhouseCoopers helps companies confront the industry's most challenging changes and issues, including:

- Addressing Sustainability
- Complying with Regulatory & Reporting Requirements
- Improving Performance & Operational Effectiveness
- Managing Industry Regulatory Change
- Industry Transactions & Consolidation
- Managing Financial Risk
- Managing Geopolitical Risk
- Recruiting & Retaining a Skilled Workforce
- Securing the Supply

3.2 University of Twente

I graduate at the University of Twente at the FMBE department (Financial Management and Business Economics). The name of the department is nowadays changed in the School of Management and Governance. The old study programme is at the moment separated in bachelor and master programmes. One could compare the study with the master Financial Engineering and Management at the University of Twente.

The School of Management and Governance offers Bachelors and Masters programmes and post-graduate education. Furthermore, scientific and applied research is conducted in widely varying environments. These include health care, higher education, commercial services and the banking sector. There are about 350 people on staff and 2200 students.

4 Problem description

In this chapter the problem will be specified. First the situation of the problem will be handled where the cause of the thesis will be described. After that the complication and the research questions will be mentioned. Further the research approach will be given where the research method and the research phasing will be explained.

4.1 Situation

The distribution company occupies a position in the energy value chain between the transmission system operator (TSO) and the customer who receives the electricity via the meter.

Figure 1: Energy value chain

Distribution companies are asset incentive companies and the distribution networks are rather complex. The distribution companies have not experienced any revolutionary change in the past 50 years. While there have been incremental improvements, designs installed in the 1950s still stand the test of time.

Most of the electricity distribution networks were built in the early 1950s just after the Second World War and many of these assets are approaching the end of their expected lifetime. So distribution companies are operating assets beyond their design limits and consequently network reliability, safety and security may be at stake. The upgrading of the electricity distribution network is also affected by the regulators, because they are reluctant to approve major network upgrades.

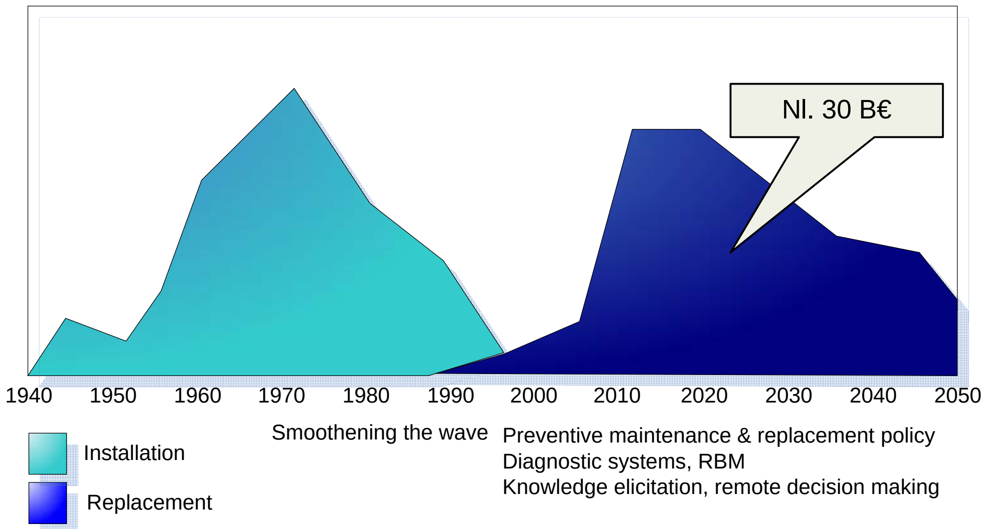


Figure 2: Replacement wave [CAP adapted]

Figure 2 shows the underlying reality of the current situation. A critical mass of assets is fast approaching their 40-year design life. A replacement wave is not expected beyond 2020 [CAP], but according to interviews with the network companies there is diffusion about the timing and the existing of the replacement wave. Given the new demands that will be placed upon more open networks the replacement wave may well be accompanied by greater application of intelligence to be better govern and control the distribution networks.

4.2 Scope

My thesis focuses mainly on the subject of asset lifecycle management of the distribution network companies in the electricity industry. These network companies nowadays have no clear insight in how to cope with upcoming threats in their industry.

In scope for the thesis will be the distribution (network) companies of the Netherlands. The assets of the three largest distribution companies of The Netherlands will be used as main input for a replacement model. The distribution companies are Essent Netwerk, Continuon and Eneco Netbeheer. Distribution is the green area of figure 1 (the energy value chain).

Transmission is distinct from electricity distribution, which is concerned with the delivery from the substation to the consumers. Transmission is between a substation close to a power plant and a substation near a populated area. Generally all levels of 110kV and higher can be defined as transmission. However high-voltage cables (110 and 150kV) are included in the scope, since the network companies are still the owners of these assets

Electricity distribution is the penultimate stage in the delivery of electricity to end users. It is generally considered to include medium-voltage (less than 50 kV) power lines, electrical substations and pole-mounted transformer, low-voltage (less than 1000 V) distribution wiring and sometimes electricity meters [WIK]. For the thesis electricity meters are included in the scope.

In scope will only be the replacement of the assets for the network companies. Elements of asset management strategy like failure-analysis and risk management with regard to these replacements will be out of scope.

The challenge for distribution companies today is how to proactively influence or react to the constant political, social and technological changes swirling around it. Figure 3 shows the most important forces that have a direct influence on the innovation benefits of the Dutch network sector; the main issue is how the network companies cope with these forces.

As already was mentioned in the background description there are at the moment ageing infrastructures. There is also much pressure from shareholders, regulators and customers to have an effective and efficient infrastructure to deliver the electricity.

The former will lead to the following problem statement:

What would be a good strategy for the ageing infrastructures of distribution network companies and what are the consequences of this strategy?

Figure 3: Sphere of consequences

4.3 Research questions

To be able to answer the above mentioned research question, the following sub questions have been identified:

1. *What is asset management?[Chapter 5]* Asset management is a very broad concept and a clearly defined definition of asset management creates clarity and leaves little room for uncertainty about what is meant by it in this thesis. Moreover, this sub question contributes to the insight in the importance of asset management. (Ageing infrastructure)

2. *What does the electricity market structure look like? [Chapter 6]* Answering this sub question gives insight in the difference interactions between the relevant actors that participate in the electricity market. (Market Structure)

3. *What is the impact of the regulatory framework for the electricity market? [Chapter 7]* Answering this sub question reveals different reasons for introducing competition and shows where regulation is still needed. (Impact of regulation)

4. *Which technologies in the energy market are affecting the asset management strategy? [Chapter 8]* Answering this sub question gives insight in how the network companies have to adapt their networks for the future. (Vision)

5. *What does the asset base of the distribution network companies look like nowadays?[Chapter 9]* Answering this sub question reveals the age and the value of the assets and serves as a starting point for sub question 6.

6. *Which replacement scenarios for the infrastructure are possible for the various network companies?[Chapter 10]* Answering this sub question gives insight in the consequences per scenario, impact on; financial, service providers and contractors, (Ageing infrastructure and Workforce)

The sub questions will be detailed out in questions with more detail if applicable. E.g. for sub question 6 is for example relevant:

- *What does the current average workforce of a utility look like (e.g. FTEs and age distribution)*
- *What is the expected (out)flow of employees within these utilities*

4.4 Research approach

A project approach based working method will be used. First the research methodology will be clarified and the phasing of the thesis will be given. Further the structure of the report will be given and thereafter the connection between the research questions, research phasing and the structure of the report will be explained.

Research methodology

This research can be described as an exploratory study orientation and introduction of an insufficiently known problem and has next to it an explanatory component, deepening of insight by means of explanation, interpretation and checking of processes.

To gather information for this type of research a qualitative research technique is used, namely interviews with specialists. The results of this survey gain more in-depth knowledge. Further the problem definition will be answered by means of evaluation and interpretation.

Research phasing

- **Phase 1: Orientation phase**: This phase consists of the exploration of the problem (background information and research questions). This starting phase will result in a clear and well defined formulation of the problem description and the research approach. Further the research questions serve as a structure for the thesis. Also the scope will be determined.

- **Phase 2: Analytic phase**: This phase consists of two sub phases namely the interview research and analyzing the data of the network companies.

- **Phase 2a – Interview research**: First a theoretical framework will is described that is used as a basis for further literature research. Then the literature research will be used to analyze the asset management problem of the distribution companies.

- **Phase 2b – Analysis of the data**: Data of the assets from the network companies is analyzed and several scenarios for reinvestment strategies are made.

- **Phase 3: Conclusion/ Recommendations:** Analyzing the results from the preceding phase.

- **Phase 4a: Fine-tuning thesis:** This phase consists of checking grammar, finalizing layout and making a management summary, which could serve as a starting point for writing the article.

- **Phase 4b: Article/ Presentation:** The last phase consists of ending the thesis by presenting it to the graduation commission and by writing an article about the conclusions.

5 Asset Management

This chapter describes the definition of asset management. First the various assets that exist are spread out. After that the definition of asset management is explained where the PAS-55 standard is introduced. Next the processes of PAS-55 are highlighted. Further the asset lifecycle is explained and in the last section an asset management strategy and a chosen asset management model is handled.

5.1 Types of assets

At the moment five different types of assets can be identified [PAS] [WEI], these are

- Physical assets; e.g. buildings, networks, plant equipment, infrastructures.
- Human assets; e.g. people skills, career paths, training, reporting, mentoring, competencies.
- Financial assets; e.g. cash, investments, liabilities, cash flow, receivables, and so on.
- Intangible assets; intellectual property assets (IP) and relationship assets like reputation with customers, suppliers, business units, regulators, competitors, channel partners, and brands.
- Information assets; digitized data, information, and knowledge about customers, processes performance, finances, information systems and so on.

The focus for the thesis is on the first group the physical assets of the distribution networks of the electricity industry in The Netherlands.

5.2 Definition asset management

At the moment various slightly different definitions about asset management exist. Let us start with an introduction of the PAS (Publicly Available Specification) 55-1, which gives the most general definition for asset management.

The Publicly Available Specification has been developed in response to demand from the industry for a standard for carrying out asset management. It is applicable to any organisation where physical assets are a key or critical factor in achieving effective service delivery. As a response to this level of interest, the decision to develop a formal reference document for asset management as a Publicly Available Specification, rather than a traditional BS or ISO standard, was taken in order to meet this demand.

To ensure consistency with other related business system standards and to facilitate its integration, it was considered that asset management would be best standardized as a specification. This specification with the information on implementing asset management is classified into key requirements. The criterion for including such requirements has been that, without them, the asset management system would be regarded as deficient.

The PAS-55 standard defines asset management as "the optimum way of managing assets to achieve a desired and sustainable outcome". PAS-55 is applicable to any physical asset intensive business, such as is found in the energy, transport, manufacturing and utilities industries, where the greatest expenditure, effort, dependency and risks are associated with the physical assets. [PAS]

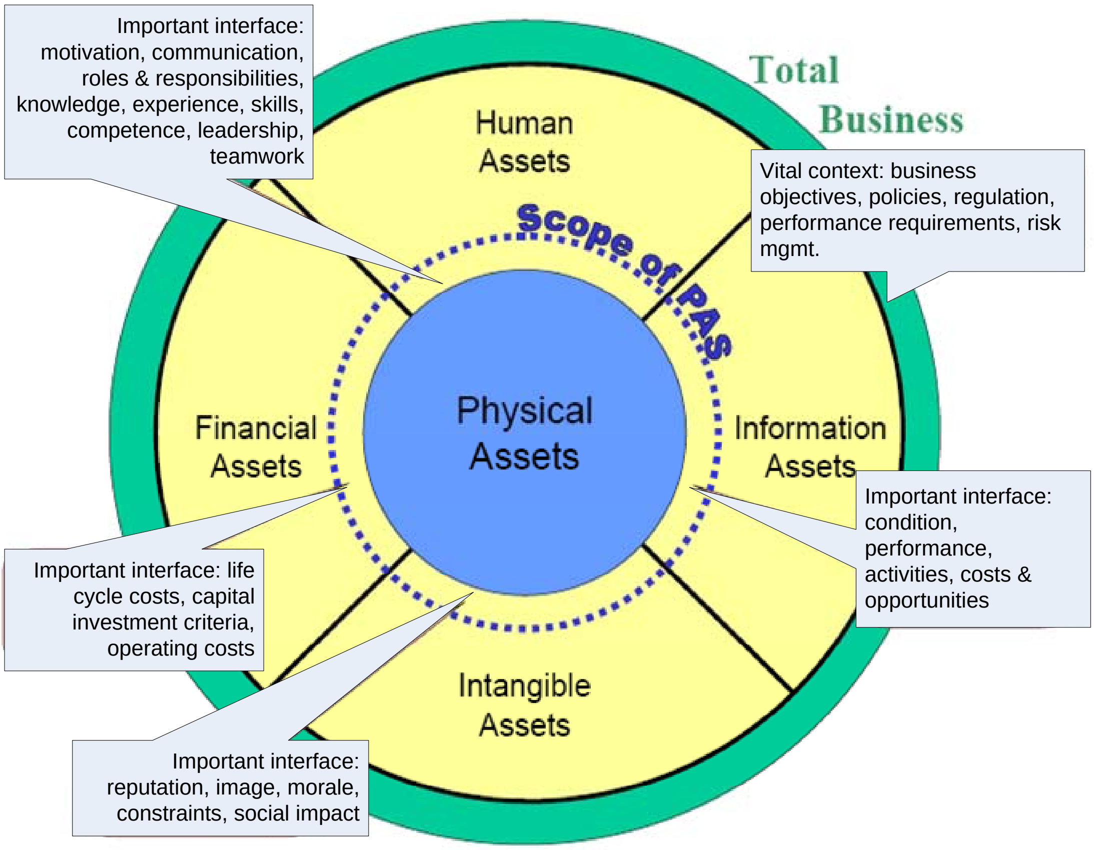


Figure 4: Scope of PAS-55 [PAS]

More definitions of asset management exist which are more specified to the physical assets of the distribution companies in the energy sector.

Roestenberg, De Croon and others (2003) created the PALM-concept (Perfect Asset Lifecycle Management) to maximize the value of technical assets for all of the stakeholders over the whole lifecycle of these assets. [ROE]

They define technical assets as complex, durable capital goods and the accompanying facilities, which are required to produce specified goods or services.

Sklar (2004) gives as definition: asset management is a business discipline for managing the lifecycle cost of infrastructure assets to achieve a desired level of service and reliability while mitigating risk.

Chandansingh and De Croon (2004): Asset management is to realize a business strategy where the created value will be improved by means of an effective balance between costs, risks and operational performances over the lifecycle of the infrastructure.

Approximately the last definition will be used as the definition of asset management for the thesis, the definition will be:

Finding an optimum way of managing assets to achieve a desired and sustainable outcome by means of an effective balance between costs, risks and operational performance over the lifecycle of the infrastructure.

5.3 Processes in PAS-55

The standard of PAS-55 is based on five successive elements as can be seen in figure 5 [PAS2]. These five elements are based on the Plan-Do-Act cycle. General requirements are asked for the asset management system (yellow area figure 5). Main task for the organization in that area is to define the scope for its asset management system.

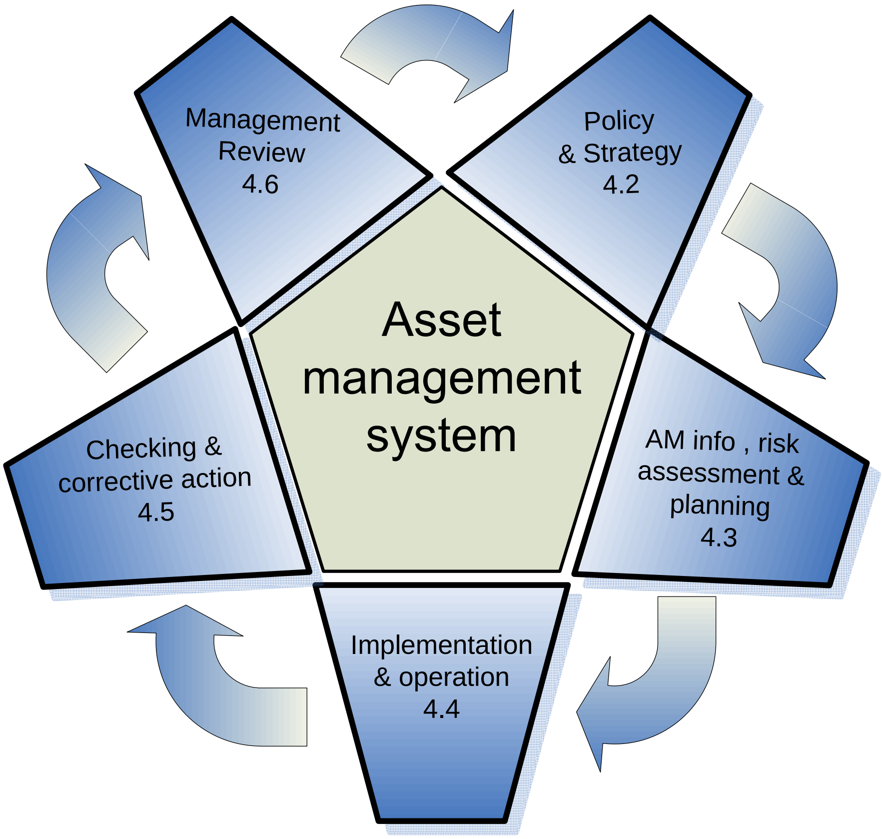


Figure 5: Asset management system elements [PAS]

In table 1 we follow the above figure through its several steps. In for example paragraph 4.2 *policy & strategy* is determined that the organization's top management shall authorize an overall asset management policy. Included in this step should be a risk management framework and the performance requirements per asset. Next to the examples several problems which companies could face in each specific step.

The interest for PAS is increasing. The standard will probably be transformed via a BS (British Standard) to an ISO-standard, because more and more companies are implementing PAS.

For the thesis the most important paragraphs from table 1 are 4.2 (asset management policy and strategy) and 4.3 (asset management information, risk assessment and planning) an 4.4 (asset management implementation and operation) Paragraph 4.2 because the thesis focuses on different strategies to cope with the ageing infrastructure, therefore a sort of an asset management action plan has to be developed for the future. Paragraph 4.2 is important for the thesis because there have to be enough employees in the planning to carry out the work. And in paragraph 4.4 is asset management operation of importance. Execution from those activities which are necessary to give an operation interpretation to reach the asset management goals.

Table 1: Realizing of PAS 55 processes to part of processes and corresponding problems which companies are facing [PAS]

Para-graph		Examples of process parts	Examples of problems for companies
4.1	General requirements	• Continuous improvement • Determination scope • To have the control of outsourced processed	• Improvements not identifiable • Interface with (internal or external) service providers not clear
4.2	Asset management policy and strategy	• Policy and strategy shall be derived from and be consistent with the organizational plan • Policy shall be consistent with the organization's overall risk management framework • Clearly state the overall/broad asset management objectives and the performance requirements of its assets, assets types, or asset systems as appropriate • Asset management strategy incl. action plan, planning and responsibilities • Policy and strategy should be visibly endorsed by top management • Permissibility of risks has to be determined	• Maintenance and engineering have their own decisions models • Risk management not linked to Corporate models • No commitment top management, relevant employees and/or suppliers • Asset management action plan often interpreted as a maintenance plan. But PAS 55 deals with the whole lifecycle and all of the long-term expenses together (e.g. .feasibility studies, engineering and building plans, maintenance but also information campaigns about safety) after they are prioritised • No permissibility of risks determined ('risk appetite')
4.3	Asset management information, risk assessment and planning	• Information system to provide adequate information needs • Risk management processes • Have control measures for non-acceptable risks • Determine qualifications employees and take care for education and training[1] • The organization shall establish and maintain a procedure for identifying and accessing the legal, regulatory, statutory and other asset management requirements that are applicable to it. • Asset management goals ('smart'[2]) and plans derived from asset management strategy	• Information need and scope not completely determined; poor data quality • Risks aren't recorded and risk analyses not accessible for others • The development of risks aren't monitored • Control measures not connected to their risks • Prioritizing of expenses related to the different goals (safety, environment, availability) not carried out; also for the several processes (engineering, maintenance, operations) • Goals are not 'smart'
4.4	Implementation and operation	• Clear organization structure and responsibilities • Procedures and tools for information management (documents and data) • Identification and execution from those activities which are necessary to give an operation interpretation to reach the goals. • Emergency procedures	• Not clear who has which role in information management • Data not current • No emergency procedures
4.5	Checking and corrective action	• Performance management and monitoring • Procedure how to cope with asset management data • Carry out periodic audits on asset management processes	• Not clear who has which authority in case of deviations • No procedure defined how important asset management data could be identified and how to cope with that.
4.6	Management review	• Management review • Continual improvement	• No demonstrable periodic management review • No demonstrable continual improvement

[1] Not only specific for 4.3, but concerns all of the processes
[2] Specific, Measurable, Achievable, Relevant and Time-based (where practical)

5.4 The asset lifecycle

During the asset lifecycle several phases can be distinguished. Concept and design, build, operate and maintain, and demolition and replacement.

In practice the difference between the several phases is very important in the decision-making process. The definition of a lifecycle of an asset has as such no added value. The concept gets value if during each step of the lifecycle decisions are made to maximize the value of the assets.

Organizations tend to have functional design. A functional department has his own manager with his own goals. These goals could conflict each other. A low-cost design could have high maintenance cost, then the manager of the design department has reached his goals, but the manager in the maintenance area.

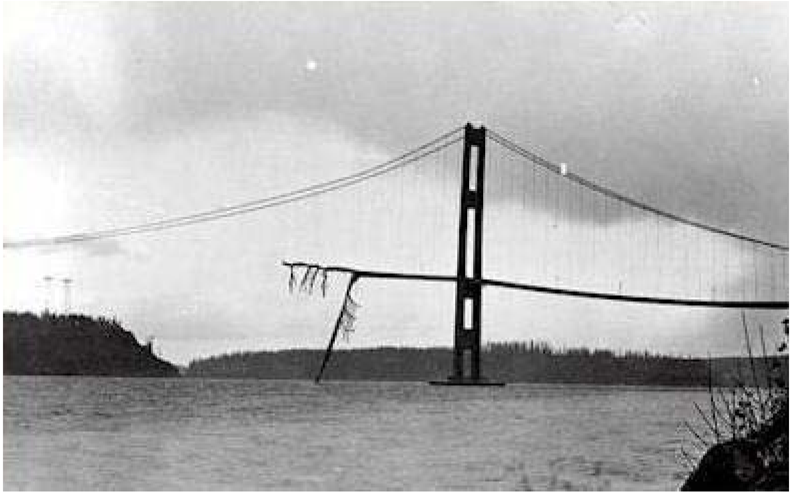


Figure 6: Tacoma Narrows Bridge

A good example to illustrate the significance of thinking in terms of asset lifecycle management is the Tacoma Narrows Bridge. The original Tacoma Narrows Bridge was built between November 1938 and July 1, 1940. Its completion was called a triumph of man's ingenuity and perseverance. Four months after it opened to the public it collapsed, in what was later called "the Pearl Harbour of engineering." [WAS]

The cause of the collapse was the design of the bridge. To save additional costs the design was altered, but the construction wasn't strong enough to hold the wind. So after all the lifecycle cost of the bridge were much higher.

5.5 Asset management strategy

Sklar (2004) has a two-dimensional view on the asset management strategy. He clarifies that the goal of asset management is to optimize both the long-term and the day-to-day performance and cost of a complex portfolio of physical assets. For an asset management strategy to be successful, it must balance between the level of service and level of risk and maintain this balance within defined budgetary constraints.

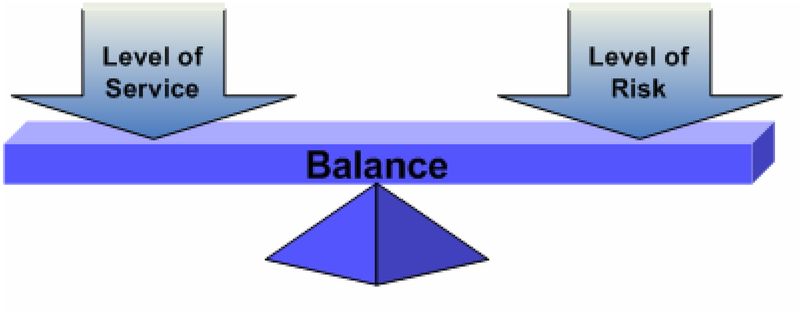


Figure 7: The balance of asset management [SKL]

Roestenberg, De Croon and others (2003) differ from the model of Sklar that they developed a three-dimension model. The dimensions in that model are durability, financial performance and operational performance. The dimension 'money' – financial performance – plays a crucial role in the creation of value. Often the financial performance is the one and only parameter for the asset management strategy. Another optimizing policy is between the financial and operational performance, but then some crucial elements are forgotten like the environment, goodwill, safety investments, training and education.

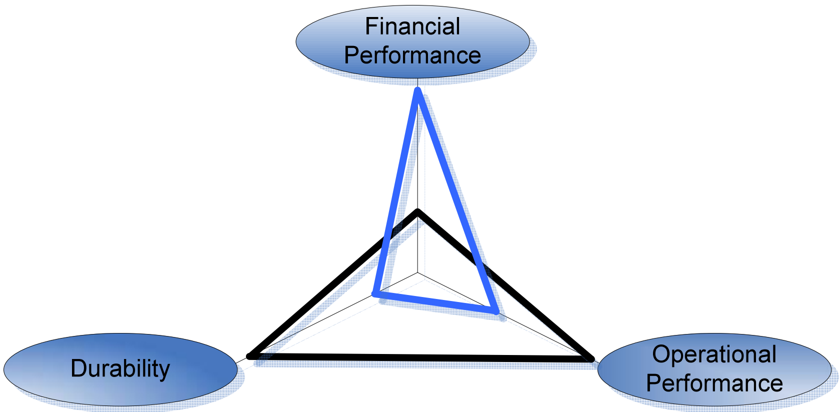


Figure 8: The balance of asset management

The asset manager has to choose a strategy (based on the wishes of the stakeholders) between two predefined extreme strategies. The blue line is called the 'Fix and Fail' strategy with the focus on the financial performance and a large chance of failing by the assets. The black line strategy is called the 'Engineering Excellence' strategy; a high focus on the operational performance with a small chance of the failing of the assets, but with high costs. Wenzler (2005) also recognizes a balancing and his balance is between operational performance, exposure of safety risks and financial performance.

According to De Croon for most distribution companies in The Netherlands the dominant strategy is 'Engineering Excellence', the operational performances is considered far more important than the 'Fix and Fail' strategy (financial focus) in the culture of the company itself.

Wenzler (2005) underlines in total four key challenges for asset management: (a) alignment of operations and with stakeholder values and objectives; (b) balancing of reliability, safety, and financial considerations; (c) benefiting from performance-based rates and (d) living with the output-based penalty regime.

A holistic approach integrates all required elements of an asset management strategy. This approach emphasizes the relationship between Vision, Business Strategy, and Asset Strategy as shown in figure 9.

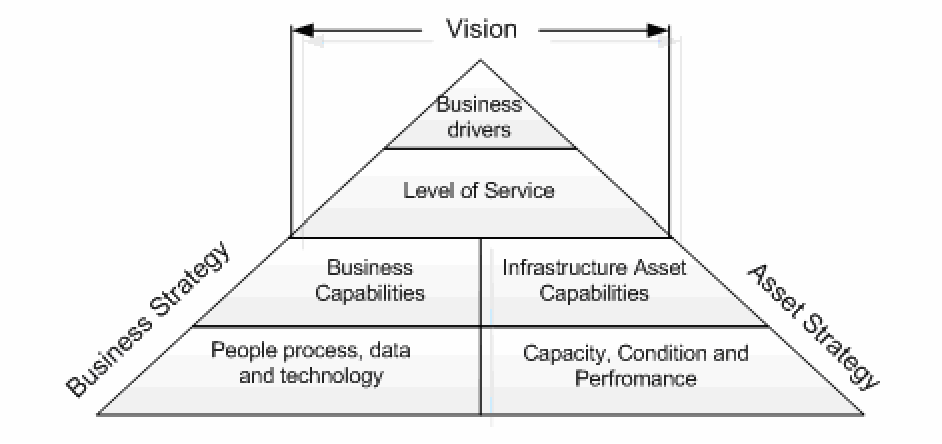


Figure 9: Holistic asset management model [SKL]

The vision component of the holistic model consists of two major components: business drivers and level of services.

Asset strategy involves the right side of the pyramid and addresses asset capabilities and capacity, condition and performance. An asset plan based on sound engineering principles is a core requirement of good asset management. An asset strategy and plan is focused around core planning, design, operation & maintenance and capital investment decisions. It is also critical to ensure that the asset strategy directly links to service level goals established as part of a utility's asset management vision [SKL].

Business Strategy involves the left side of the pyramid and addresses business capabilities that are achieved through people, process, data, and technology. A successful business strategy addresses business processes that effectively support asset management.

5.6 Conclusion

Physical assets are the assets that are in scope for the thesis. PAS-55 is the specification for any physical asset intensive business, such as is found in the energy industry. The definition of asset management is "finding an optimum way of managing assets to achieve a desired and sustainable outcome by means of an effective balance between costs, risks and operational performance over the lifecycle of the infrastructure". Processes of PAS-55 which are important are the asset management strategy, asset management planning and asset management operation.

For any asset management strategy there is always a trade-off between cost, service and/or risk. For the thesis risks and service are not in scope because data isn't available or statistically proved. Failure rates could differ per specific asset and per specific material. But according to interviews with the network companies generally is assumed that not investing will lower the service (a higher interruption frequency).

From the model of Sklar is important from the left side of the pyramid "business strategy" the two components people (work force) and technology (see chapter 8). From the right side of the pyramid "asset strategy" the components performance and condition is important. These two factors are translated into the age profile of the assets, which can be found in appendix 4, 5 and 6 for each network company.

6 Market Structure

6.1 Introduction

This chapter will give the reader a view about the electricity market in general. The reader who is familiar with the electricity sector could skip this introductive part. The chapter starts with the energy value chain and the scope from a liberalisation point of view.

6.2 The energy value chain

The energy value chain consists of Production, Trade, Transmission (or TSO; Transmission System Operator), Distribution (or DNO; Distribution Network Operator), Metering, Sales and ends when the Customer is reached.

Figure 10: The energy value chain [FEN, adapted]

The liberalisation of the electricity market in The Netherlands was completed by mid 2004, since then everyone has been free to obtain electricity from their supplier of choice.

The liberalisation has a severe effect on the energy value chain. In the figure below you can see how the vertical integration of the value chain is separated now. The main cause for this separation was to increase the competition within the energy sector.

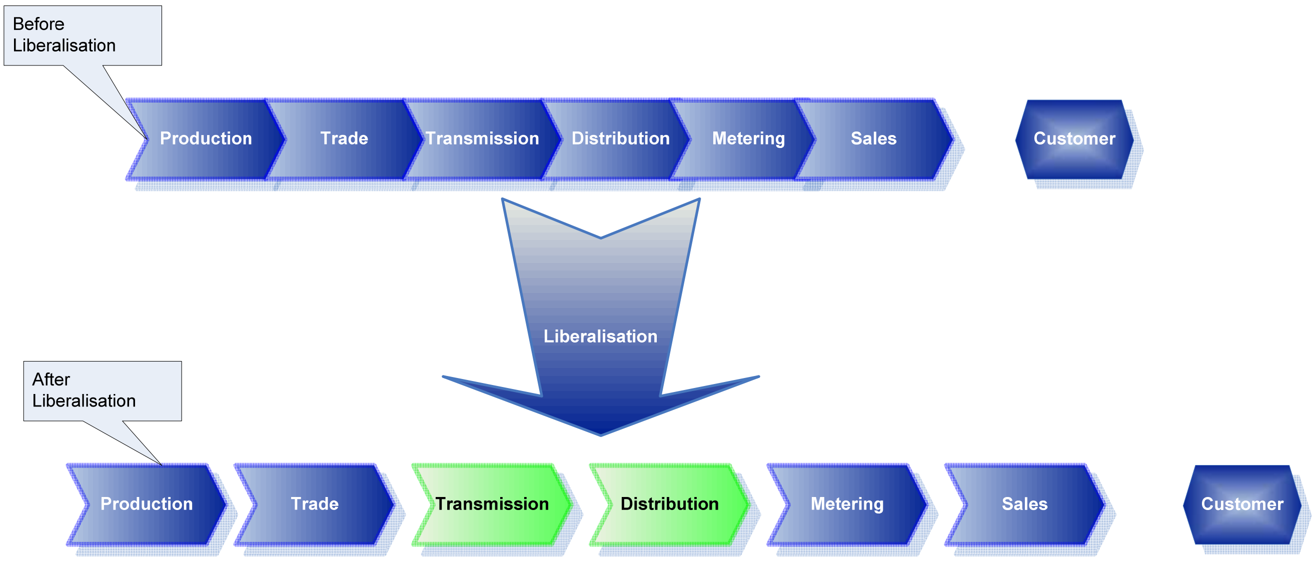


Figure 11: Liberalisation effect on energy value chain [FEN, adapted]

This chapter is focussing mainly on the green area at the bottom of figure 11; Transmission and Distribution. Transmission is only discussed in this chapter; the scope for the rest of the thesis is within the distribution area. First a description of the energy value chain will be outlined.

6.2.1 Production

The first phase of the energy value chain is the production of electricity. In the figure below the production capacity of The Netherlands for 2005 is given. The main production is done by steam turbines and COGAS-units. COGAS-units are combined gas and steam turbines. The durable energy sources are in minority, but will be of increasing value in the future.

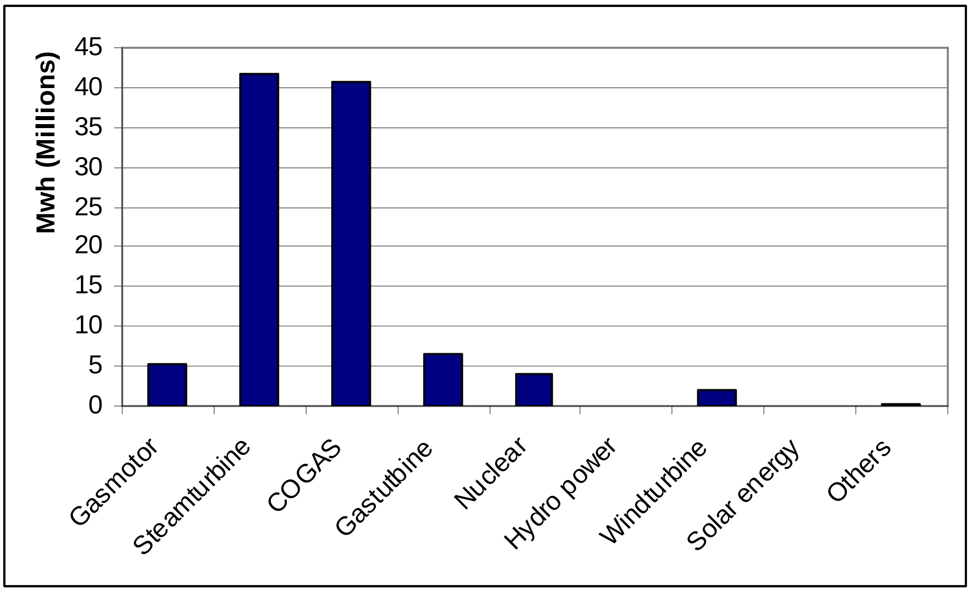


Figure 12: Production electricity per installation type for The Netherlands [CBS]

6.2.2 Trade

The Amsterdam Power Exchange (APX) is responsible for the trading of electricity. APX B.V. is an independent fully electronic exchange for anonymous trading on the spot market. The spot market has been operational since May 1999 offering distributors, producers, traders, brokers and industrial end-users a spot market trading platform in the form of day-ahead transactions: trading today for delivery of electricity tomorrow.

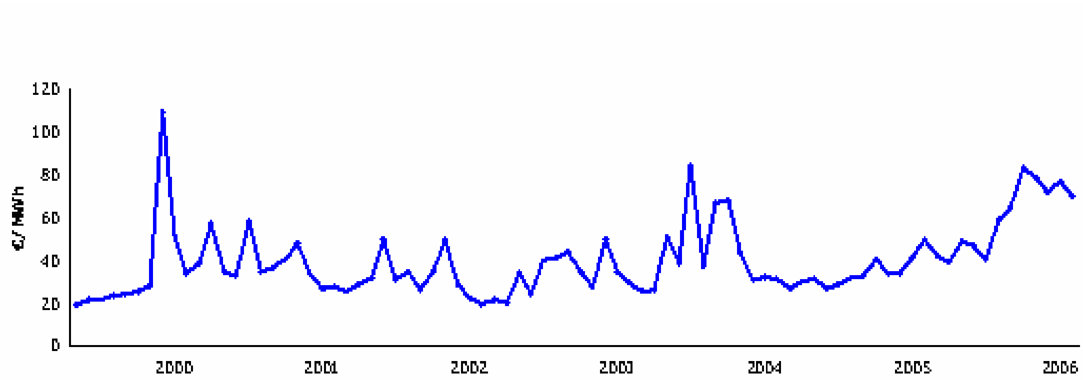


Figure 13: APX electricity prices [APX]

Every larger electricity consumer has to nominate the electricity demand or supply for the next day. If it turns out a different amount of electricity is used, this will cause unbalances on the national electricity network. TenneT (see paragraph 3.4) is the organisation that looks after the balance of supply and demand on the national grid. APX provides its members standardized products to sell and purchase and is the central counter party in all electricity trades. N.V. Nederlandse Gasunie owns 25.5% of the shares of APX; the other 74.5% are held by TenneT Holding B.V. [APX]

6.2.3 Transmission

Transmission refers to the bulk transfer of electrical power from place to place. Typically, power transmission is between a substation close to a power plant and a substation near a populated area. This is distinct from electricity distribution, which is concerned with the delivery from the substation to the consumers. Due to the large amount of power involved, transmission normally takes place at high voltage (110 kV or above). Electricity is usually transmitted over long distances through overhead power transmission lines (such as those in figure 14).

Figure 14: Transmission lines

Underground power transmission is used only in densely populated areas (such as large cities) because of the high capacitive and resistive losses incurred as well as the increased costs of installation. [WIK]

6.2.4 Distribution

The position of the distribution company in the energy value chain is between the transmission operator and the end user who receives the electricity. Distribution companies are asset intensive companies and because of the variety of distribution cables and the constantly increasing number of branches, the distribution networks are rather complex. The technology used, however, is severe and the distribution networks have not experienced any revolutionary change since the past 50 years [CAP].

6.2.5 Metering

Metering is a separate unit in the energy value chain but it may well be merged into distribution in the near future. The rationale behind this is from an asset management point of view. The meter is connected to the distribution lines and thereby forms a technical unit. In addition, the regulation has recently changed. Metering tariffs for retail customers may be regulated in the future. It may thus be that the meter market will not thrive and that metering will be brought into the regulation domain as is currently the case for distribution networks. [CAP]

6.2.6 Sales

Customers nowadays can choose between the several suppliers of energy. That's why sales are very dependent on what the customer wants. Price is being perceived very important for the customers. Utilities have invested heavily in making the administrative processes more efficient and effective. In the two months after the full market opening 4% changed from their electricity supplier and 1.2% of their gas supplier. The months thereafter more people changed from their original supplier.

6.3 TenneT and the high voltage network

TenneT is the Dutch Transmission System Operator and has 493 employees and its share is held by the State of The Netherlands.

In short TenneT has the following tasks to perform [TEN01]:

- TenneT is according to the Netherlands Electricity Act the administrator of the 220kV and 380kV transmission grids, to ensure that the electricity transactions are channelled in the right direction, and as such is also referred as the Transmission System Operator ('TSO'). In appendix 1 you can see the infrastructure of TenneT in The Netherlands.
- In total TenneT was responsible for 2003 kilometres of 380kV high-voltage lines and cables, 683 kilometres of 220kV high voltage line and cables and 551 kilometres of 150kV high-voltage lines and cables.
- TenneT is also responsible 18 substations for 380kV electricity transmission and 12 substations for 220kV electricity transmission, including 23 connections.
- TenneT is the administrator of the 150 kV transmission grid in the province of 'Zuid-Holland' (former TZH – Transportbedrijf Zuid-Holland).
- TenneT monitors the continuity of electricity supply throughout the Netherlands and safeguards the reliability of supply.
- TenneT entertains joint ventures with foreign TSOs and fellow organisations domestically so as to be able to acquit itself of its duties adequately.

According to the law, a connection is one or more links between an immovable property (like a building) and the electricity network, or two or more links between grids of different voltage.

In principle, anyone can apply to TenneT for a connection, and TenneT is obliged to accept every application. However, connection of an 'immovable property' to the extra-high-voltage grid (at 380 or 220kV) or the high-voltage grid is only of interest for very heavy consumers. Currently, there are only two consumers (Kollo silicon carbide B.V. and Aluminium Delfzijl B.V. in Groningen), four producers and five other grid companies with a connection to the extra-high-voltage grid. And there are two consumers, two producers and five other grid companies with a connection to the high-voltage grid. [TEN02]

6.4 Law of independent network management; the separation debate (November 2006)

The splitting law states that the distribution networks have to be owned by the government now and in the future. The high-voltage cables of 110kV and higher have to be managed by TenneT (only managed, not owned) and the electricity companies have to split their networks. But the last part of this law was adjusted by means of a motion before the 'Eerste Kamer' approved the law.

6.4.1 Essence splitting law

The essence of the splitting law was removed, because the motion states that the distribution networks <u>don't have to be separated from the rest of the company</u>, unless:

- The European Union will introduce a directive which will force the companies to split their networks from the rest of the company.

- Independent network management will be jeopardized, by for example risky foreign activities and/or cross-border activities.
- There will be a disruption of stable market relations and non-transparent, discriminatory financial relations
- It lacks equal access to the distribution networks

The first part of the motion will not happen soon, because a European directive will not happen in the near future according to minister Wijn. According to the minister the motion has to be seen as an appeal to the electricity companies to not jeopardize independence network management.

If the electricity companies were forced to split they probably were bought by other foreign electricity companies. Therefore the electricity companies Essent, Nuon, Eneco and Delta are glad they don't have to dispose their distribution networks. At the same time they see also possibilities to develop foreign activities. According to a spokesman of Eneco foreign activities with for example Belgium will not jeopardize their company. Nuon argues that the term 'risky' will depend on the interpretation of the law. When will a foreign activity be a risky one? And who will the judge of that question?

But the playing field will be limited for the electricity companies. International mergers will not be possible and acquisitions of foreign commercial companies will enhance the risks for the distribution networks in The Netherlands. So there is always a threat of possible splitting. There is one way to avoid endless discussion about foreign activities and to develop a long-term strategy and that is the option for the electricity companies to voluntary split.

6.4.2 Cross Border Leases (CBLs)

Cross border leases are transactions in which an investor based in the US buys or leases assets abroad and then immediately leases them back to the lessee. The US investor benefits from such a transaction through the realisation of US tax advantages which are in part transferred to the original owner of the asset. Between 1994 and 2002 CBLs were conducted for a large number of Dutch power plants and electricity networks. [TON]

The US investor leases an asset, an electricity distribution network, for a period exceeding the usual lifetime of the grid by at least 25%. Usually, this so-called 'head lease' is conducted for a duration of 30-99 years, depending on the kind of asset. The asset is immediately leased back to the original owner for a much shorter time period, in the case of electricity networks often for 25 years (sublease). Both leases cannot be terminated before their end-date. The original owner receives a purchase option for the head lease which can be executed at a predetermined price the moment the sublease ends. The original owner remains full control over the assets and also has the obligation of properly maintaining it. Due to differences in tax systems both parties are able to depreciate the value of the assets in their accounts.

As the US investor shares his tax benefits with the original owner, the payment for the head lease exceeds the sum necessary for the continuous payment of the sublease. The net effect of the owner is between the 3 and 6% of the value of the asset. [TON]

The American Jobs Creation Act of October 2004 effectively eliminates tax-advantages for new cross-border leases. It is thus in the interest of US investors that CBLs are not altered before the end of the sublease. A 'material alteration' in the contract would bear the risk of US tax authorities considering the amended CBL as a new transaction, incurring less favourable tax conditions. In such an event, US investors could terminate (or have to) terminate the

CBLs, which consequently would entail a repayment of the financial benefit from the energy company to the US investor.

- The separation of the electricity companies can have consequences for their credit ratings. The credit ratings of network companies will probably still be good enough to comply with the CBLs. For the holdings of the new separated commercial part of the company a lower crating rating could be the case, but this could be remedied by providing additional collateral.
- The potential effects of transferring control of the transmission lines with a voltage equalling or exceeding 110 kV to TenneT are unclear. These lines are usually not covered in separate CBLs but are subject to CBLs with lower voltage lines.

Early termination events for the CBLs are generally very limited in nature and the risk of unscheduled early termination is rather low. Moody's does note however that the US environment is becoming more hostile to these tax-driven structures and any attempt to restructure them could be used as justification for early termination. Early termination events mainly relate to non-compliance by network companies under the terms of the leases, and include issues such as payment default. [MOO]

There are a couple of clauses that give some cause for concern that they may be invoked in certain circumstances. These relate to potential legislation particularly with regard to the question of possible privatisation of the networks: the concerns relate to *burdensome buyout* relating to regulatory change which could make the transactions burdensome (for example, should legislation require the network company to cease to participate in the leases and hence trigger a buyout with attached penalties); or *regulatory event of loss* (for example, the concern that legislation may be implemented that would mean that the company could never be privatised and hence could potentially restrict the investor from exercising its rights to early termination under the lease).

6.5 Merger Essent and Nuon

On Thursday 01 February Essent and Nuon have announced their merger plans. In the merger proposition 55% of the new company will be in hands of the Essent shareholders and the shareholders of Nuon will have 45%. The two largest energy companies want to create a strong Dutch energy company which will be able to compete within Europe. EssentNuon will still be a relative small company compared to Eon (Germany) and EDF (France). The merger isn't for sure because it has to be approved by the shareholders of the two companies and by the NMa (Dutch authority concerning policy on competition). [ENE01]

The purpose of the merger is to create synergy advantages and to create more purchasing power. In a world with decreasing energy reserves the latter will be of increasing importance according to Mr. Boersma. [ENE01]

EssentNuon will set up an independent network company. At the moment the economical ownership lies in the hands of the mother companies. The new network company of EssentNuon will have their own name, own management, own commissioners, own financial resources and own personnel. It is the intention that no discussion arises about the connection of the network company and the commercial activities of EssentNuon.

Essent and Nuon have studied the law of independent network management and they concluded that there will be space for an economic collaboration with another European player in the energy market. [ENE03]

If EssentNuon enter into a European alliance, than separation is unnecessary according to Mr. Boersma (director Essent and future director of EssentNuon), because sufficient independent network management will be created. The announced merger is a first step in creating a good position in the Northwest-European energy market. [ENE03]

But the politic is critical about the merger and for eventually 'second steps'. In contrast with the intention of EssentNuon a lot of discussion has been occurred: [ENE02]

- A fear exists about the monopoly position of EssentNuon.
- As long as the network will be in the same hands as the commercial part there always are risks for the distribution network. An international merger is only possible if the financial position of the distribution network won't be influenced according to Mr. Ketting (energy specialist of a political party).
- According to Mr. Ketting the purchasing power of the new company will be weak because of the relative small size of the new company in Europe. Also he doubts if the merger has advantages for the consumers. The new created company will have no extra access to new energy sources and these are the largest costs for the company.

6.6 Conclusion

The energy value chains consist of production, trade, transmission, distribution, metering, sales and the customer. Liberalisation has divided all of these chains to introduce more competition in the electricity sector. Fur the scope of the thesis it is important to know that the high-voltage cables of 110kV from the distribution networks will be managed by TenneT according to the splitting law. But the network companies will be the owner of them, so when replacing these assets the network companies have to deal with that aspect scope. More about the different distribution companies can be found in chapter 9.

Cross border leases were conducted for a large number of Dutch power plants and electricity networks. According to Moody's the early termination events for the cross border leases are very limited and the risk of unscheduled early termination is rather low.

On Thursday 01 February Essent and Nuon have announced their merger plans. Purpose of the merger is to create synergy advantages and to create more purchasing power. The announced merger is a first step in creating a good position in the Northwest-European energy market. But the politic is critical about the merger and for eventually 'second steps'. It is difficult to draw any conclusion about the merger because at the moment there is a lot of discussion about the (political and legal) consequences of it.

7 Regulation Netherlands

As a result of the natural monopoly of network companies, the Dutch government implemented, since the year 2000, a price cap system to regulate tariffs charged by distribution network companies. The regulation mechanism used in this first period is based on benchmarking of the performances of network companies in order to provide companies with incentives to act in an efficient manner.

The goal is to set a target price reduction (the X factor) for companies that will force them to eliminate existing inefficiencies and pass the benefits on to consumers in the form of lower retail prices. If a company manages to reduce its costs by more than the X factor, it is allowed to keep the excess. This incentive structure, therefore, remains balanced and the gains from efficiency improvements are shared between customers and shareholders.

The regulation system of the regional network companies is nowadays based on yardstick competition; this means that performances of the network companies will be compared to imitate competition. The average performance of all network companies will be the basic assumption.

The regulation system consists of two components;

- Price component; Basic principle is that each network company could realise the same revenues per unit outcome. To improve the efficiency the DTe has enforced an efficiency reduction for each network company (the x-factor). Network companies who are reducing their costs per output more than the average are realising relative more profit.
- Quality component; the quality term (the q-factor) is introduced in this round to ensure that the focus isn't only on costs but also on reliability. If a network company invest more in quality the breakdown minutes will decline. If a specific network company performs better than the average than the company could ask higher tariffs.

The tariffs will be determined according to this formula:

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

Whereby:

TI	= the total income in year t or respectively year t-1
cpi	= relative change consumer price index
x	= the reduction to improve the efficiency
q	= the quality term

7.1 Determination of the x-factor

The idea of the first regulatory period was to create a level playing field to bring the network companies to the same efficiency level to allow benchmarking to these companies. Because the network companies differ in their efficiency (see table 1), implementing a generic x-factor would penalize firms that were already relatively efficient, while rewarding inefficient firms who find it much easier to become more efficient. ONS was the only network company who was efficient.

Table 2: Efficiency network companies (DEA)

Network Company	DEA Score
ONS	100%
Conet	96%
NRE	95%
Nuon	**94%**
Eneco	**93%**
Westland	91%
Essent	**85%**
Delta	83%
Rendo	81%

In September 2000 the DTe published the first X-factors (table 2); these factors were based on the DEA methodology. The final prices for the first regulation period were only agreed in May 2003. This was almost two-and-half years later than was planned.

According to the industrial tribunal (CBb) the Electricity Act did not allow DTe to set x-factors that could vary between individual companies. So the same x-factor must be applied to all of the network companies. Article 58:1:b the Electricity Act says that:

*"x = **the** discount factor to stimulate the efficient operation by retail licence holders,.."*

DTe was forced to implement generic x-factors for all the network companies and agreed in May 2003 to set the x-factor at 3,2 percent. That agreement also stated that the x-factors for the second period would be individual. So that the initial idea of the first regulatory period, a level playing field, will be reached at the end of 2006.

The application of the no 'reformation in peius' principle[3], which means that if a network company appeals against the DTe the x-factor never can be higher than the previous determined one, was very favourable for the network companies (especially for Essent Netwerk). They could therefore benefit from mistakes made by the DTe.

Table 3: X-factors for the first regulatory period

Network company	2000	2001	2002	2003
Eneco	8,1%	7,0%	4,4%	3,2%
Essent	0,6%	0,6%	4,7%	0,6%
Nuon	7,7%	7,2%	6,8%	3,2%
Sector average	*5,1%*	*4,4%*	*5,1%*	*2,0%*

Table 4: Revenue reduction (€ million)

Network company	2000	2001	2002	2003	Change 2000-2003
Eneco	205	146	74	83	-59%
Essent	26	26	147	26	0
Nuon	270	217	168	114	-58%
Sector average	*511*	*376*	*384*	*209*	*-59%*

Table 3 gives a summary of the process of the x-factor determination by the DTe. More interesting is table 4 which gives a summary about the revenue reductions from the first regulatory period. In 2000 the total savings were €511 million and after several objectives to these x-factors the total savings were only €209 million at the end of 2003. The main cause for

[3] Reformatio in peius (from Latin reformatio, 'change' - actually, 'improvement', and peius, 'worse') is a Latin phrase used in law meaning that a decision from a court of appeal is amended to a worse one.

this was the badly drafted legislation (a uniform x-factor and the 'reformation in peius' principle). These mistakes by the DTe have cost the consumers of electricity about €300 million. If the actual cost saving per customer would be calculated this was €70 in 2000, but the actual final was only €29, so a loss of €41 per customer.

As already said in stead of benchmarking the DTe has chosen for yardstick competition in the second regulation period. The x-factor will be determined based on the average efficiency improvements in the sector. The network companies can generate more profit when their efficiency improvement is greater than the average in the sector.

Table 5: X-factors of three regulation periods

Network company	2001-2003	2004-2006	2007-2009
Eneco	3,2%	2,7%	1,1%
Essent	0,6%	3,8%	1,1%
Nuon	3,2%	1,3%	1,1%
Sector average	2,0%	2,7%	1,1%

The average x-factor for the second period was 2,7% (table 3). During the second regulatory period the x-factor was determined by measuring the efficiency change between 2002 and 2005. To calculate the efficiency improvements of the several companies DTe looks at an index of the turnover (Combined Output, CO) and looks at an index of costs (Standardized Economical Costs; SEC).

The standardised economical cost (SEC) for a network company in a specific year is determined by adding up de operational expenses (OPEX) and the capital expenses (CAPEX).

$$SEC = OPEX + CAPEX$$

These SEC will be corrected by investments which are considered as a substantial investment or as a regional difference. The operational expenses of a network company are determined in consequence with regulatory accounting rules (RAR). The capital costs of a network company in a year are determined to multiply the standardised asset value (SAV) with the WACC and to add up the depreciations in that year:

$$CAPEX = SAV \times WACC + Depr.$$

The standardised asset value consists of two parts: one old (till the year 2000) and a new part (from 2001). The old part of the SAV was determined every year by deducting the old part of the SAV by the standardised depreciations:

$$SAVt(old) = SAVt\text{-}1 - Depr\ (old)$$

The new part of the SAV is determined by adding up the difference between the new investments and the new depreciations to the SAV:

$$SAVt = SAVt\text{-}1 + (Inv. - Depr.)$$

Table 6: Developments SEC and CO 2002-2005

Network company	SEC	CO	SEC/CO
Eneco	1,5%	2,4%	-0,9%
Essent	-0,5%	1,1%	-1,6%
Nuon	-3,3%	1,9%	-5,2%
Sector average	-1,2%	1,9%	-3,0%

Nuon has made the best progress in reducing cost between 2002 and 2005; therefore Nuon has been rewarded with a relative low x-factor. Eneco wasn't able to reduce their costs in stead they have higher costs during the period, but their output was much better than the average in the sector. Essent was in between, but much closer to Eneco than to Nuon.

The sector efficiency was estimated for the second round. After the period the real efficiency will be compared to the estimation. The difference will be corrected in the third round. The DTe hasn't published figures about the real x-factor, but calculations show that the adjusted x-factor will approximately be 0,85% lower than the estimated one. This roughly will deliver the network companies five percent of the yearly turnover.

The x-factor in the third regulation round is based on the *yearly* average efficiency change of all network companies. This change has an advantage that changes of costs in the intervening years will be used too.

7.2 The q-factor

The quality for the network companies will be measured by the System Average Interruption Duration Index (SAIDI). The SAIDI is calculated by multiplying the System Average Interruption Frequency Index (SAIFI) and the Customer Average Interruption Duration Index (CAIDI).

- The "System Average Interruption Frequency Index" ("SAIFI") measures the number of service interruptions experienced by all of the customers of a given utility and is measured by dividing the total number of service interruptions in a year by the number of the network customers.
- The "Customer Average Interruption Duration Index" ("CAIDI") measures how long it takes a utility to restore service after an interruption and is scored by adding up the durations of each service interruption in a year and dividing the total by the total number of customer service interruptions, thereby deriving the average outage duration for that year.

This system of only using SAIDI for measuring the quality could have disadvantages. For instance, if there were many service interruptions but the interruption durations were short, the SAIDI number would mask the large number of service interruptions. Also, if there were few service interruptions but the average duration was very long, the SAIDI number would cover up the length of time the utility was taking to restore service after interruptions.

The purpose of measurement standards is to identify areas in which a utility can improve its performance. The SAIFI and CAIDI standards address two entirely different components of electric service. A high number of service interruptions as measured by SAIFI may indicate that the utility is not adequately maintaining its delivery system. On the other hand, if the number of service interruptions was low but the average outage duration was long, then the utility should work to improve service restoration after outages.

The opinion of DTe is that the system for the regulation of quality is less complex and clearer if only SAIDI will be used. Another disadvantage is that the valuation of electricity interruptions will be more complex, because the valuation models of the SEO (Stichting voor Economisch Onderzoek) assume the separate indicators SAIFI and SAIDI.

SEO has defined four situations where they define the price according to the frequency and the duration; also in each situation SEO defines two separate groups; households and companies, because of their different experience, for further details see [BAA].

Table 7: q-factor network companies

Network company	SAIDI	q
Conet	1,6	0,6%
ONS	3,0	0,6%
NRE	6,6	0,4%
Westland	9,6	0,3%
Essent	16,3	0,1%
Delta	17,1	0,1%
Eneco	20,2	0,0%
Nuon	24,0	-0,1%
Rendo	24,2	-0,1%

A positive q-factor means a rise of the permitted turnover.

7.3 Other regulatory changes

The Weighted Average Cost of Capital (WACC) is the weighted average return per invested Euro. If the WACC will be lowered the x-factor will be higher, so that will mean that the tariffs also will be lowered.

Each period the DTe investigates what a reasonable cost of capital is for the network companies. This could lead to changes in the x-factor. On the basis of research the DTe has lowered the WACC from 6,6% to 5,8%. If the cost of capital is reduced by 1% the x-factor is raised by 1,5%.

Till the second round the x-factor was estimated for each regulation round. After the period the re-calculation took place. The outcomes thereof were divided in the next round. Advantage is that network companies and investors have more security about the revenues. Also this is a less complex method.

But a wrong estimation of the x-factor can have severe consequences for the network companies. Also the estimated x-factor has no connection with the actual costs made during the period. If costs are much higher than expected the shareholders will bear these costs.

The correction for the catch-up: the purpose of the catch-up is to take into account that it is relatively simply for companies who are at the moment inefficient to become relatively more efficient than the other network companies.

The correction for the catch up is a discussion point between the DTe and the network companies. The expectation exist that the network companies don't agree with this correction. If they appeal, the re-calculated figure could be doubled. The new calculation of 5% (10%)

will probably be divided over the years of the third round. This will deliver the network companies a turnover rise of 1.7% (3,4%)

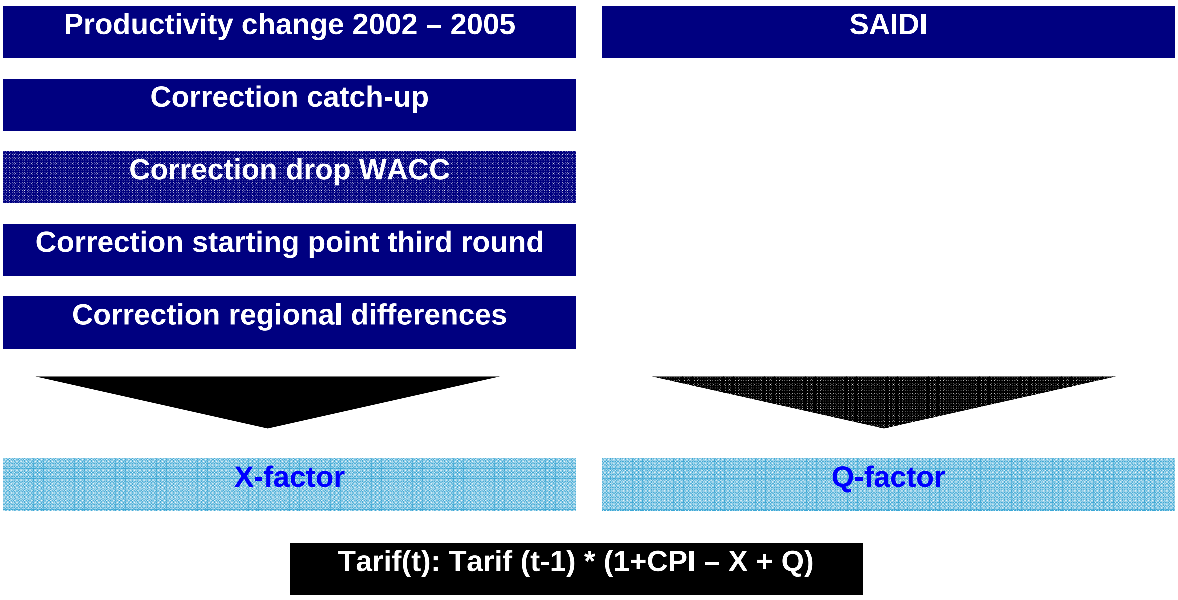
The correction of the starting point third round: because the x-factor in the second round was determined too high it will be corrected in the third round. This is because the tariffs of the second will be used as a starting point of the calculations of the third round.

Research shows that Delta has structural more costs than the other network companies, because of water-intersections. There are also indications of other regional differences, but these aren't yet statistically proven according to the DTe. The number of interconnections per consumer will be investigated during the third round and could lower of raise the tariffs during the third round.

7.4 Conclusion

The efficiency change, the correction of the catch-up, the correction of the WACC, the correction of the starting point of the third round and the correction of regional differences have all an influence of the x-factor of the third round.

In summary the tariffs of the third round will be based according to the scheme below.



It's very important to understand the regulatory scheme because the consequences can have a severe financial impact for the network companies. So if a network company had a tariff turnover of 100m and a x-factor of 1% and a q-factor of 0,5%, the new tariff will be (1 – 1% * 0,5%) * 100 = 99,5 million (0,5 million difference).

The consequences for the replacement of assets are that doing nothing (or late replacement/ fix and fail strategy) will have a preference above early replacement (engineering excellence). The main reasons therefore are that regulation periods are short-term fixed (three till five years) and that regulation as can be seen by the x-factor is subject to changes. If there are no regulatory changes it doesn't matter if one company will replace their assets earlier than another network company, because each company will have to make their replacement investments in one or another regulatory period. For the electricity companies a longer regulation period would enable them to develop longer-term replacement strategies.

8 Technology Development

This chapter will start with the drivers for the supporting technologies. What are the expectations from the customers of electricity and what main issues from the market? As an answer to these drivers, three issues will be explained, namely smart metering (based on smart consumers/users with for example specific contracts and secondly condition based monitoring; if a switch passes information to a network company the switch could be replaced before it brakes down), renewable energy sources and distributed generation.

8.1 Drivers for supporting technologies

The most important supporting activities in the electricity sector are the services for the customers and the technology development.

The several drivers for the supporting technologies are mentioned below.

- Customers will demand a product that will meet their needs at a price they can choose [CAP]
- Expectations utilities to be able to handle multidirectional electricity flows and the accompanying administration. [CAP]
- Environment is more important, reduction of greenhouse gas emissions and use of renewable energy resources. [DTE] [CAP] [SAM]
- A shift is observed from more centrally fed systems to locally fed systems. [SAM] [CAP]
- Energy market efficiency, transparency and equal access to all participants will remain a key objective. [DTE]

8.2 Smart Metering

A smart meter is a meter that determines and stores in real-time or near real-time energy consumption it provides the possibility to read consumption both locally and remotely and – with regard to electricity – can also be utilised remotely to limit the consumption by the consumer or to switch it off. [SID]

A basic assumption [SID] is that the *price* of smart meters will be determined by the European market. The scope of the Dutch market (in other words, the demand for smart meters) will be too limited to lead to a substantial drop of prices of smart meters. It is assumed that the *data communication infrastructure* has sufficient capacity and is available at marginal costs.[4]

Obstacles to the large-scale implementation of smart meters are [SID]:

- Regulated or non-regulated meter market; The fact that households do not purchase smart meters demonstrates that somewhere there is something wrong in the way the current free market operates. Households do not see the advantages if they buy a smart meter (No reduction for them)
- Also it could be that the smart meters aren't smart enough. At the moment there are pilots to try and test the smart meters.
- Current metering companies do not merge into one or more stronger companies, but rather remain close to their mother companies.

[4] Quantifying technologies are Power Line Communications (PLC, via the existing electricity grid), communication via wireless modem (GSM or GPRS) and Internet via ADSL modem (existing Internet connections).

- Development in the supporting data infrastructure; an additional obstacle is that the supporting data infrastructure is still largely on the move. While one player has opted for the PLC technique, other players prefer Internet and GSM or in combination with PLC. Also the maintenance cost could be extremely high and there is fear within the network companies that the technology does not last very long. [Essent Interview]
- Ownership issues; it is important to re-establish who will be the future owner of the meter. This will prevent a situation in which a meter will have to be changed when changing a supplier. In view of the new market model that will be created, property rights of the metering data will also need to be reviewed.

Data can be split into three groups [CAP]: meter, operational and commercial data.

The first group, meter data, consists of real-time interval data on consumption, distribution and transmission node meters. The second group, operational data, contains asset condition monitoring data (heat, vibration, temperature etc.) to optimise the asset lifecycle and to make more efficient use of the network.

And the third group, commercial data is used only for services that contribute to a better margin for utilities. The electricity grid will be a highway of data and therefore it will be able to meet the growing digital needs of today's economy.

An example of the ownership issues in the commercial data group, such as customer Internet traffic, that should be handled according to Internet Service Providers (ISP) rules. Ownership issue here is; who is the ISP. Is this the distribution company whose infrastructure is needed to carry the data or is this the sales company that has sold the Internet service to the customer?

The Ontario Energy Board [OEB] has a price plan for smart meters. Under that price plan, the price that consumers will pay for electricity will vary based on the period during the day when electricity is used.

Three periods are specified by the Ontario Energy Board:

- On-peak (when demand for electricity is highest);
- Mid-peak (when demand for electricity is moderate); and
- Off-peak (when demand for electricity is lowest).

These periods will be different in the summer than they are in the winter.

The difference between the on-peak and the off-peak is very high; seven cents/kWh. Some questions about the periods are: Won't the increased demand in the off-peak period turn it into a peak period. This has according to the OEB not happened in other areas. But the consequence could also be that when prices in the off-peak period will slightly rise than prices in the on-peak could drop.

Consumers will not be able to shift all of their electricity use away from peak demand periods, but the more they are able to do so, the more they can manage their costs and contribute to lower overall peak electricity prices for everyone. Or contract could be developed where the price is lower, but also the delivering risk will be much lower.

Because of smart metering the network companies doesn't have to replace their existing assets with assets with more capabilities. Main reason therefore is the shifting of electricity demand between the high and the low peaks.

8.3 Different forms of generation technologies

Environmental concerns are a great driver for new energy sources. More and more energy will be generated through new ways. But sustained economic growth and the increase of energy will contribute to the increase in green house gas emissions if we adhere to the current electricity generation methods based on fossil fuels (see figure 15).

The policy intention according to paper the Netherlands aims to cover 3% of the energy consumption from Renewable Energy Sources (RES) by 2010 and 9% by 2020. Also the attention has shifted in the past years to the prevention of environmentally harmful emissions, in particular CO_2. [SAM][WAL]

RES may take a large share of the total generation and the power fluctuations may be huge and rapid, especially regarding solar power. This implies either unnecessary large momentary reserve capacity or automated operation functions as human operators will not be able to manage such situations. One solution is probably a compromise. Depending on the penetration share of RES, the reserve capacity needs to increase with additionally types of storage, and automated functions will probably increase in time as distributed automation will be developed and integrated.

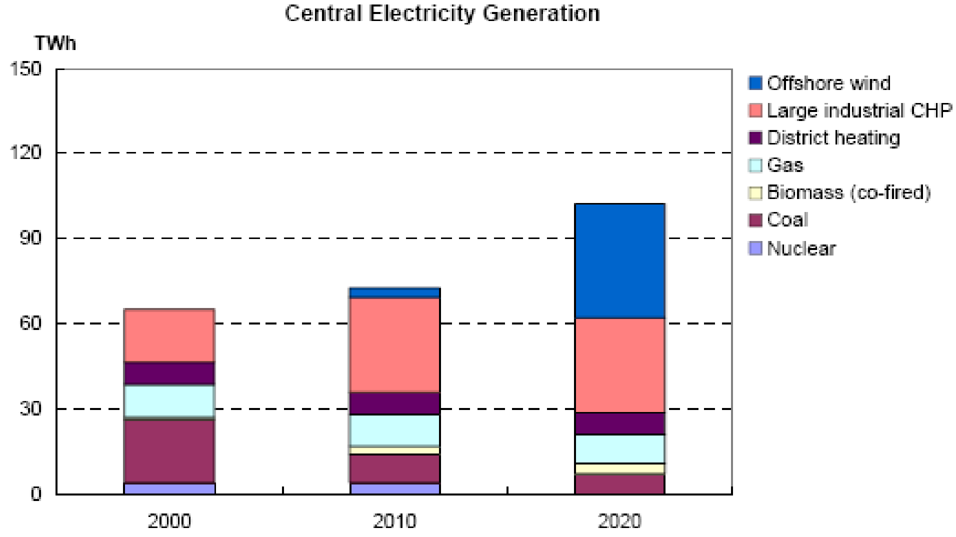


Figure 15: Central electricity generation The Netherlands [SAM]

In the Netherlands the most important forms of Renewable Energy Sources (RES) are and probably will be wind energy and CHP. In 2020 more than 30% will be coming from wind power. [SAM]

8.3.1 Combined Heat and Power (CHP) units

Combined heat and power (CHP) technologies produce both electricity and steam from a single fuel at a facility located near the consumer. These efficient systems recover heat that normally would be wasted in an electricity generator, and save the fuel that would otherwise be used to produce heat or steam in a separate unit. [USC]

CHP offers huge advantages in efficiency and much lower air pollution than conventional technologies. A wide variety of CHP technologies generate electricity and meet thermal energy needs (direct heat, hot water, steam, process heating and/or cooling) simultaneously, at the point of use. Due to their capture of useful energy both as electricity and thermal output (heating, cooling, steam, hot water, dehumidification, etc.), CHP systems should always be able to exceed the total fuel efficiency of even the best central power plants, dividing the energy content of the fuel inputs into the delivered energy content of the total useful output, and taking average transmission and distribution line losses into account. A state-of-the-art central plant (a combined cycle combustion turbine using natural gas) offers maximum system fuel efficiency for delivered power in the range of 55-60% [USC]. At this efficiency level, CHP systems will effectively double the central electric system's average delivered fuel-use efficiency of about 30%. However, under common circumstances, CHP systems will achieve efficiencies exceeding 70%. CHP systems achieving efficiencies exceeding 80% are frequent, and some systems have been shown to reach levels in excess of 90%.

CHP power plants can be divided into five types: backpressure, extraction condensing, gas turbine heat recovery, combined cycle and reciprocating engine power plants. [CHP] For a short description about the difference CHP methods see appendix 2.

8.3.2 Wind Energy Converters (WEC)

Wind power is the fast growing technology in Europe. Europe has approximately 74% of the world's installed wind capacity. Even if not proper from an economic point of view, wind power is the cheapest form. In the future nations could have more than 50% of total electricity production. According to the scenario of Sambeek wind power will be the most important source of energy in The Netherlands, followed by CHP.

Figure 16: wind site

The yearly production time depends on system technology, hub height and site. On-shore wind turbines may produce 2100 hours/year and, while off-shore wind turbines are expected to produce during 3500-5000 hours/year. [NIE01][NIE02]

At good wind sites it is already fully competitive with new traditional fossil fuel and nuclear generation. Its cost also continues to fall as the technology improves and the use of individual sites is maximized. Around the world, it is likely that 15-20% is an appropriate average figure for the potential penetration of wind power into national transmission systems.

The design of a wind turbine is based on standard components and well-known technology for all the important functions. Furthermore, the simplicity and robustness of the construction is vital considering reliability, maintenance and for operating and maintaining the plant. [SVE]

8.3.3 Solar/Photovoltaic (PV)

Solar power has a high potential, but has not reached a justified financial solution. It is commonly believed than when it will be marketable it will be a good way of generating electricity. One square meter area PV could produce a maximum of 100-200 watts depending of the incoming radiation. The location of this source of energy will be very distributed and the capacity varying from small to a couple of MW. This distributed generation may affect the power system critically if not integrated properly.

Energy storage can increase the value of photovoltaic and wind-generated electricity by making supply concurrent with periods of peak consumer demand. Energy storage may facilitate large-scale integration of intermittent renewable resources such as wind and solar into the electric network. Strategically placed storage systems can increase the utilisation of existing transmission and distribution, which can be used to reduce the pressure on individual transmission lines that are near maximum rating by reducing substation peak load. Energy storage can also serve customers as a controllable demand-side management option that provide services, such as; improved power quality, uninterruptible power supply for outages etc.

The consequences of RES for the network companies are hard to predict. In the near future probably nothing will change, but because other energy sources will diminish it has to be the future. RES will be more and more efficient, but a technology breakthrough will probably occur when RES will replace the main electricity sources.

8.4 Distributed generation (DG)

New technologies are already integrated in the power system, although so far to a minor extent. Many of the technologies mean to improve the system performance and the system reliability.

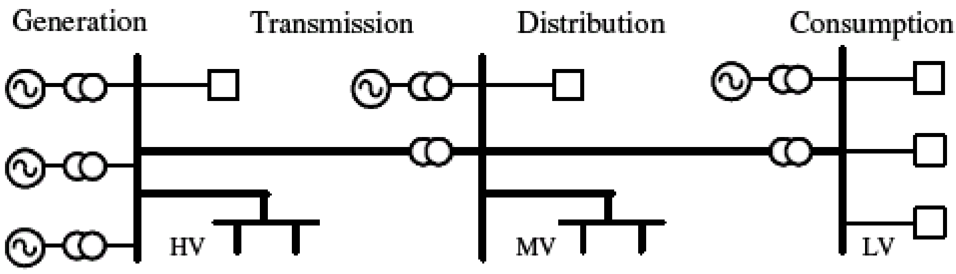


Figure 17: Overview current electricity grid[5]

The paradigm is going to change due to probably large-scale integration at the medium-voltage or low-voltage levels. Electricity is being produced more closely to the customer.

Distribution system operators (DSOs) have a key role in providing access to the distribution network and in providing network services to distributed generation. Scheepers and Van Werven (2005) attention goes out to analysing the potential role of DSOs in the changing electricity market. It is analysed how DSOs can alter their business focus to adapt to the changing electricity market with its increasing penetration of distributed generation and concurrently contribute to the competition strength of distributed generation. The rapid developments in distributed technologies open up new business opportunities in the liberalised market environment.

Scheepers and Van Werven (2005) define distributed generation as *an electric power generation source that is connected directly to the distribution network or on the customer side of the meter*. The general definition of DG in the Electricity Directive (2003/54/EC): *'distributed generation' means generation plants connected to the distribution system,* what corresponds with the definition of Scheepers and Van Werven (2005).

[5] HV= High-voltage, MV= medium-voltage and LV = low-voltage

Ten Donkelaar and Scheepers (2004) have defined the differences between Combined Heat Power (CHP), Renewable Energy Resources (RES) and DG. Large hydropower plants and offshore wind parks with a capacity of 100 MW and more that feed electricity into the transmission network cannot be considered as distributed generation.

Table 8: CHP, RES distributed versus large-scale generation [SAM]

	CHP	RES
Large-scale generation	▪ Large district heating* ▪ Large industrial CHP**	▪ Large hydro ▪ Off-shore wind ▪ Co-firing biomass in coal power plants ▪ Geothermal energy
Distributed generation	▪ Medium district heating ▪ Medium industrial CHP ▪ Commercial CHP ▪ Micro CHP	▪ Medium and small hydro ▪ On-shore wind ▪ Tidal energy ▪ Biomass and waste incineration/gasification ▪ Solar energy (PV)
*Typically >50 MW **Typically >10 MW		

For both the network-related benefits it is crucial to differentiate between short-term and long-term benefits. In the short term some of the mentioned benefits may actually be additional costs to the system. There may be a need for additional grid capacity because of DG entering the market. There may also be a need for additional balancing power because of the intermittent character of wind power or PV. Since the reliability of the system is already very high the possibility that DG will improve this situation is very low. But in the long run a more decentralised system has the potential to be superior to a centralised system in economic terms, and therefore the long-run benefits must already be considered today in some way.

Table 9: Benefits and costs for network companies [SAM]

DG can create benefits to the electricity system	DG can create costs to the electricity system
• *Distribution capacity cost deferral:* the development of small-scale DG facilities near a load can postpone necessary investments in additional distribution and transmission capacity absolutely or temporarily. DSOs can benefit from these new DG facilities as it can reduce their investment cost in upgrading or extending the distribution network. The costs of distributing electricity differ from location to location, and placing DG facilities in 'high-cost areas' may reduce costs for DSOs. • *Operational cost savings:* distributed generation can reduce cost for operation and maintenance of the distribution system. Values regarding engineering cost include: - reduction of losses, - voltage support, - reactive power support equipment life extension. • *Congestion belief* • *Reliability improvement:* through grid relief and therefore a lower probability of blackouts.	• *Connection costs:* the connection of the DG plant to the distribution network incurs expenses regarding connection lines and grip update, depending on the location of the DG facility. When choosing the location of a DG facility close to an existing grid may reduce connection costs. • *Metering cost:* metering of DG production presents a cost that is allocated outside the network, and can be attributed to the DG operator. The costs for a management and control system that collects automatically metering data and provide control signals to the DG plants should, however, be attributed to the DSO. • *Costs for network upgrade and extension:* induced by DG plants. • *Cost for additional planning efforts.* • Transaction costs (e.g. administration costs etc.)

8.5 Smart Grids

Two defined proposals of smart grids are micro-grids and virtual utilities. Micro-grids are generally defined as low voltage networks with DG sources, together with local storage devices and controllable loads (e.g. water heaters and air conditioning). They have a total installed capacity in the range of between a few hundred kilowatts and a couple of megawatts. The unique feature of micro-grids is that, although they operate mostly connected to the distribution network, they can be automatically transferred to islanded mode, in case of faults in the upstream network and can be resynchronised after restoration of the upstream network voltage.

Within the main grid, a micro-grid can be regarded as a controlled entity which can be operated as a single aggregated load or generator and, given attractive remuneration, as a small source of power or as ancillary services supporting the network.

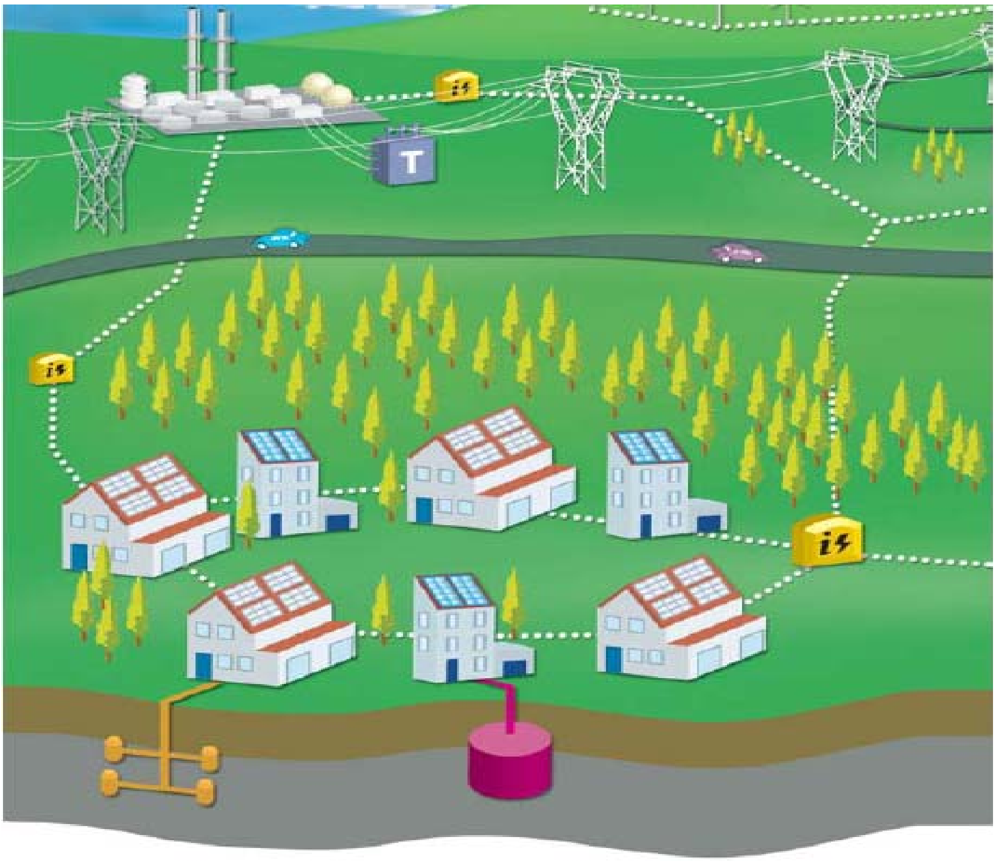


Figure 18: Micro-grid [EUC]

Virtual utilities (or virtual electricity market) adopt the structure of the internet-like model and its information and trading capability, rather than any hardware. Power is purchased and delivered to agreed points or nodes.

Its source, whether a conventional generator, RES or from energy storage is determined by the supplier. The system is enabled by modern information technology, advanced power electronic components and efficient storage.

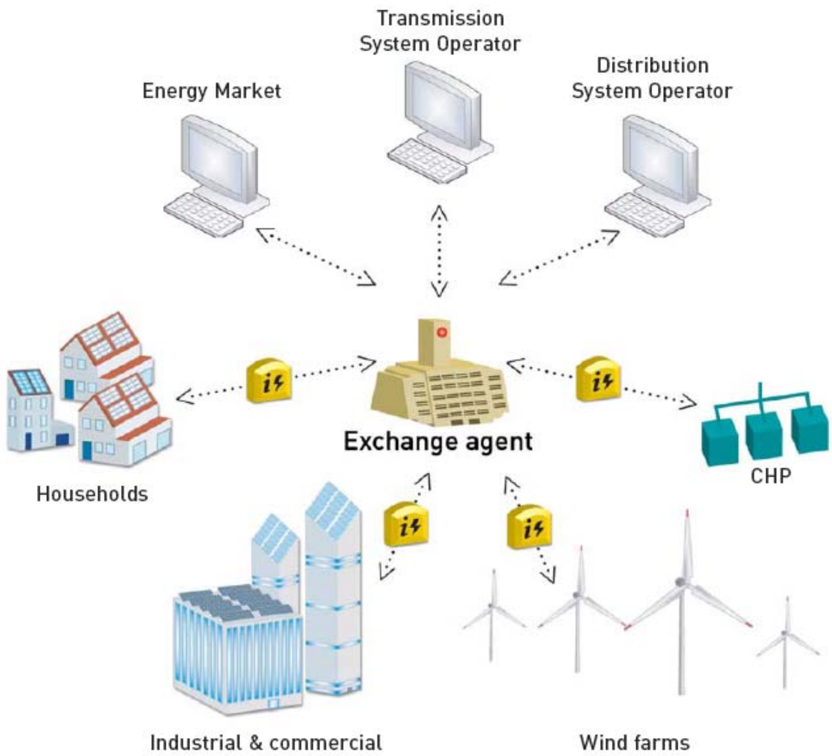


Figure 19: Virtual utilities [EUC]

There is much uncertainty in many aspects of future grids [EUC}:

- In the primary energy mix
- In the electricity flows created by the liberalised market
- Of the instantaneous power output of many RES
- In regulatory frameworks and investment remuneration in innovation

Important for the distribution networks is that they will become active and will have to accommodate bi-directional power flows. The European electricity systems have moved to operate under the framework of a market model in which generators are dispatched according to market forces and the grid control centre undertakes an overall supervisory role (active power balancing and ancillary services such as voltage stability). Distribution networks, on the other hand, have seen little change and tend to be radial with mostly unidirectional power flows and "passive" operation. Their primary role is energy delivery to end-users.

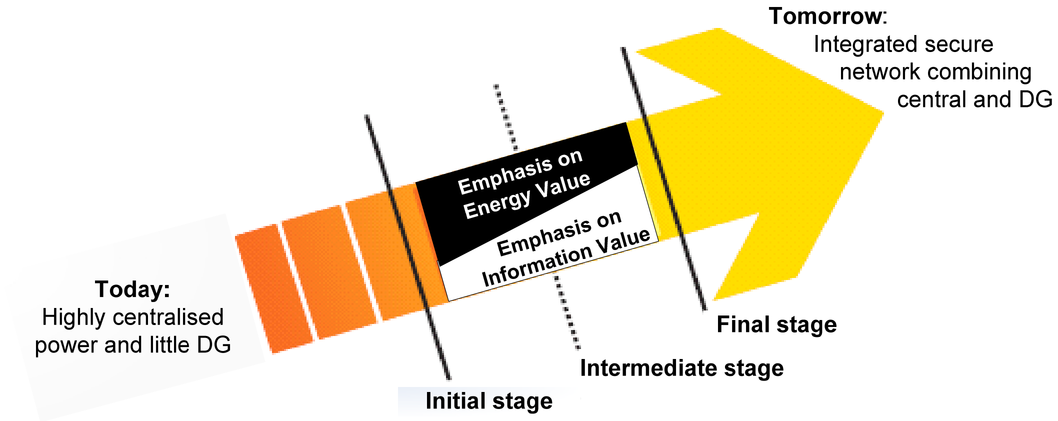


Figure 20: Evolution active management [EUC]

In these situations, success will most likely be achieved through combining efforts and resources within a co-operative research, development and demonstration programme. In the absence of a central planning regime, this can only be accomplished if all stakeholders form a shared vision for future grids and develop an implementation framework that is consistent with the liberalised business model.

To enable the concepts for change to be realised and the benefits to become a reality, the change of the electricity supply structure towards progressively more DG, RES and active grids requires that a number of wider and disparate factors be addressed.

These include [EUC]:

- Improvements of security standards in the context of critical infrastructures;
- Integration of both central and distributed generation;
- Integration of innovative technologies into existing grids;
- Harmonisation of equipment standards to allow "plug-and-play";
- Increased funding for large research incentives, including public and private sharing;
- The impact of neighbouring electricity systems on the European network;
- Higher education and skills issues.

With regards to education and skills, it is already evident that an insufficient number of well-trained engineers are being produced in the power engineering field. In order to develop, operate and maintain future networks, cross-functional, interdisciplinary educational strategies must be adopted. Recruitment strategies must be enhanced to meet the skill sets needed. Multidisciplinary curricula should include not only power engineering and information technologies, but also economics & market, regulatory & legal and environmental aspects. A skills shortfall is a key risk to the successful adoption of the Smart Grids vision for Europe.

8.6 Conclusion

This chapter tries to grasp the future electricity network according to technology developments. Because of green house gas emissions and the diminishing of the existing electricity sources renewable energy sources will be the future.

According to figure 20 it will be a combination of central and distributed generation. DG facilities can reduce investment cost in upgrading or extending the distribution network. The same can be said about smart metering, because energy demand will be shifted from the high demand peak periods to the lower ones. Smart metering probably will be one of the first innovations in the distribution network.

Both the micro grid as the virtual utilities use distributed generation like CHP. CHP will also lower the use of the distribution network, because electricity is produced at the place where it is consumed. Because new technologies will lower the use of the distribution network a technology factor will be introduced in the replacement model in chapter 10. This technology factor will reduce investments in the existing network. Another assumption for the replacement model is that because of the new technologies the network will be replaced by exactly the same network (no addition distribution capacity will be installed).

It is difficult to predict when the new developments or the new technologies have an influence for the network companies, but as one can see in figure 15 in 2020 there probably will be accomplished a substantial change in the energy mix for the Netherlands. Therefore that year will be the starting year for the technology factor in the replacement model in chapter 10.

9 Asset Base of the Netherlands

This chapter focuses on the asset base of the network companies of the Netherlands. First an overview of the network companies will be given. Hereafter the origin of the data will be introduced shortly. Thereafter several asset groups will be determined and charts will be drawn based upon data which goes back to approximately the construction time of the network; the beginning years of 1900. The most assets were installed around 1970 as can be seen in appendixes 4, 5 and 6 per network company. Each of the charts will give the age profile of that specific asset. From the perspective of the asset base per network company a chart could be drawn for The Netherlands as a country.

9.1 Overview of the network companies

The Netherlands has several different network companies. The network companies are listed next to figure 21. There are four companies who are dominating the market. These are Essent Netwerk, Continuon, Eneco Netbeheer and Delta Netwerkbedrijf.

1. RENDO Netbeheer
2. CONET
3. Continuon
6. ENECO (E-Netbeheer)
7. Westland
8. ONS Netbeheer
9. DELTA Netwerkbedrijf
12. NRE Netwerk
13. Essent Netwerk
14. InfraMosane[6]

Figure 21: Overview network companies the Netherlands

To have a view about the characteristics of the network companies they will be compared to each other by means of several factors to show the market position they possess and more important it gives an indication for the reliability of further analysis. These factors are: the length of the network in kilometres, the number of connections of a network company and the combined output. The length of the network is a good indicator for the size of the company. It also indicates how much maintenance, repair and replacement will be necessary in the future. The combined output is an approach of the realised sales in number of

[6] Some numbers are omitted due to mergers and acquisitions of network companies

connections, consumption and capacity, expressed in euros. Because we only have the detailed asset data of Essent Netwerk, Continuon and Eneco Netbeheer, the figures for the rest of the distribution network companies are grouped in the category 'others'. [NUO][ESS][ENE]

Table 10: Percentages the three network companies of total in the Netherlands [BRA]

Company	# interconnections	Combined output (x €1000)	km network
Eneco	1,800,000	450,000	49,000
Essent	2,500,000	640,000	116,000
Continuon	2,800,000	670,000	93,000
Others	460,000	128,000	17,000
% of total	94%	93%	94%

As shown in the above figures the three main network companies dominate the market in the Netherlands. If the total length of the network is measured the market share of them are combined they have 94 percent of the market. In case of the total interconnections they have a market percentage of 94 percent and if the combined output of Essent, Eneco and Nuon are summed up than 93 percent are in the hands of them.

The analysis is based on the data of Essent Netwerk, Eneco Netbeheer and Continuon only, but according to the figures above the conclusions of the thesis can be applied to the whole market, because approximately 93 percent of the market is in control of these three companies.

9.2 Origin of the asset base data

In 2001 a revaluation project has been carried out for Essent, Eneco and Nuon. This research has been carried out by:

- KEMA
- Gastec
- Troostwijk (acknowledge assessor)

PwC has played the role with regard to the model creation (e.g. the model has to fulfil fiscal rules) and to secure the quality of the data.[7] PwC has validated the data of KEMA and Gastec with regard to the data of the electricity companies themselves. This data is a very important starting point for this research.

9.3 Asset Groups

Because the data consist of many assets these assets had to be grouped together to develop a workable replacement model. Information on the value and the number of assets for about 100 years was put together. From the perspective of the data of Company A there were 727 different product numbers. These product numbers were already divided into different product categories. For example a high-voltage cable could be a product category and within that product category there were various product numbers, because there were high-voltage cables with different diameters. For Company A there were 81 product categories. Within these product categories there were assets which could be grouped together.

[7] The network companies couldn't make many depreciations, because the asset base of the network companies was relatively old and many assets had a book value of '0'. Because of this revaluation project the assets gained a new book value, so they could be depreciated. Therefore the network companies have to pay less tax (more depreciation means less profit).

For example within the 81 product categories there was a category high-voltage cables primary and high-voltage cables secondary these were put together because the assets perform the same function. After this step there were again less product categories to classify. Also the two other network companies had a classification of product categories, so similarities between the product categories had been reduced by that.

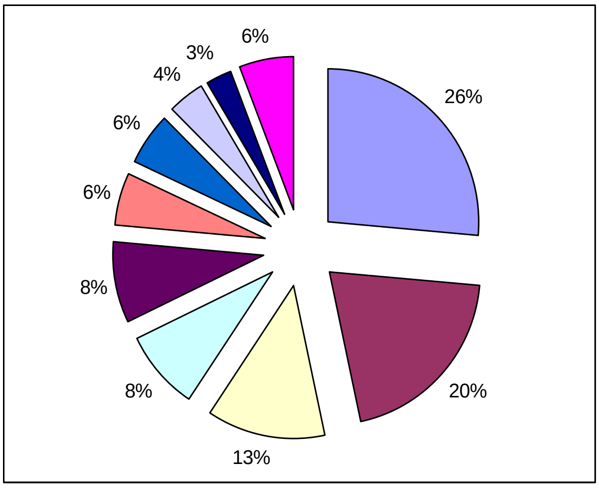
Hereafter there were approximately 20 product categories left. The final asset groups were determined based on their net replacement value (NRV). Assets installed in 1997 were considered to have a higher net replacement value than the ones installed in 1900. The analysis resulted in the following list of assets groups:

- Medium-voltage cables; cables with medium-voltage tension (transport function)
- Low-voltage cables: cables with low-voltage tension (transport function)
- Power connections: the connections with the electricity grid
- Station fields & components (for protection and control)
- Medium-voltage installations (switch gear)
- High-voltage cables: cables with high-voltage tension
- Medium-voltage buildings
- Power transformers: a device to change to voltage of electricity
- Electricity meters: a device to check the consumption of electricity
- Other assets: assets which are left over by other groups (e.g. foundations and towers)

9.4 Asset base Company A

Company A has an asset base which has a value of 11,3 billion Euros. The percentages in the following pie charts are based on the NRV[8].

	Asset group	NRV (€)	# or km[9]	%
	Medium-voltage cables	3.0 billion	95.000	26
	Low-voltage cables	2.3 billion	56.600	20
	Power connections	1.4 billion	2.500.000	13
	Station fields & components	954 million	29.000	8
	Medium-voltage installations	952 million	89.500	8
	High-voltage cables	625 million	3.500	6
	Medium-voltage buildings	630 million	45.800	6
	Power transformers	452 million	47.700	4
	Electricity meters	294 million	2.300.000	3
	Other	661 million	-	6

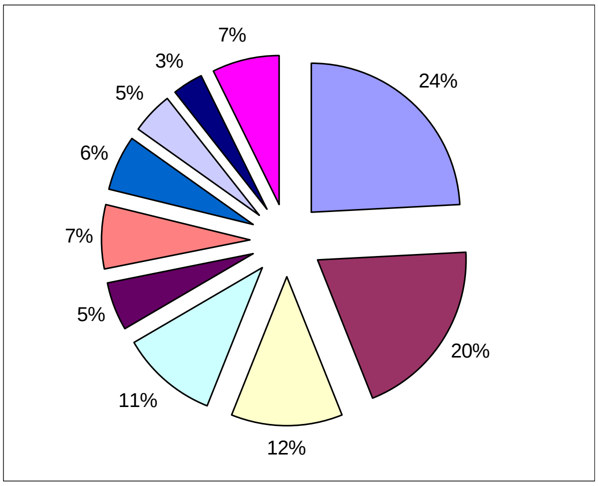


[8] NRV= Net Replacement Value in Euros
[9] Only cables are in km

9.5 Asset base Company B

The asset base of Company B has a net replacement value of 9,1 billion Euros.

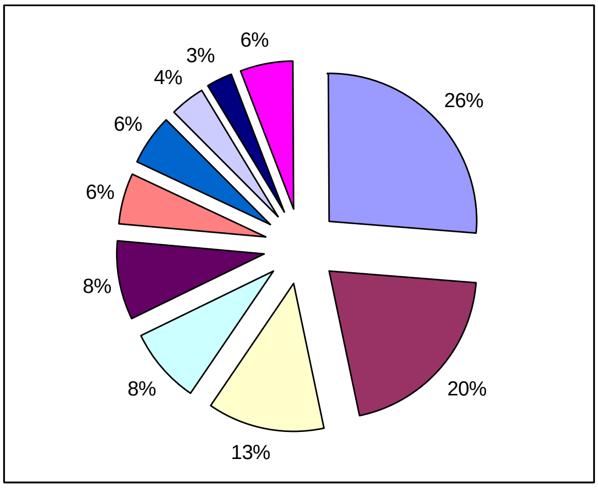
	Asset group	NRV (€)	# or km	%
	Medium-voltage cables	2.2 billion	75.000	24
	Low-voltage cables	1.8 billion	46.000	20
	Power connections	1.1 billion	2.600.000	12
	Station fields & components	969 million	14.000	11
	Medium-voltage installations	488 million	69.000	5
	High-voltage cables	617 million	1.900	7
	Medium-voltage buildings	528 million	36.600	6
	Power transformers	446 million	40.600	5
	Electricity meters	292 million	2.600.000	3
	Other	662 million	-	7



9.6 Asset base Company C

The asset base of Company C has a net replacement value of 3,7 billion Euros.

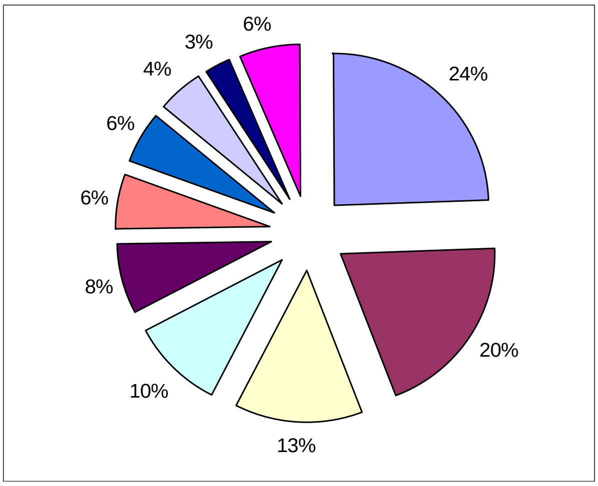
	Asset group	NRV (€)	# or km	%
	Medium-voltage cables	684 million	36.000	26
	Low-voltage cables	680 million	16.000	20
	Power connections	663 million	1.300.000	13
	Station fields & components	391 million	9.000	8
	Medium-voltage installations	370 million	21.000	8
	High-voltage cables	201 million	1.900	6
	Medium-voltage buildings	172 million	12.000	6
	Power transformers	179 million	15.400	4
	Electricity meters	139 million	1.300.000	3
	Other	186 million	-	6



9.7 Asset base of the Netherlands

The asset base of the Netherlands has a net replacement value of 24,0 billion Euros. The following chart is not the asset base for the Netherlands for 100%. It is the asset base of the three large network companies of the Netherlands. The net replacement values and the numbers (or kilometres) from the three network companies are added up. It could be argued that other network companies than the former three have slightly different asset bases. A network company which has a smaller geographically area will have less low- and medium-voltage cables (as can be seen in the chart of Company C). But the chart of the Netherlands will give approximately the right figure for the Netherlands based on their percentage of the market as can be read in paragraph 9.1.

	Asset group	NRV (€)	# or km	%
	Medium-voltage cables	5,9 billion	206.000	24
	Low-voltage cables	4,7 billion	119.000	20
	Power connections	3,2 billion	6.300.000	13
	Station fields & components	2,3 billion	52.000	10
	Medium-voltage installations	1,8 billion	179.000	8
	High-voltage cables	1,4 billion	7.200	6
	Medium-voltage buildings	1,3 billion	95.000	6
	Power transformers	1,1 billion	104.000	4
	Electricity meters	725 million	6.200.000	3
	Other	1,5 billion	-	6



9.8 Conclusion

The asset base of the network companies is quite similar qua asset base distribution to each other. More than 50% percent of the NRV is caused by three largest asset groups; namely medium-voltage cables, low-voltage cables and power connections. This figure is based purely on the net replacement values. This does not mean that these assets are the most critical ones for the network company.

In the next chapter the replacement model will be introduced and the asset base will be used as main input for that model. To determine the reliability of the model for The Netherlands one can argue that the model includes at least 93% of the population. Because the network companies have about the same asset base distribution (as can be seen in the pie charts) conclusions can be drawn for the Netherlands as a whole. Reliability of the model itself can be read in paragraph 10.1.3.

10 Replacement model for the Netherlands

This chapter focuses on the replacement model for the Netherlands. The analysis of the asset base in the previous chapter will be used as main input. At the moment we know which assets the three major network companies own. What we like to know is when a replacement wave will take place and what the consequences for the companies will be. Interesting questions are: 'are enough employees available to do the job?' and 'what are approximately the financial consequences for the network companies?' In the different scenarios the perception from the previous chapters will be used: regulation, technology etc.

10.1 Structure of the model

The structure of the model can be clarified in generally three parts. The first part focuses on how the model is developed. The second part describes the cost assumptions and the FTE assumptions. And the third part of this paragraph handles the outcome and the reliability of the model.

10.1.1 Developing the model

Because the history of the installed assets is known we could project the earlier installation wave on the future. This thought was the basis for the first version of the replacement model.

- The first replacement model makes use of an average life expectancy for all the assets. This means that a life expectancy must be chosen for all the assets for all the three network companies. This model can reproduce the original asset base to the future for each asset. If for example a life expectancy of fifty years is chosen all (100%) of the assets installed in 1970 are to be replaced in 2020. This will give a graph like figure 2.
- In the second version of the model three separate life expectancies and three replacement percentages can be chosen. If someone thinks that 80% of the installed asset base will last no more than forty years then for example a combination can be made of 40% with life expectancy 30 and 40% with life expectancy 40 (and 20% life expectancy 50).
- In the third version of the replacement model a differentiation can be made for the earlier defined asset groups. New to the previous model is that assumptions can be made for an asset group. This means that if someone argues that the high-voltage cables will last much longer that the other assets the life expectancy of the asset group 'high-voltage cables' can be enlarged to a combination of seventy, eighty and ninety years with 33% for each life expectancy.
- In the last version of the model every separate network company can use their own strategy. This means that expectations for one company can differ from another. In this model one of the network companies can replace earlier or later than the other network companies. Also a technology factor is included in the model. With this factor the influence of new technology can be introduced. For the model it means that the starting year the technology factor can be changed and that a replacement reduction (in percentages) can be changed. As already said in chapter 8 new technologies will probably reduce the amount of replacements in the existing network.

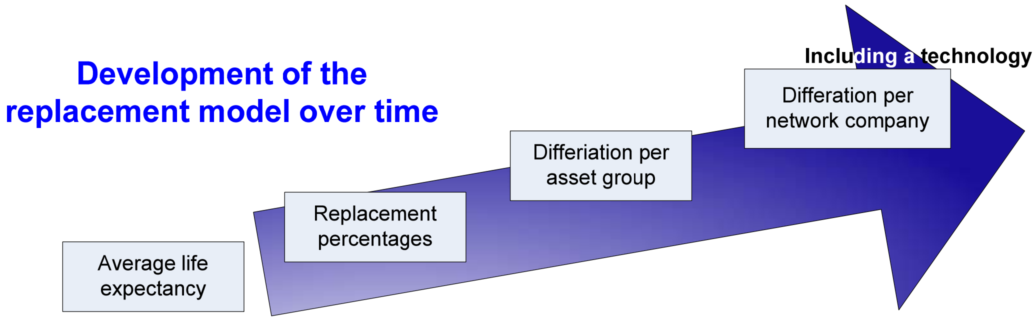


Figure 22: development replacement model

10.1.1.1 Cost assumptions

When the total number (or km's) of the assets and the net replacement values are known then the numbers can be multiplied with each other to get the total investment costs. According to the interviews the costs can be divided into three cost categories: own personnel, materials and third parties (contractors).

During interviews the three network companies state that the division of costs are (approximately) respectively 1/3, 1/3 and 1/3. This number is being verified by a benchmark of 30 asset intensive companies (see appendix 8). One of the interviewers did mention the fact that it was an average; a cost distribution for an electricity meter could be different than it is for a high-voltage cable.

10.1.1.2 FTE assumptions

During the first interview round with the network companies the outcome was that according to the interviewees not the ageing (physical) assets was their main problem, but their ageing human resources. Therefore to give the model an extra dimension data on the work force is put into the model.

During interviews with three HRM specialists of the network companies it was said that the average cost of a FTE in 2006 was about fifty-five euros per hour (overhead included). And a FTE worked about forty weeks of forty hours per week. The average capacity utilization (CU) was about seventy-five percent. This percentage is being verified by a benchmark of 30 companies in the energy sector. Summarising this will mean that a FTE will be working seventy-five percent of his time on replacements and that will be 1200 hours per year.[10]

The starting point to calculate the number of FTEs needed is the total personnel cost (TC_{FTE}) which could be calculated by the 33% percentage. The model divides the total personnel cost by the cost of an FTE per hour (FTE_H). This will deliver the total number of hours needed (TH_{FTE}) to do the job.

1. $TH_{FTE} = TC_{FTE} / (FTE_H)$

[10] So the total workable hours for an FTE per year (Wh) are 1200.

To calculate the number of FTEs needed (FTE_{NEED}) the number of hours an FTE will actually be working per year is necessary (HoT_{FTE}). The number of FTEs needed to do the replacements can now be calculated.

2. $HoT_{FTE} = CU * Wh$
3. $FTE_{NEED} = TH_{FTE} / HoT_{FTE}$

If the inflow and the outflow are known the surplus or shortage can be calculated. FTE_{AVAIB} is the number of FTE which is available to do the replacements.

4. $FTE_{SURPLUS/SHORT} = FTE_{AVAIB} - FTE_{NEED}$

The outflow could be determined during the interviews. This is a painful subject to the interviewees, because the average age of the work force is approximately 55 years old and the half of the total work force will leave the company within the next eight till ten years.

Data about the inflow of people is a lot harder to get or to develop because of several factors. First one is that the managers responsible for attracting new employees for the network company could not provide. Why they don't know it? This is because the number of people who passes their exam isn't exactly known. And secondly the people who are passing do not choose immediately for a job in the engineering area. The data of the interviews will be used as a main input for the model. Accurate data from isn't available from the national agency of statistics (CBS).

Of importance is also the impact of the FTEs for replacements in relationship with the total amount of FTEs. This is because not all of the available FTEs will perform replacement activities.

Table 11: Relationship FTEs replacement with FTEs total

Work activity	FTEs
Total	(a)
Maintenance	(b) = x% * (a)
New construction	(c) = y% of (a)
Expansion	(d) = z% of (a)
Replacement	(e) = a – b – c – d

Maintenance will be about 3,1 % of the total replacement value according to appendix 8. New construction will be about 4,1% and expansion will be 1,0% of replacement value. FTEs left for replacement will therefore be (100% - x – y – z) * (a). According to the interviews with the network companies new construction will be done almost completely by contractors (except some supervision), so FTEs available for replacement will be 100% – 3,1% – 1,0% * (a) = 95,9%. In every scenario there will be included 1,5% overtime work [Appendix 9]. This will increase (e) by 1,5%. The replacement model also assumes an efficiency increase of 1,1%. That figure is based on the total productivity increase of the Netherlands. [CBS]

10.1.2 Output of the model

If the user has chosen the variables the model can calculate the costs for each asset group. For each asset group a net replacement value has been defined according the model of Troostwijk. Following the example of the power connections in appendix 7, for each year the number of the power connections is multiplied by this net replacement value.

Now the total investments for power connections are known. According to the cost percentages between materials, personnel and contractors the most important cost for the thesis is known, namely the personnel. Hereafter formulas 1 till 4 can be used to make the calculations.

10.2 Scenarios of the model

In this section we are concentrating on the effects of a specific scenario. The most important outcomes per scenario are the total investment costs and the total FTEs used. The first scenario is the early replacement scenario, the second the late replacement and the third scenario is a combination of scenario one and scenario two and at the end a most likely scenario will we shown.

10.2.1 Scenario 1: Early replacement

This scenario will make use of a relatively early replacement of assets. An advantage is that at the moment more FTEs will be available to do the work than in the near future. It is also cheaper to replace assets before they are broken. For this scenario the technology factor is off, so no replacement reduction.

A relatively big disadvantage is that the costs will be high and the shareholders or the regulator will not approve these investments. Shareholders argue that there is not enough profit for them and the regulator could argue that the investment will have a severe impact on the price of the electricity. The assets will be replaced with life expectancies of 30, 40 and 50. For this scenario the accompanying replacement percentages are given in appendix 7 table 17.

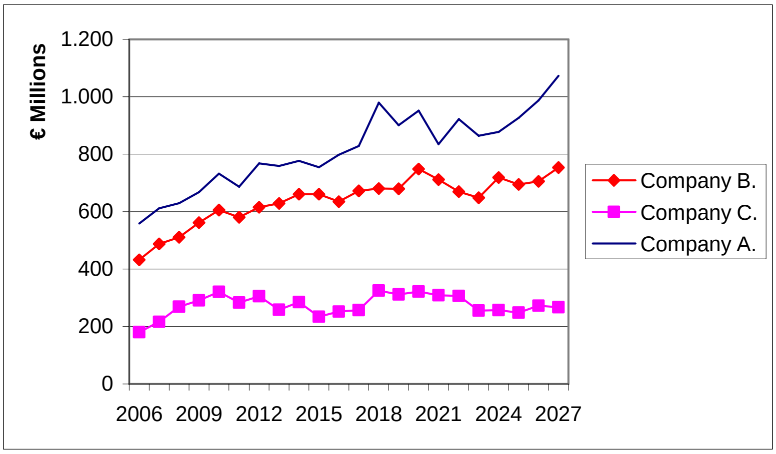
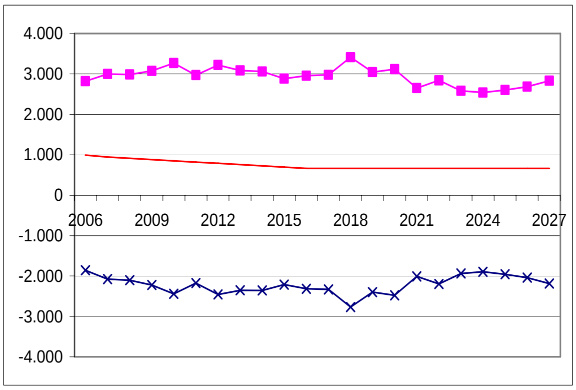


Figure 23: Investment forecast scenario 1

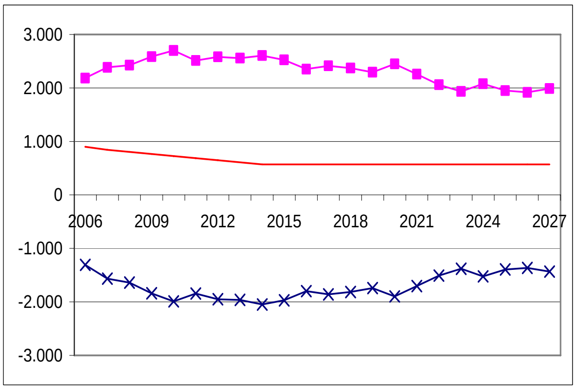
Because every network company has to replace all their electricity meters with smart meters within a short period of time [EZJ] an adapted replacement scheme for electricity meters applies for all the scenarios. It means that 80% of all the electricity meters will be replaced within the first 8 years (2007-2014), 10% in the next two years (2015-2016) and the last 10% in the two years thereafter (2017-2018).

➢ Charts of FTEs per network company and The Netherlands as total

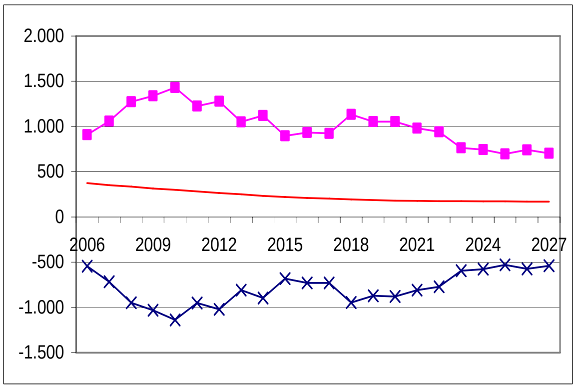
Company A



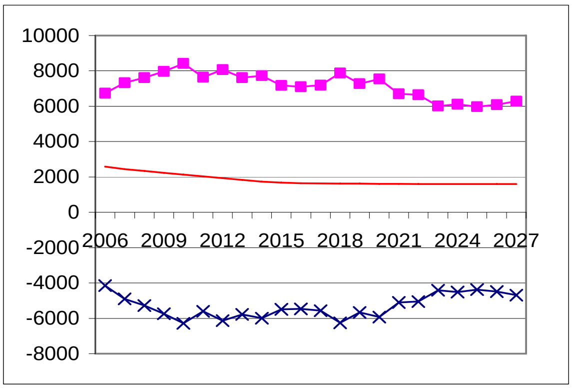
Company B

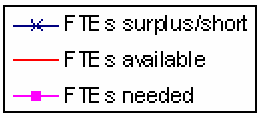


Company C



the Netherlands





Note that is an extreme scenario. In figure 23 one can see that the starting value in 2006 of Company A is approximately €560 million, which is much higher than the investment prognosis from Company A itself, which is about €100 million. A similarity from figure 23 with Company A is that the investments will double up within 30 years. There will be a rise for Company A to about 1.1 billion at the end of the forecasting period. If for figure 23 a longer horizon was taken the investments drop after 2030. The FTE chart shows that Company A has a structural shortage in FTEs every year (on average 2,200)

The starting value of Company B is €430 million, which is much higher than the investment prognosis from Company B itself, which is about 100 million for replacements [INB]. Company B has also a strong investment rise to €750 million in 2027. The FTE chart will show there will be an average shortage of about 1,700 FTEs per year during the forecasting period.

The starting investment value of Company C is €180 million, which also is much higher than the investment prognosis from Company C itself, which is about €90 million [INC]. The FTE chart shows that there will be a shortage between 500 and 1000 FTE every year. For the Netherlands as total it means that there will be a huge shortage in FTEs.

Table 12: Conclusions scenario 1

	Company A	Company B	Company C
Average FTEs short/yr	2,200	1,700	800
Total investments 2006-2027 (€)[11]	17.9 billion	14,1 billion	6,0 billion

10.2.2 Scenario 2: Late replacement

Here the assets will be operated with a life expectancy of 70, 80 and 90 years with replacement percentages of 33% for each asset group. Main advantage is that investments will be postponed and the network companies can react to a possible technology breakthrough or react to regulatory changes. That is why in 2020 the technology factor will be set on 80%. It means that the replacement investments will be reduced by 20%.

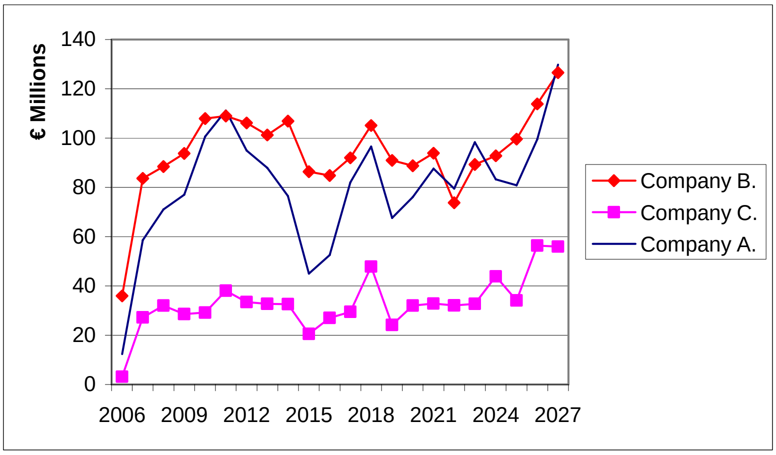


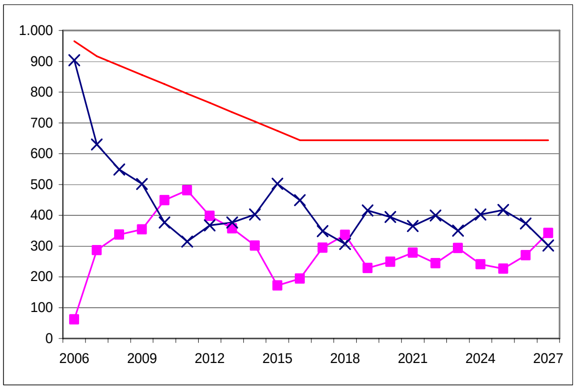
Figure 24: Investment forecast scenario 2

In figure 24 the impact from the electricity meters can be seen very well[12]. All the three network companies have an investment rise from 2006 till 2007 (start replacement electricity meters). Fifty percent of the total replacements is being caused by the replacement of electricity meters. Also the impact of the technology factor in 2020 can be seen very well, because of the drop in investments from 2019 to 2020. Company B has a higher investment forecast than Company A according to this replacement scenario because Company B has installed more low-voltage cables between 1910 and 1940 (see also appendixes 4 and 5).

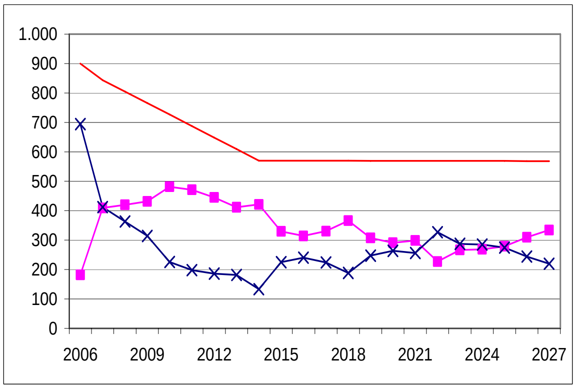
[11] The sum of the total investments per year including inflation of two percent accounts for all the conclusion tables
[12] The electricity meters will be replaced according to the scheme as explained in scenario one.

- Charts of FTEs per network company and The Netherlands as total

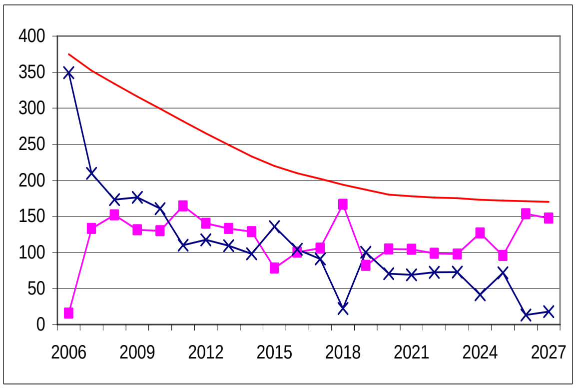
Company A



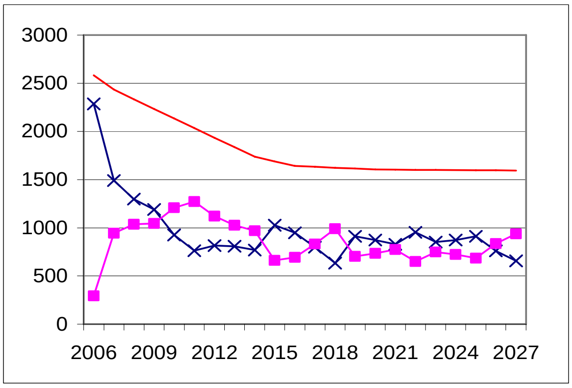
Company B

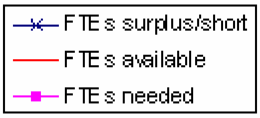


Company C



the Netherlands





The FTEs available will exceed for every network company the FTEs needed and therefore each network company has enough human resources to do the replacements. Table 13 shows the conclusions from scenario 2.

Table 13: Conclusions scenario 2

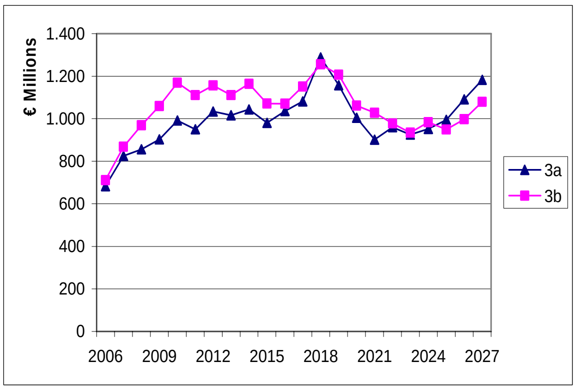
	Company A	Company B	Company C
Average FTEs surplus/yr	430	270	110
Total investments 2007-2027 (€)	1.8 billion	2,1 billion	730 million

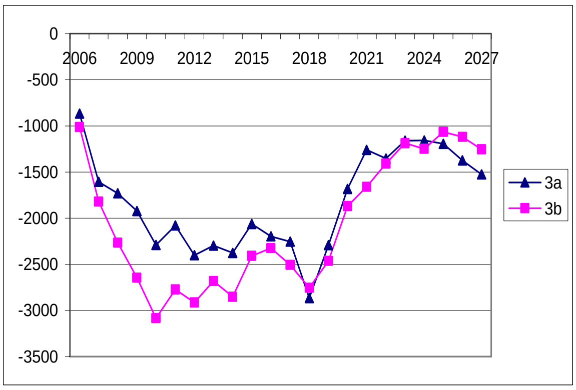
10.2.3 Scenario 3: Different strategies

This scenario uses different strategies for the network companies. One scenario gives insight if one large network company will have an early replacement and the other two have a late replacement. The other strategy will be if one large network company will have a late replacement and the other will have early replacements. For early replacement the same life expectancies as in scenario 1 will be used (40, 50 and 60 years) and for late replacement the life expectancies of scenario 2 will be used (70, 80 and 90 years) for all assets. The replacement percentages for the early replacement part will of this scenario be the same as in scenario one (paragraph 10.2.1) and the replacement percentages for the late replacement part of this scenario will be the same as in scenario 2 (paragraph 10.2.1). The technology reduction will be set on 80% starting in 2020 (as in scenario 2) and will be put on only for the late replacement part of this scenario.

The charts of scenario 1 and scenario 2 can be used so see the consequences per network company, so only total investment costs for the Netherlands and an overview about the FTEs for the Netherlands will be shown.

- Scenario 3a: one network company early (Company A), other two network companies late
- Scenario 3b: one network company late (Company A), other two network companies early





Scenario 3a and 3b do not differ much form each other as can be seen in the investment forecast chart on the left. But scenario 3b has more replacement investments in the beginning years of the forecasting period. An explanation therefore is that the combined asset base of Company B and Company C (together €12,8 billion) is larger than the asset base of Company A (€11,3 billion). Also more meters have to be replaced in the beginning years. Regarding the Netherlands scenario 3a has a preference above 3b, because of the lower investment costs and a lower average shortage of FTEs.

Table 14: Conclusions scenario 3a and 3b

	Company A	Company B	Company C	the Netherlands
3a Average FTEs surplus/short/yr	-2,200	270	110	-1,820
3a Total investments 2027-2027 (€)	17,9 billion	2,1 billion	730 million	20,7 billion
3b Average FTEs short/yr	430	-1,700	-800	-2,300
3b Total investments 2007-2027 (€)	1,8 billion	14,1 billion	6,0 billion	21,9 billion

10.2.4 Scenario 4: Most likely scenario

The former scenarios are all extreme ones; every asset will be replaced. The most likely scenario will make use of more realistic scenarios according to information from interviews with the three network companies and their capacity documents. This will be a scenario where in the near future electricity meters will be replaced by smart meters for all the network companies and where the investments in high-voltage cables will be limited because the life expectancy of that asset is higher than the other assets. Also the network companies were asked to give expectations about their expenses, so their expenses can be compared with the outcomes of the replacement model. As in scenario 2 the technology factor will be set on 80%. It means that the replacement investments will be reduced by 20%.

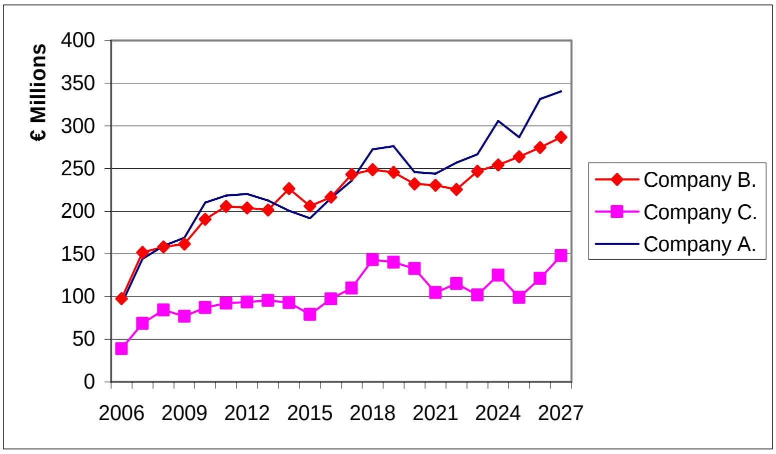
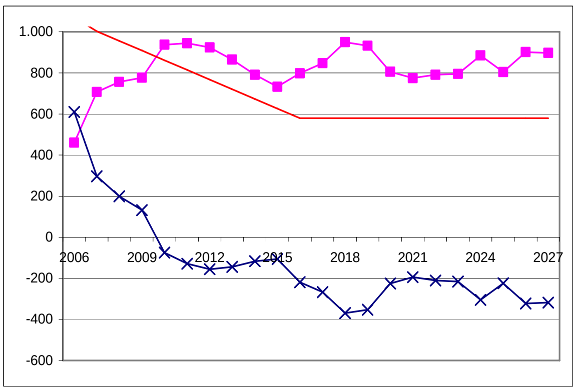


Figure 25: Investment forecast most likely scenario

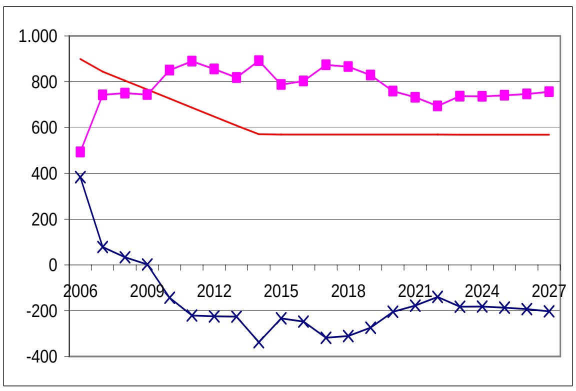
As can be seen in figure 25 the total investments rise from 2006 till 2027. The 2006 starting value for Company A is €91 million, for Company B €97 million and for Company C €38 million. Total cost for the period 2006-2027 for Company A will be €5,1 billion, for Company B it will be €4,8 billion and for Company C it will be €2,2 billion. The replacement reduction is 20% because of the technology factor and it starts from 2020.

- Charts of FTEs per network company and The Netherlands as total

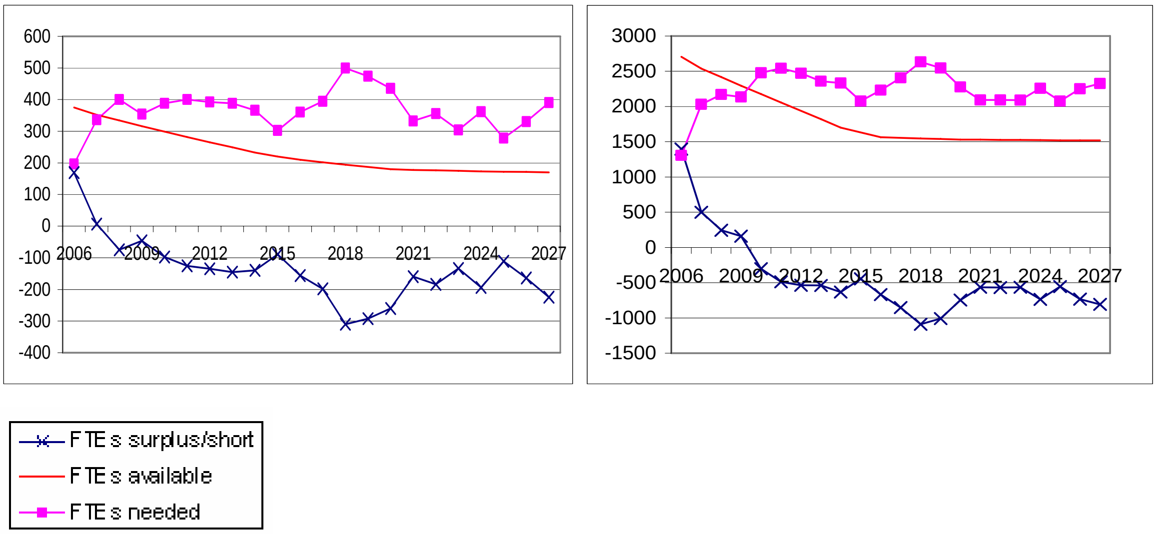
Company A



Company B



Company C *the Netherlands*



A FTE shortage of 75 for replacements occurs for the first time in 2008 for Company C, for Company B this occurs in 2010 (144) and for Company A also in 2010 (75). For the Netherlands it means that the first labour shortage occurs in 2010 of 300 FTEs. From these charts can be seen that there will be a shortage in FTEs in the near future for all the network companies in the Netherlands. Note that the scope is for the FTEs is for the Netherlands only and the network companies will probably will make use of more foreign employees as they do at the moment.

When replacements aren't executed the chance of failures within the network could be higher. When that happens more FTEs have to be assigned to fix the network and the bottleneck is precisely the number of FTEs.

Table 15: Conclusions most likely scenario

2007-2027	Company A	Company B	Company C	the Netherlands
Average FTE short/yr	120	160	140	430
Total FTEs short	2,700	3,500	3,050	9,500
Total investments (€)	5.1 billion	4,8 billion	2,2 billion	13,8 billion

If the surplus of FTEs in the first years will be used for replacement work the total amount of FTEs will be still large for the forecasting period. Remarkable is that Company A has a lower shortage than the other two network companies.

10.2.5 Reliability of the model

Because the model is heavily dependent on the input of the data some remarks will be given about the data. Errors could occur because of the following:

- Only for three network companies data is available, so there could be a margin of error if conclusions are drawn for The Netherlands as a whole. According to table 10 the three network companies have at least 93% of the Netherlands.
- In the original asset base for the network companies could be errors.
- The average value per asset group is being determined according to weight factors. For example when there are many medium-voltage cables with a high diameter this asset has a greater impact on the average medium-voltage cable price than medium-voltage cables with a small diameter. But when only a specific asset will be replaced (only

medium-voltage cables with a small diameter) within an asset group (medium-voltage cables) that value could be too low or too high.

- For one network company (Company A) the amount of investments from 1998-2006 are known (see figure 26). Prognoses after 2027 could be made to grasp the whole replacement wave. But data of the asset base was only available till 1998. Data of installed assets from 1998-2006 isn't available. The scenarios have as main output the impact per network company on their work force and the costs which are being made to perform the replacements.

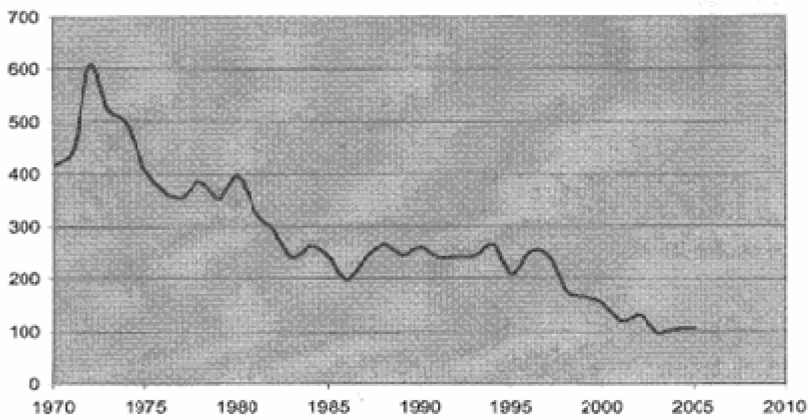


Figure 26: Company A investment volume (€)

- The cost structure is constant in the model. If for example materials will be more expensive it means that the replacement value of assets will be higher. It will therefore have an effect on expenses, not on the FTEs. According to the interview with Johan Huisma the cost assumptions of 1/3, 1/3, 1/3 is not very accurate for transformers of the high-voltage network. For these assets the material costs have a much higher percentage of the total. If the material costs for *all* the power transformers are 70%, the contractor costs are 15% and the personnel costs are 15% the difference with the total amount of FTEs needed is 6,4% for the period 2006-2027. But Huisma also stated that the material percentage of the low-voltage assets is lower. The maximum will therefore be 6,4%.
- As already mentioned the intake of FTEs could vary by each year and this is hard to predict.
- The electricity meters are an asset group which is being under discussion, because it isn't sure who will be the owners of them. The model assumes that the network companies will be the owners of them, so the costs (incl. installation) will be for them. The cost per smart meter is €100 without installation and maintenance. [EZW]
- Installation and maintenance cost for the new electricity meters are estimated at a value of €75 per meter. The impact if the installation and maintenance costs will be 10% higher (or lower) this means that the replacement value of an electricity meter will be 4,3% higher (or lower). FTEs needed will therefore be increased or decreased by 1,4% per year (33% work force percentage of 4,3%).

- The cost per FTE for the replacement model is €55 per hour. When the costs per FTE are higher less FTEs are needed for replacement work, because the total work force costs are divided by the cost per FTE per hour (see FTE formulas). If the cost per FTE is 10% higher, 10% less FTEs are needed. If the cost per FTE is 10% less, 10% more FTEs are needed.
- The capacity utilization for the model is 75%. Hands on tools are therefore 75% times 1600 hours equals 1200 hours. The standard deviation from the benchmark is 13%.
- The hands on tools are 1200 hours and it will grow by 1% every year to increase the efficiency of the employees. The difference of having an efficiency growth of 1% is a difference of 10% for the period of 2006-2027. An error could exist of about 0,5% a year.
- The overtime factor is 1,5% of the total number of FTEs available in. If the overtime factor is 0,3% less (standard deviation, see appendix 8) the error will be less than 1 FTE per year per network company.

A detailed sensitivity analysis can be read in appendix 9. A software simulation tool (Crystal Ball) is used to calculate the difference probability distributions for the base case scenario.

10.3 Conclusion

Each scenario has his own capital investments and its own consequences on the usage of the FTEs in The Netherlands. Each scenario has its own advantages and disadvantages.

If there will be no replacements it will be beneficial in the short term for the network companies and the consumers; no costs are made for the network company and no extra costs will be transferred to consumers. But the network will be older and more failures will occur and the number of FTEs available will be less. And when the failures rise more FTEs have to be assigned to fix them and the network will still be older. The danger exists that the network company can't get out of this negative cycle. In the long term a no-replacement strategy isn't the optimal strategy for the network companies and the consumers.

If we look at a good way to optimize the work force it is best to replace earlier. Replacements that can be done now will be done now. The average age of the asset base will go down and the customers minutes lost will probably remain on the same level as it is today.

But the insecure factors as regulation and technology improvements will give an advantage to a late replacement strategy. If one of these factors will change in the future the network company can change their strategy from a late to an early replacement one.

To evaluate the asset management replacement strategies the general asset management model of Roestenberg, De Croon and others (2003) has to be adapted for this specific problem. The model lacks a flexibility factor. The two extreme strategies 'fix-and-fail' and 'engineering excellence' are being named respectively 'late replacement' and 'early replacement' strategy.

The replacement model has four dimensions; financial performance, operational performance, risk and flexibility.

- *Financial performance*: the expenditure in euros for the given time horizon. The less or the later money is spend, the higher the financial performance will be.
- *Operational performance*: the performance of the distribution network. It means that if no investments are made the performance will deteriorate.
- *Level of risk*: the risk that necessary replacements cannot be carried out. The risk that a network company will be in a visual circle; more and more employees are necessary to fix the failures in the network and replacements have to be carried out as well.
- *Flexibility:* the degree a company can react to changes of their environment. A higher flexibility means that a network company can make better investment decisions in the future.

The early replacement strategy doesn't have a very good short-term financial performance, because investments are being made at an early stage. On the other hand the operational performance will improve or be the same and the level of risk will is lower because FTEs will now be used to do replacements. The risk of the earlier mentioned negative cycle will be low. But the flexibility of this strategy is a weak point. The network company cannot anticipate to regulatory changes or benefit from technology improvements and therefore has a risk to be more expensive than other network companies.

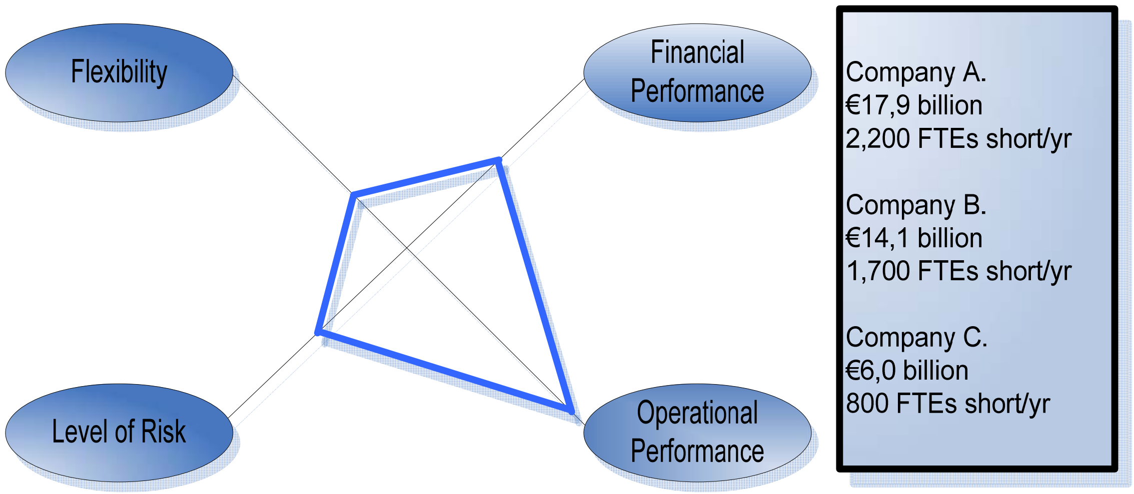


Figure 27: Early replacement strategy

The late replacement strategy will obviously have a good short-term financial performance, because investments are being made in the future. Operational performance probably will be lower when time goes by and that can be of influence because of the q-factor. The level of risk will be high because of the uncertainty of the availability of enough FTEs and that can be a very high risk. A great advantage of this strategy is the flexibility factor. With this strategy the network company can better anticipate (and therefore benefit) to a situation with a lot of distributed generation.

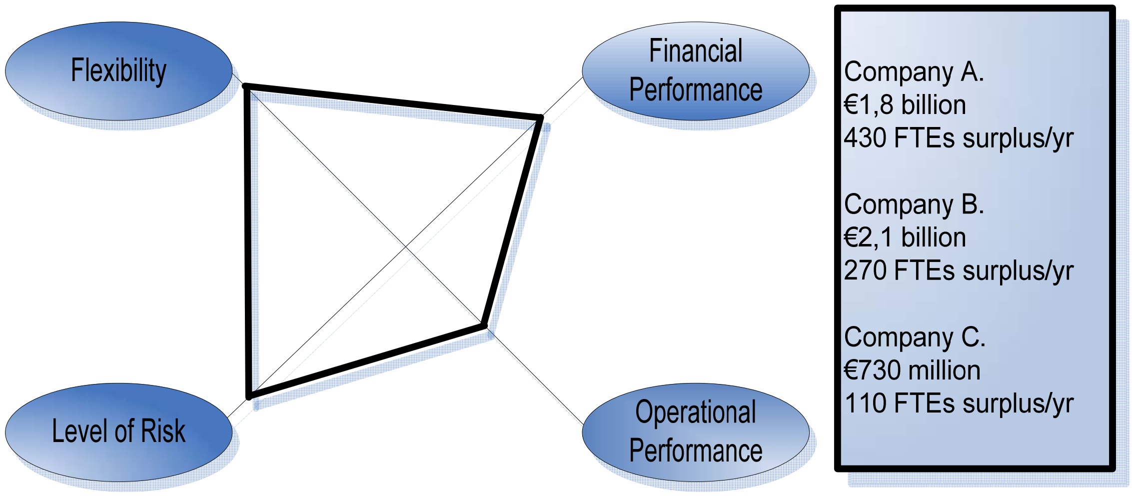


Figure 28: Late replacement strategy

At the moment the network companies more or less follow the late replacement strategy (figure 28) which has a good short-term financial performance. In the future the risk of having enough FTEs to perform all the replacements can have a negative impact on the operational performance and eventually also on the long-term financial performance of the network company. Flexibility is very valuable but the timing of these the advantages is difficult to predict.

11 Conclusions and recommendations

In this chapter the conclusions of the research will be presented briefly, recommendations will be outlined and suggestions for further research will be introduced. In the thesis the following research question was formulated:

What is a good investment strategy for the ageing infrastructures of distribution network companies and what are the consequences of this strategy?

11.1 Most important conclusions and recommendations

Sub questions have been formulated to give a detailed answer to the main research question. Below follows a summary of the most important sub conclusions from the research, whereupon the main research question will be answered.

- If a company has a preference for operational performance it would be best to adapt the early replacement strategy. A disadvantage is that the short-term financial performance will not be high. Total investments for this early replacement scenario are for Company A €17,9 billion, for Company B €14,1 billion and for Company C €6,0 billion. The 2007 investment prognosis from Company A and Company B themselves is about €100 million per year. Company A indicated that the total investments will double up within 30 years. The 2007 investment prognosis from Company C is about €90 million. Company C indicated that it will approximately be the same the coming years. Average investments per year following this scenario are for Company A €810 million, for Company B €640 million and for Company C €275 million (much higher than the network companies indicated). Another disadvantage of the early replacement strategy is that chances of anticipating to new technologies or regulatory changes will be smaller. The average FTEs short per year for Company A is 2,200, for Company B 1,700 and for Company C 800.

- If a network company has a preference for flexibility the network company has to adapt the late replacement strategy. But the network company has to accept the accompanying delivering risks (operational performance) and the risk of a future shortage in employees. Advantages of this strategy are that the short-term financial performance will be good and that the chance of anticipating to new technologies or to new regulatory rules will be high. This will lead to less replacement investments and therefore a higher short-term financial performance. Investment are for Company A €1,8 billion, for Company B €2,1 billion and for Company C €730 million. Average investments per year for Company A are €80 million, for Company B €94 million and for Company C €33 million. These figures are slightly lower than the investment prognoses form the network companies themselves. The average FTEs surplus per year for Company A is 430, for Company B 270 and for Company C 110.

- The late replacement strategy has also the preference above the early replacement strategy if the network company can bear the financial consequence of not-delivering. Suppose the number of customer minutes lost rises with 5% a year and the network company has to pay for these expenses. If the average loss per kWh is valued at €1 [INA] then the total failure cost will not make a significant difference in the profit of the network company (approximately 5%). It will make a difference in the profit of approximately 50% if an average lost kWh will cost the network company €10.
- Because there are not enough employees at the moment the network companies are forced to follow the late replacement strategy. Outsourcing is also possible but the size and the development of the contractor market is out of scope. This strategy has the most advantage from the flexibility component; there is a higher possibility to react to changes in the market. But the main disadvantage is that when companies don't have enough employees to do replacements, the network will be older and more failures could arise. More failures mean more employees are required to fix these failures and here lies the risk of the late replacement strategy.
- According the most likely scenario a FTE shortage of 75 for replacements occurs for the first time in 2008 for Company C, for Company B this occurs in 2010 (144) and for Company A also in 2010 (75). For the Netherlands it means that the first labour shortage occurs in 2010 of 300 FTEs. Total investments for Company A will be €5,1 billion, for Company B €4,8 billion and for Company C €2,2 billion. Average investments per year for Company A are €230 million, for Company B €220 million and for Company C €100 million. According to these investment forecasts the most likely scenario follows more the late replacement strategy than the early replacement strategy. Also the average investments per year follow the expectations from the network companies themselves rather well.
- Uncertainty about the investment and FTE forecasts remains within the model. The sensitivity analysis of the model for the most likely scenario shows that for Company C it is for more than 80% certain that their investments will exceed €1,6 billion. For Company B it is for more than 80% certain that the investments will exceed €3,5 billion and for Company A it is for more than 80% certain that their investments will exceed €3,8 billion.
- For the most likely scenario it is for more than 83% certain that there will be a shortage in FTEs for Company A. It is for more than 90% certain that Company B has a shortage in FTEs and for Company C it is for than 99% sure that there will be a shortage in FTEs. The following charts show the probability distribution of the number of FTEs short.

Backgrounds

- In literature different visions exist about the definition of asset management. On basis of these definitions a 'new' definition has been laid down for the purpose of the subject of this research. Asset management is: "*Finding an optimum way of managing assets to achieve a desired and sustainable outcome by means of an effective balance between costs, risks and operational performance over the lifecycle of the infrastructure.*"
- The energy value chains consist of production, trade, transmission, distribution, metering, sales and the customer. Liberalisation has divided all of these chains to introduce more competition in the electricity sector. The distribution networks are primarily the scope for the research. For the scope of the thesis it is important to

know that the high-voltage cables of 110kV and higher from the distribution networks will be managed by TenneT according to the law of independent network management. The network companies will still be the owners of these assets thus the replacement consequences are for them.

- Cross border leases were conducted for a large number of Dutch power plants and electricity networks. According to Moody's the early termination events for the cross border leases are very limited and the risk of unscheduled early termination is rather low.
- On Thursday 01 February Essent and Nuon have announced their merger plans. Purpose of the merger is to create synergy advantages and to create more purchasing power. The announced merger is a first step in creating a good position in the Northwest-European energy market. Some politicians are sceptical about the merger and for eventually 'second steps'. It is difficult to draw any conclusion about the merger because at the moment there is a lot of discussion about the (political and legal) consequences of it
- Regulation periods are short-term fixed (three till five years) and regulation as can be seen by the x-factor is subject to changes. If there are no regulatory changes it doesn't matter if one company will replace their assets earlier than another network company, because each company will have to make their replacement investments in one or another regulatory period. Except if there will be regulatory changes than it does matter. For the electricity companies a longer regulation period would enable them to develop longer-term replacement strategies.
- The new energy sources will be a combination of central and distributed generation (DG). DG facilities can reduce investment cost in upgrading or extending the distribution network. The same can be said about smart metering, because energy demand will be shifted from the high demand peak periods to the lower ones. Smart metering will be one of the first innovations in the distribution network. It is difficult to predict when the new developments or the new technologies have an influence for the network companies, but in 2020 there probably is a substantial change in the energy mix for the Netherlands will be accomplished. It means that less replacement investments are necessary from that period, because of lower expected redundancy in the distribution network. For the model a replacement reduction of 20% starting from the year 2020 has been used.
- The asset base of the network companies is quite similar qua asset base distribution to each other. More than 50% percent (measured in net replacement value euros) is caused by three largest asset groups; namely medium-voltage cables, low-voltage cables and power connections.

11.2 Recommendations for further investigation

- Research has to be carried out to the strategy of contractors and related the amount of employees of these contractors. They face the same problem of their ageing human resources as the network companies. What are the intake and outflow figures from these companies and how do they try to solve these problems? This should be combined with the following
- Research has to be carried out to the work force in other countries. Are there enough employees available in other companies and are they capable to perform the tasks.
- An investigation to the asset replacement in detail to failure rates. If there is enough data to investigate when an asset will fail than there will be no unnecessary replacements. A cost-benefit analysis has to be performed for each part of the distribution network. Only replacements in critical parts of the network should be carried out.
- Research in developing plans with governments and other utilities so that together with for example the sewer system and the water companies' asset management strategies could be developed so that it will be the optimal strategy for a specific city. So streets don't have to be opened as much as they do now.
- Essent and Nuon probably merge with each other according to the newspapers. What are the regulatory consequences for this new company and for the other network companies?

12 References

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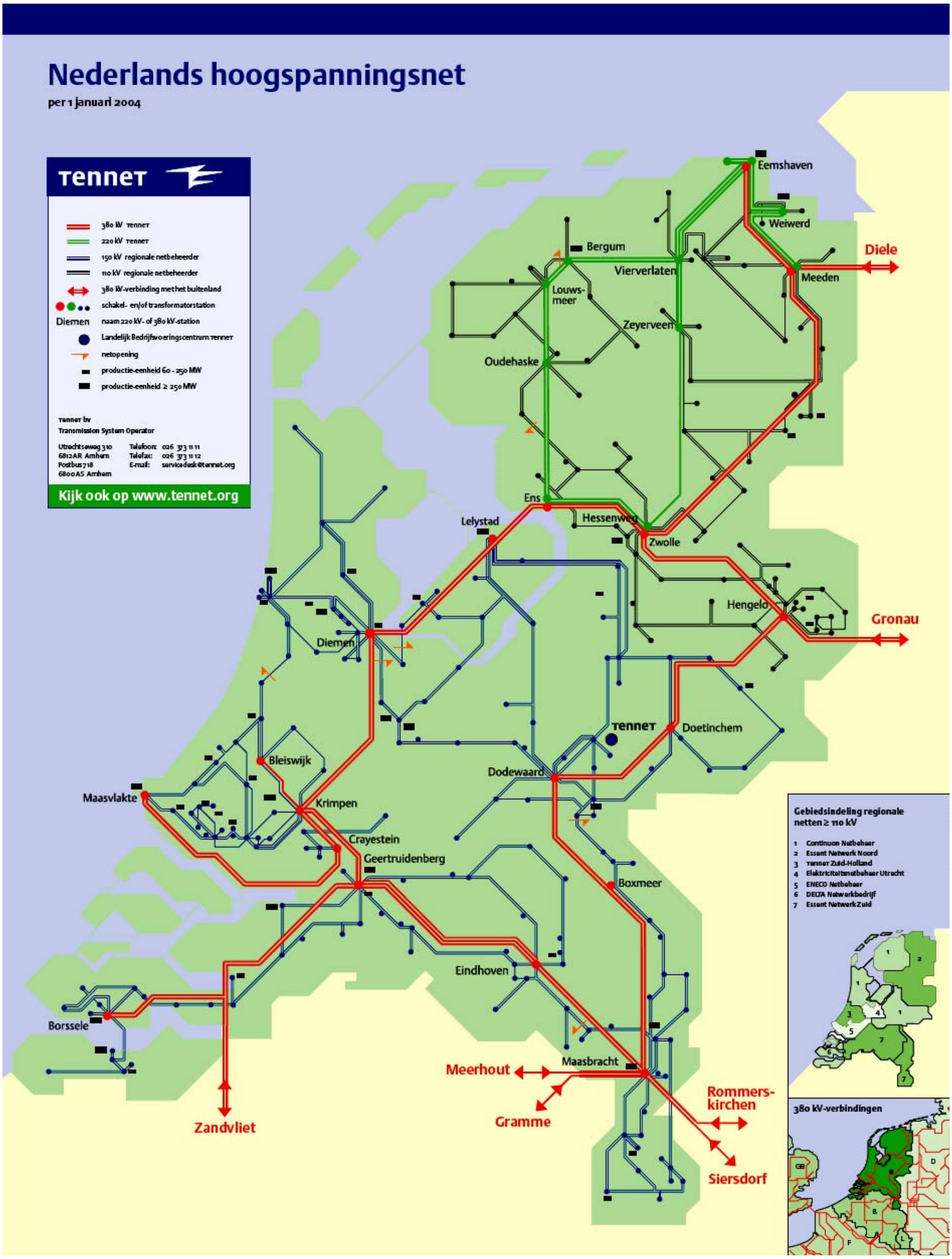
13 List of figures

14 List of tables

15 Appendixes

A.1 Infrastructure TenneT



A.2 CHP methods and percentages

- Steam - backpressure power plant

The simplest cogeneration power plant is the so-called backpressure power plant, where CHP electricity and heat is generated in a steam turbine. Another main component of the backpressure power plant is the steam boiler, which can be designed to fire solid, liquid or gaseous fuels.

Steam - extraction condensing power plant

A condensing power plant is generating only electricity. However, in an extraction condensing power plant some part of the steam is extracted from the turbine to generate also heat.

- Gas turbine with heat recovery boiler power plants

In gas turbine heat recovery boiler power plants heat is generated with hot flue gases of the turbine. The fuel used in most cases is natural gas, oil, or a combination of these. Gas turbines can even be fired with gasified solid or liquid fuels.

- Combined cycle power plants

Recently, natural gas fired combined cycle power plants consisting of one or more gas turbines, heat recovery boilers, and a steam turbine have become quite common.

- Reciprocating engine power plant

Instead of a gas turbine, a reciprocating engine, such as a diesel engine, can be combined with a heat recovery boiler, which in some applications supplies steam to a steam turbine to generate both electricity and heat.

Plants with steam backpressure turbines generated 32% of CHP electricity and nearly half of CHP heat in EU-25. Combined cycle plants generated 23% of CHP electricity and 12% of CHP heat. The contribution of plants with steam condensing turbines in CHP electricity generation was 18%, but they produced more CHP heat than combined cycle plants with a share of 20%. In the Netherlands combined cycle is the most used method of CHP electricity generation. [EUR]

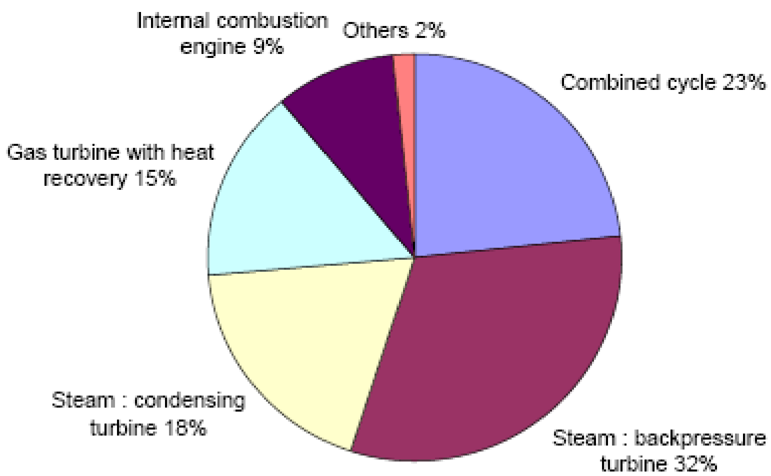
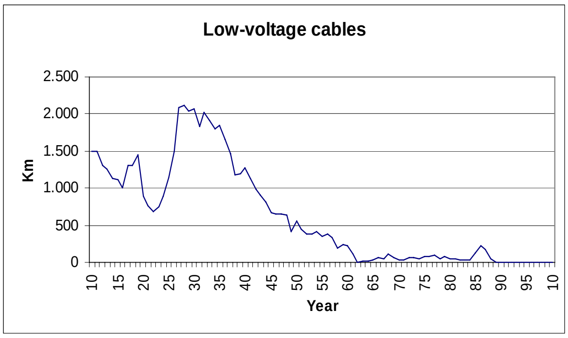


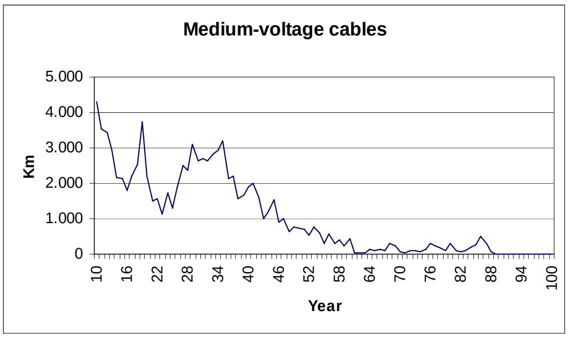
Figure 29: Distribution of the various CHP-methods [EUR]

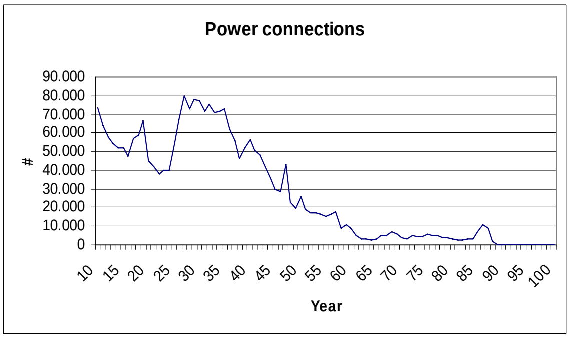
A.3 Smart meter pricing chart of Ontario

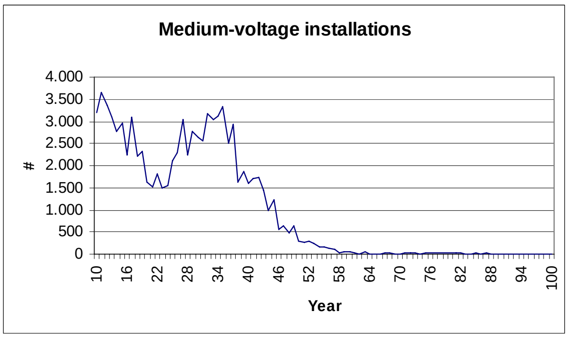
Day of the week	Time	Time-of-use	Price (cents/kWh)
Weekends & holidays	All day	Off-peak	3.5
Summer Weekdays (May 1st – Oct 31st)	7:00 a.m. to 11:00 a.m.	Mid-peak	7.5
	11:00 a.m. to 5:00 p.m.	On-peak	10.5
	5:00 p.m. to 10:00 p.m.	Mid-peak	7.5
	10:00 p.m. to 7:00 a.m.	Off-peak	3.5
Winter weekdays (Nov 1st – Apr 30th)	7:00 a.m. to 11:00 a.m.	On-peak	10.5
	11:00 a.m. to 5:00 p.m.	Mid-peak	7.5
	5:00 p.m. to 8:00 p.m.	On-peak	10.5
	8:00 p.m. to 10:00 p.m.	Mid-peak	7.5
	10:00 p.m. to 7:00 a.m.	Off-peak	3.5

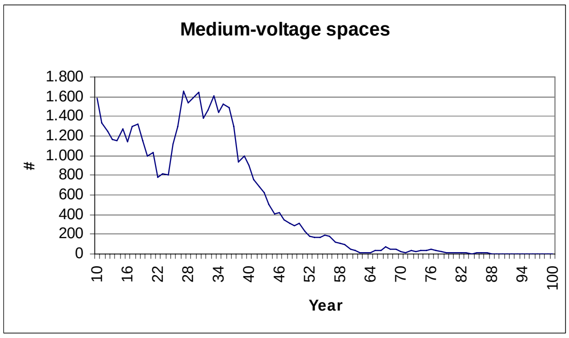
A.4 Asset base Company A

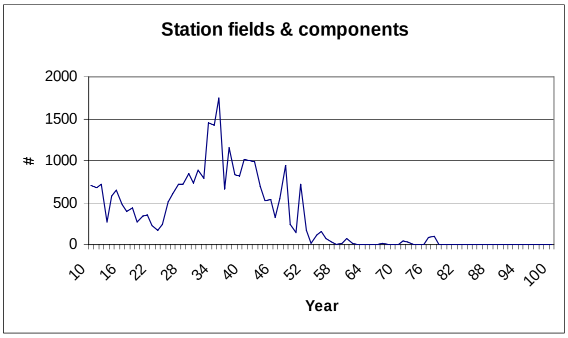


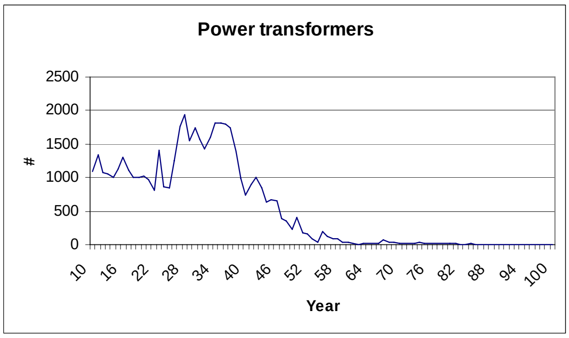


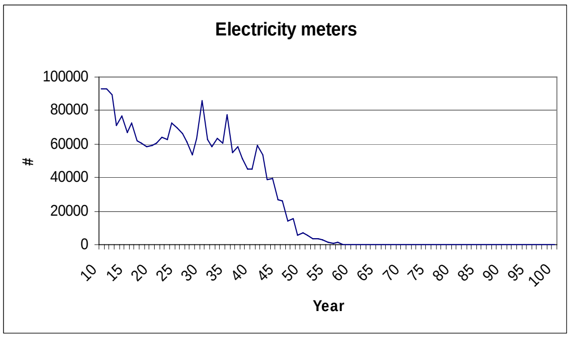


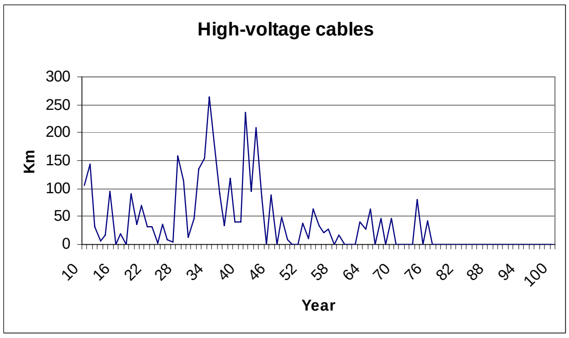




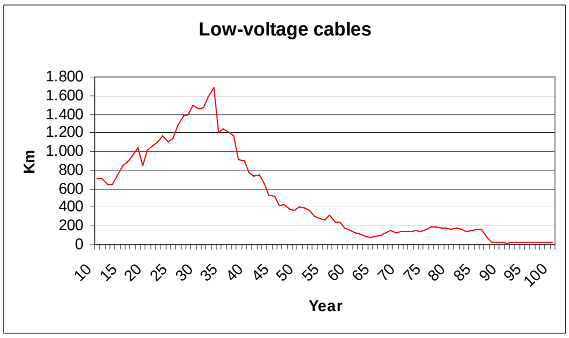


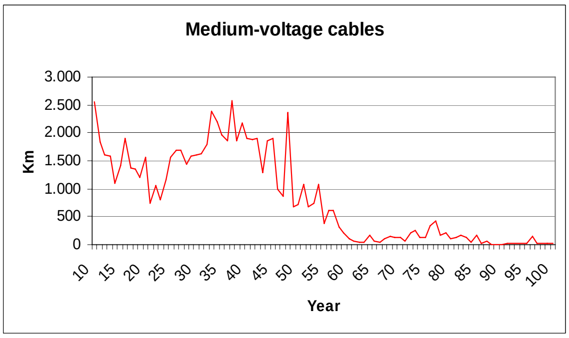


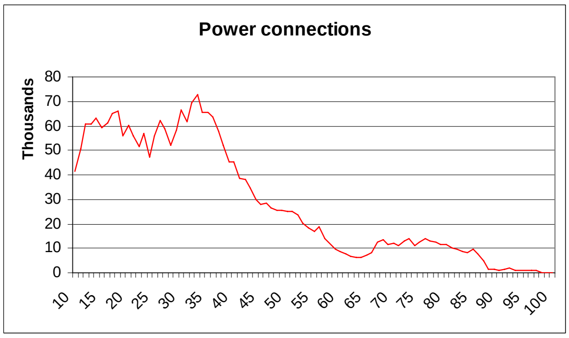


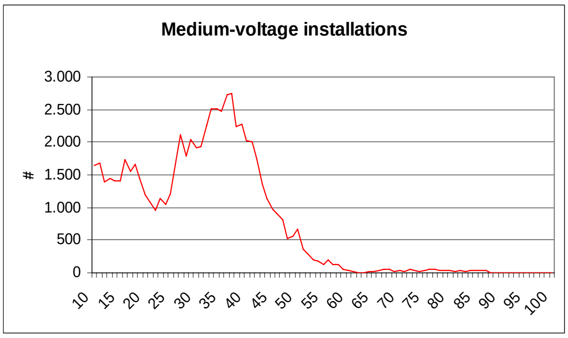


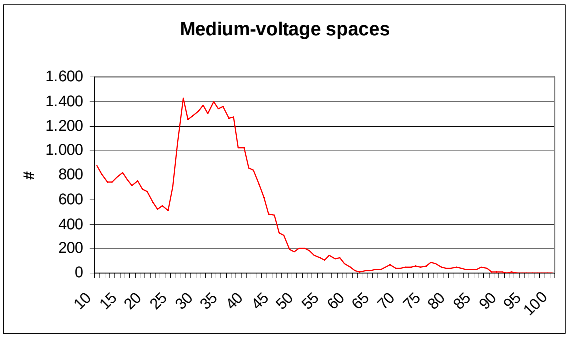
A.5 Asset base Company B

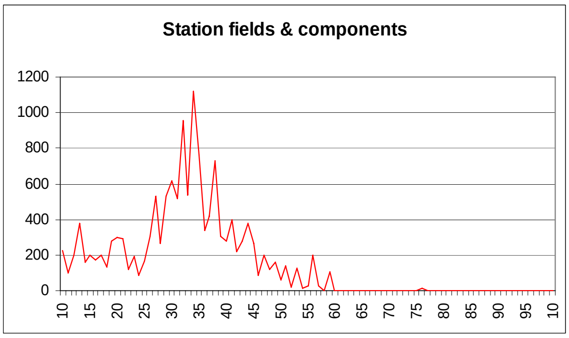


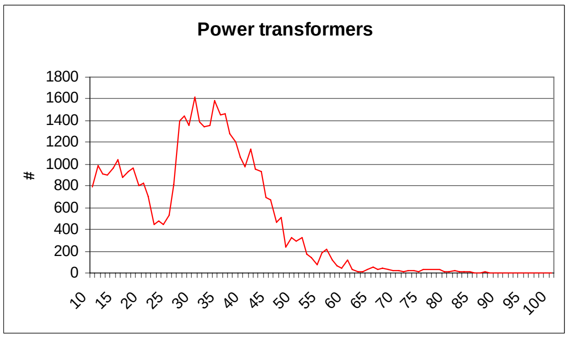







Medium-voltage spaces
#
Year


Station fields & components


Power transformers
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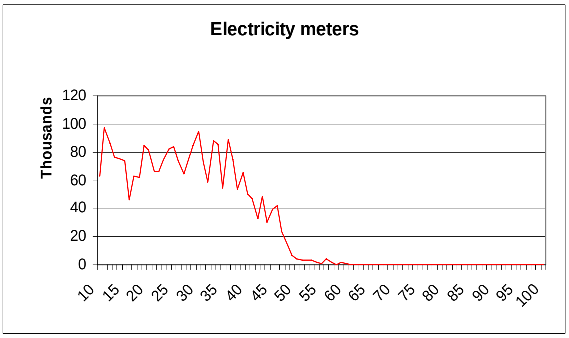
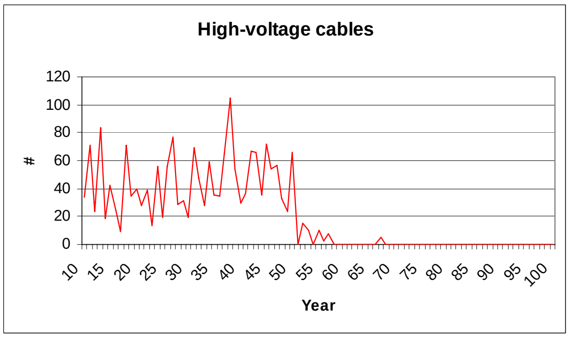
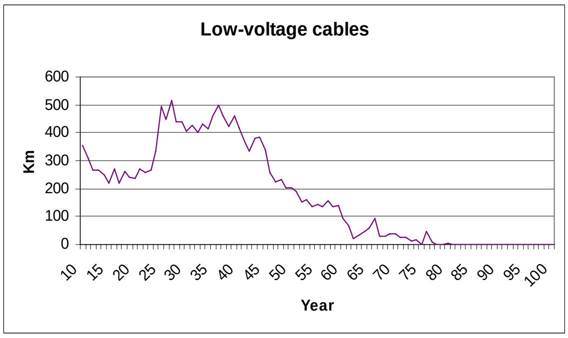
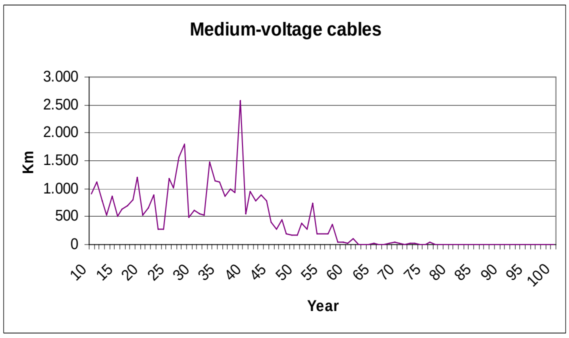
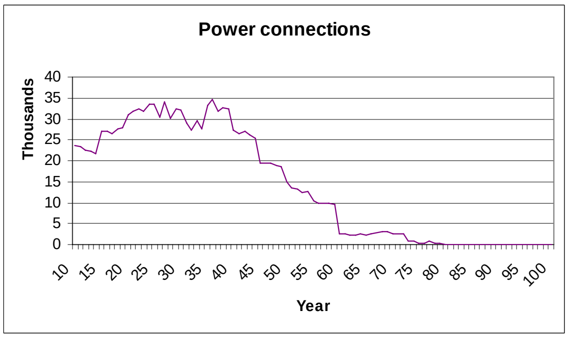

Electricity meters
Thousands

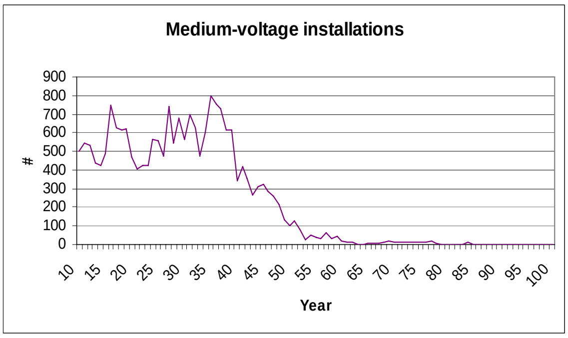

High-voltage cables
#
Year

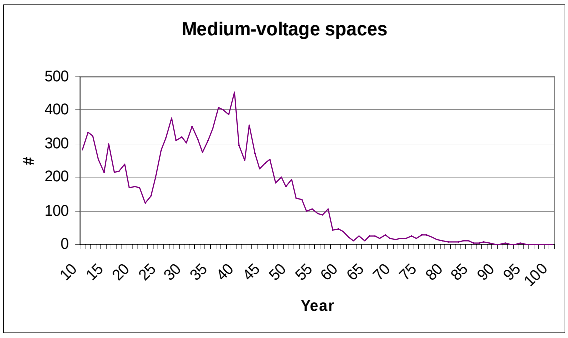
A.6 Asset base Company C

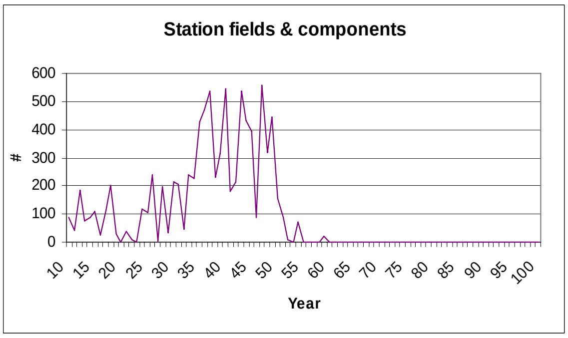


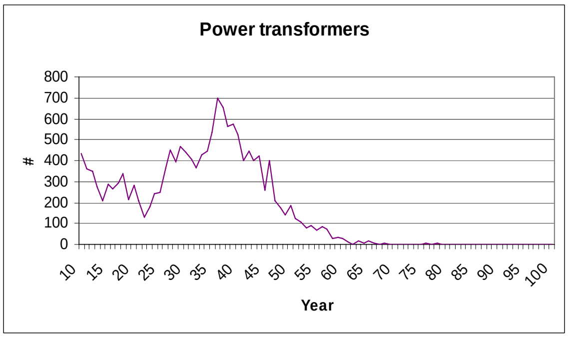


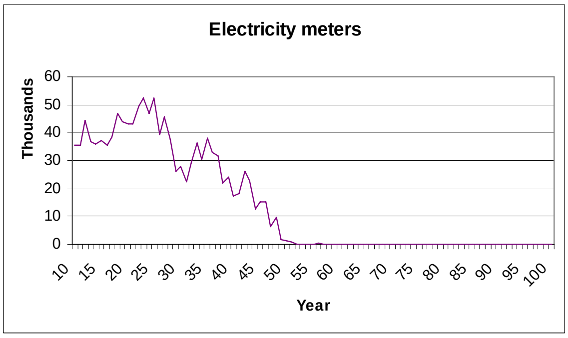


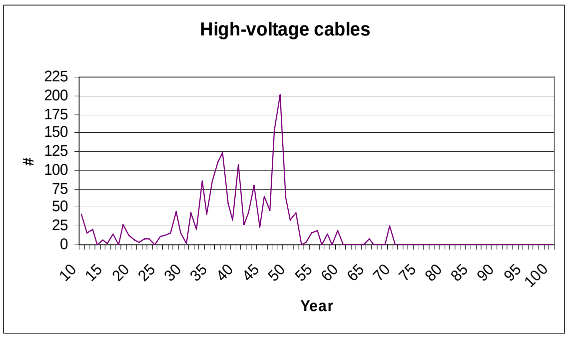












A.7 Illustration of the replacement model

The replacement model makes use of different replacement waves per asset group. On the following page you can see the input field of a network company. Each network company has his own field with input variables. The green 100% is just a control field to make sure that the three replacement percentages sum up to 100%.

A future replacement wave for an asset group can be adjusted in the replacement model by a percentage and by the life expectancy per asset group. As a user of the model you can choose both the starting points of the wave and the magnitudes through the percentage given by the user. Given a scenario you could advance or delay the starting date of the replacement wave.

It could be illustrated the best by an example. If the power connections are taken as example and the variables of 40%, 40%, 20% with life expectancies of respectively 30, 40, 50 years are being used (see the table below). For simplicity these variables are the same for each network company.

Power Connections		
Replacement percentage 1	40%	Wave 1
Life expectancy 1	30	
Replacement percentage 2	40%	Wave 2
Life expectancy 2	40	
Replacement percentage 3	20%	Wave 3
Life expectancy 3	50	

The model gives the total expected number of power connections that have to be replaced, for the years 2006 till 2027. For the year of 2006 we have for example 135 thousand power connections to replace. This number is the sum of nine separate replacement waves; for each network company the sum of their power connections have been calculated according to the given variables.

A wave starts about 30 years back as can be seen in the example therefore only analysis could be made till 2027. Peaks of the installed asset base can be found around 1970, so the peak of wave 3 is later than the one in wave 1.

Table 16: Variables of replacement model

Variables	
FTE Cost/hour	€55
Hands on Tools Hours/ FTE	1200
Workable hours	1600
Capacity utilization	75%
Inflation	1,1%
Efficiency growth	1,1%
Overtime	1,5%

Technology Factor	
Start Year	2020
Replacement reduction	80%

Table 17: Input field for a network company

100%	Low/Medium-voltage Cables	
	Replacement percentage 1	33%
	Life expectancy	30
	Replacement percentage	33%
	Life expectancy	40
	Replacement percentage	33%
	Life expectancy	50

100%	Medium-voltage spaces	
	Replacement percentage 1	20%
	Life expectancy	30
	Replacement percentage 1	60%
	Life expectancy	40
	Replacement percentage 1	20%
	Life expectancy	50

100%	High-voltage Cables	
	Replacement percentage 1	33%
	Life expectancy	40
	Replacement percentage 1	33%
	Life expectancy	60
	Replacement percentage 1	33%
	Life expectancy	70

100%	Medium-voltage installations	
	Replacement percentage 1	20%
	Life expectancy	30
	Replacement percentage 1	60%
	Life expectancy	40
	Replacement percentage 1	20%
	Life expectancy	50

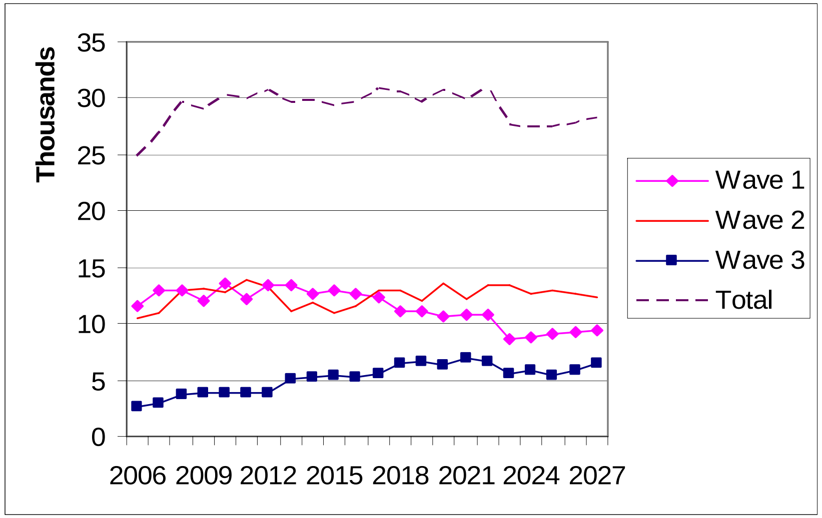
100%	Power Connections	
	Replacement percentage 1	40%
	Life expectancy	30
	Replacement percentage 1	40%
	Life expectancy	40
	Replacement percentage 1	20%
	Life expectancy	50

100%	Power Transformers	
	Replacement percentage 1	40%
	Life expectancy	30
	Replacement percentage 1	40%
	Life expectancy	40
	Replacement percentage 1	20%
	Life expectancy	50

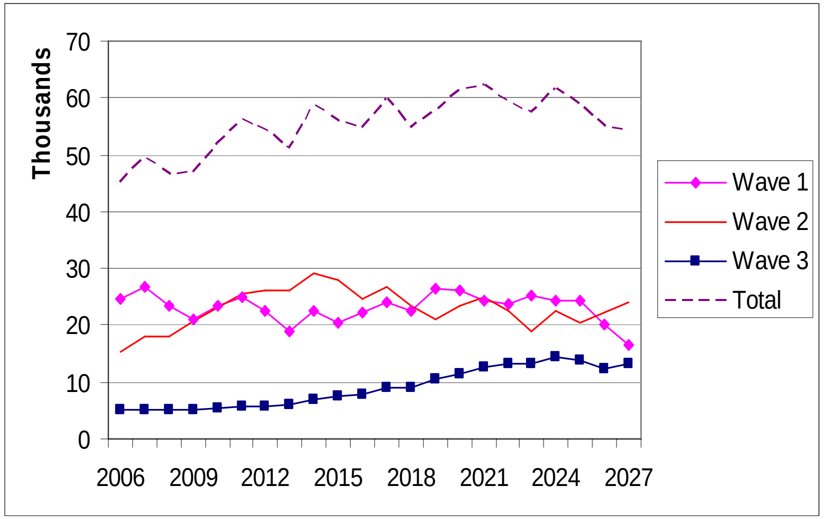
100%	Electricity Meters	
	Replacement percentage 1	80%
	Replacement till	2015
	Replacement percentage 2	10%
	Replacement till	2017
	Replacement percentage 3	10%
	Replacement till	2019

100%	Station Fields & Components	
	Replacement percentage 1	20%
	Life expectancy	30
	Replacement percentage 1	60%
	Life expectancy	40
	Replacement percentage 1	20%
	Life expectancy	50

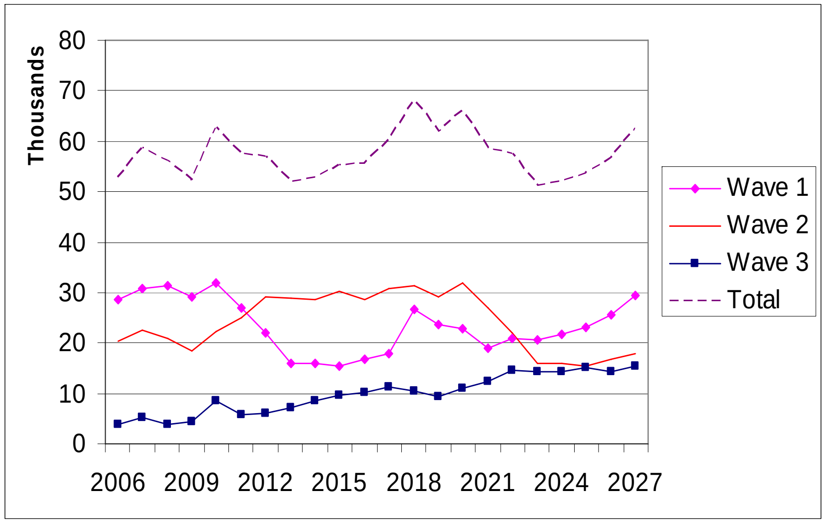
Company C



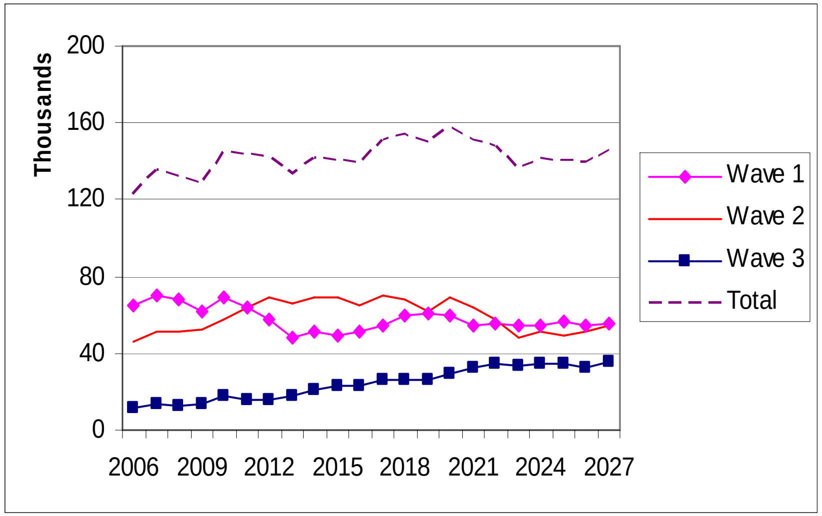
Company B



Company A



The Netherlands



A.8 Verification of data indicators

The benchmark consists of more than 150 asset intensive companies. For example data about Company C is part of the dataset. The standard deviation is being calculated to show the spread within the groups. Note that not all the 150 companies have values for the indicators below.

Benchmark data indicators	Average benchmark score	St.dev.
FTE Capacity Utilization	77,0%	13%
Overtime work	1,5%	0,3%
Maintenance cost/ Replacement value	3,1%	2,4%
Expansion/ Replacement value	1,0%	1,1%
New construction / Replacement value	4,1%	3,7%
Material cost/ Total replacement cost	32%	4,5%
Personnel cost/ Total replacement cost	35%	4,8%
Contractor cost/ Total replacement cost	32%	7,9%

Interview data indicators	Average interview score
Material cost/ Total replacement cost	33%
Personnel cost/ Total replacement cost	33%
Contractors cost/ Total replacement cost	33%
Capacity utilization	75%
Workable hours	1600
FTE cost/hour	€55

Asset data indicators from PwC research
Installed assets from 1900 till 1998 for Company A, Company B and Company C.
The replacement values per specific asset

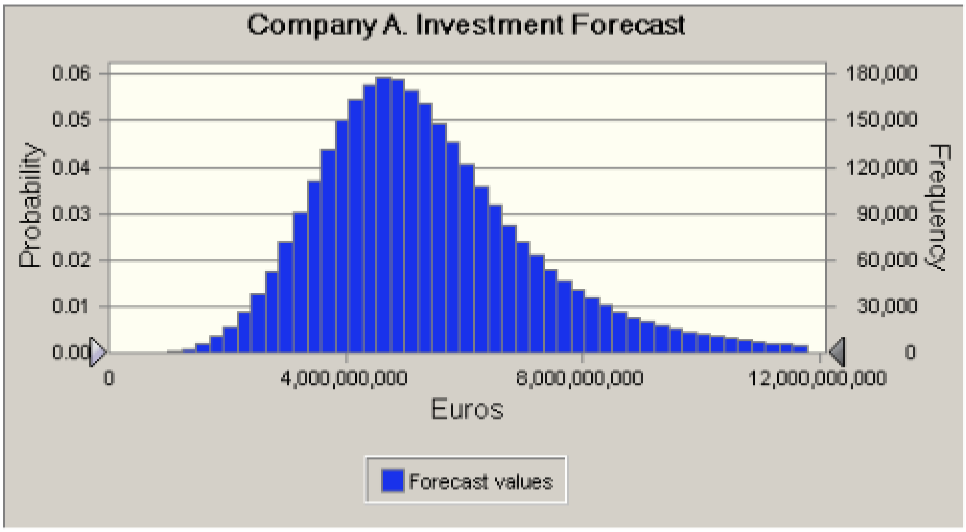
CBS data indicators	
Efficiency growth per year	1%
Inflation per year	2%

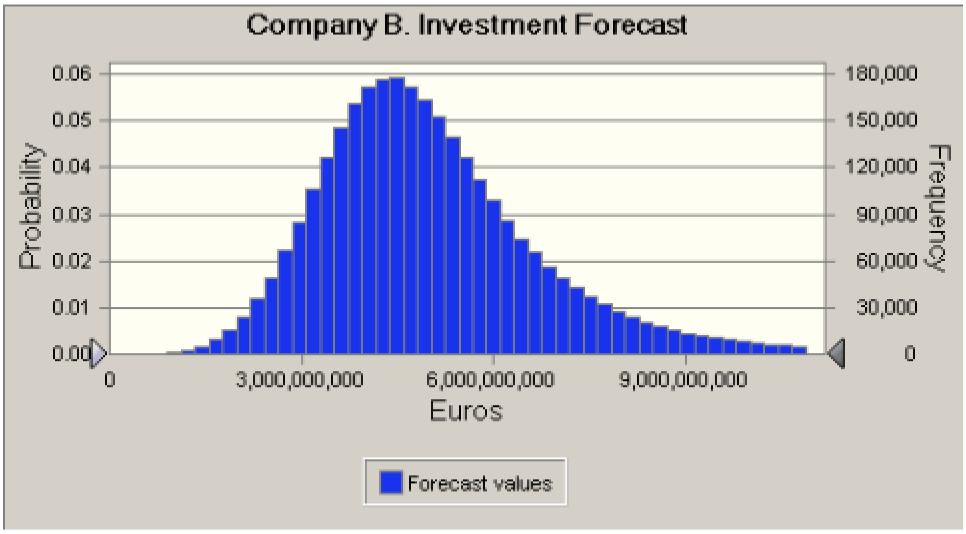
A.9 Sensitivity of the model

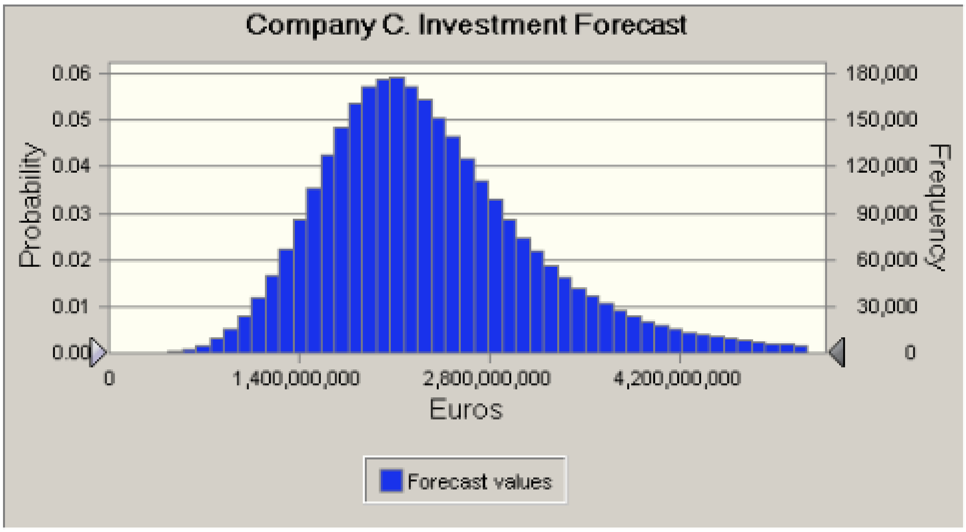
The model uses averages as input. To check the sensitivity of the model a simulation tool called Crystal Ball has been used. The probability assumptions for the following variables have been defined: FTE cost/hour, capacity utilization, inflation, overtime work and efficiency growth.

Because the model makes a forecast for about thirty years inflation figures of the past thirty years has been used to define the probability distribution for this variable. Crystal ball has an option to fit the data into a probability distribution. For the inflation variable it assumes that inflation has a logistic distribution with mean 2,02% and a scale of 1,04%.

The charts on the following page show a simulation run of 3 million trials. The medians of the forecasts are approximately the same as the base case (most likely one) scenario. For Company C it is for more than 80% certain that their investments will exceed 1,6 billion euros. For Company B it is for more than 80% certain that the investments will exceed 3,5 billion euros and for Company A it is for more than 80% certain that their investments will exceed 3,8 billion euros.





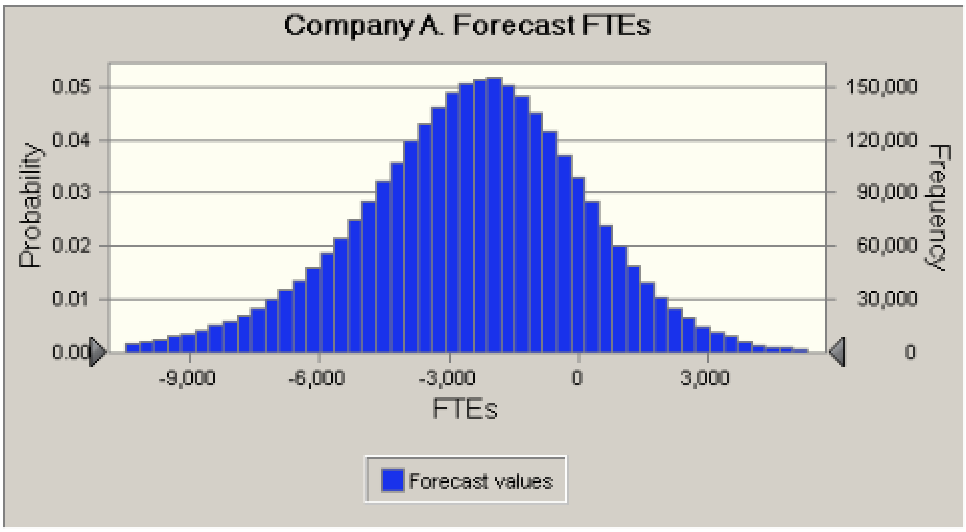


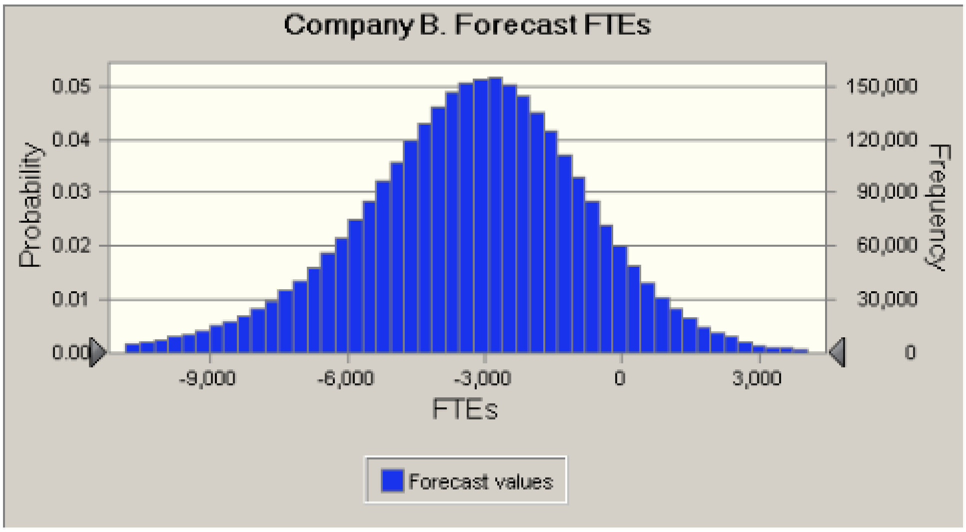
Capacity utilization is a starting variable. The base case scenario assumes a 75% starting value. The interviews with the distribution companies also mention that the 75% is the figure that they are also using with their calculations, but in reality this figure will not be lower than the 75%. Therefore a gamma distribution is assumed with parameters: location 75%, scale 1% and shape 1.

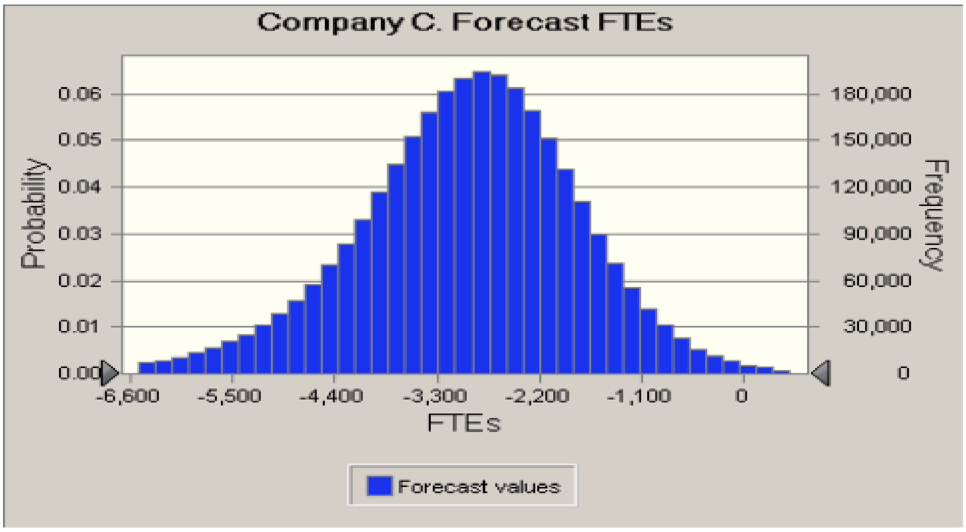
For overtime work and efficiency growth a normal distribution is used as probability distribution. Overtime work has a mean of 1,5% and a standard deviation of 0,3% and efficiency growth has a mean of 1,1% and a standard deviation of 0,4%. There is not enough data available to use the probability fitting option of Crystal Ball.

For the cost of an FTE/hour a logistic distribution as probability distribution is assumed with parameters mean 55 and scale 1.

According to former probability distributions Crystal Ball gives the following forecast for the total FTEs short or FTEs surplus. It is for more than 83% certain that there will be a shortage in FTEs for Company A. It is for more than 90% certain that Company B has a shortage in FTEs and for Company C it is for than 99% sure that there will be a shortage in FTEs. The following charts show the probability distribution of the number of FTEs short.




Company B. Forecast FTEs
Probability
0.05
0.04
0.03
0.02
0.01
0.00
Frequency
150,000
120,000
90,000
60,000
30,000
0
-9,000
-6,000
-3,000
0
3,000
FTEs
Forecast values


Company C. Forecast FTEs
Probability
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Frequency
180,000
150,000
120,000
90,000
60,000
30,000
0
-6,600
-5,500
-4,400
-3,300
-2,200
-1,100
0
FTEs
Forecast values