Energimarknadsinspektionen
Swedish Energy Markets Inspectorate

Ei R2018:12

Cost-benefit analysis of investments in the transmission network for electricity

The Swedish Energy Markets Inspectorate (Ei) is an authority which is commissioned to strive for well-functioning energy markets.

The main purpose of our work is to ensure Sweden has well-functioning distribution and trade of electricity, district heating and natural gas. We shall also safeguard customers' interests and strengthen their position on the markets.

In concrete terms, this means that we monitor companies' compliance with the regulatory framework. We are also responsible for developing the rules of play and informing customers of which rules apply. We regulate the terms for monopoly companies that run electricity and natural gas networks and monitor the competitive energy markets.

Energy markets require rules to provide a level playing field – we ensure that the rules are followed.

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The Swedish Energy Markets Inspectorate R2018:12
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The report is available on www.ei.se

Foreword

In June 2017, the government commissioned the Swedish Energy Markets Inspectorate (Ei) to establish guidelines for cost-benefit analyses of investments in the Swedish transmission network for electricity. The overall purpose of the assignment is to improve the basis for decision-making on investments in the transmission network so that the projects implemented are welfare-improving for society.

At present, there is no requirement in the Electricity Act (ellagen) that a transmission power line should be welfare-improving or that a cost-benefit analysis should be included in the application for a network concession, even though the regulatory process of granting network concession aim at preventing inefficient investments in the transmission network. In accordance with its instructions given by the Swedish Government, the Swedish transmission system operator (TSO), Svenska kraftnät, shall conduct a cost-benefit analysis of investments in the transmission network. It is therefore a natural development that a network concession for a transmission power line can only be issued if the installation is welfare-improving and that a cost-benefit analysis should be included in the application for a network concession in accordance with the proposed amendment that Ei presents in this report.

Considering the large investments in terms of volume and value, any additional transaction costs associated with the proposed amendment will be quickly balanced by increased benefits if projects that are not welfare-improving for society are postponed or completely avoided. This will streamline the use of resources in the economy, the use of Government funding and, in the long run, also lead to lower network charges for electricity grid customers.

Eskilstuna, April 2018

Anne Vadasz Nilsson
Director General

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Proposed amendment Electricity Act (ellagen) (1997:857)

Current wording	*Proposed wording*

Chapter 2

§ 6 a

A network concession for a transmission power line may only be issued if the installation is welfare-improving for society.

By way of derogation from the first paragraph, a network concession for a transmission power line may be issued if there are special reasons for waiving the requirement that the power line should be welfare-improving for society.

A cost-benefit analysis must be included in an application for a network concession for a transmission power line. This assessment must show whether the investment is welfare-improving and be subject to an audit by an independent third party. The assessment must be conducted after consultation with the stakeholders affected.

The Government, or authority appointed by the Government, may issue regulations on
1. Requirements on the content of cost-benefit analyses for investments in a transmission power line,
2. Detailed guidelines on the effects that should be included in the cost-benefit analysis and how they should be quantified and monetised,
3. How and with which stakeholders the consultation should be conducted, as well as
4. Publication of cost-benefit analyses for investments in a transmission power line.

§ 15 f

A reassessment in accordance with § 15 b shall apply to the following requirements:
1. That the installation is suitable from a public point of view,
2. That the power line is designed for the voltage specified in § 7, and
3. That the network concession meets the regulatory requirements of § 8.

The network concession may be reassessed and then subject to conditions set out in § 11.

A reassessment in accordance with § 15 b shall apply to the following requirements:
1. That the installation is suitable from a public point of view; 2. That the power line is designed for the voltage specified in § 7; and 3. That the network concession meets the regulatory requirements of § 8.

If the installation is a transmission power line, the requirements of § 6 a must also be met.

The network concession may be reassessed and then subject to conditions set out in § 11.

Changes to the Electricity Code (elförordningen) (2013:208)

§ 5

An application for a network concession for a power line must be made in writing and submitted to the network authority. It must contain the environmental impact assessment as required in accordance with Chapter 2, § 8 a, second paragraph 2 or 3 Electricity Act (1997:857) as well as information on the following:
1. The transmission needs that the power line is designed to meet. If the power line is intended to reinforce existing lines, this must be stated as well as information submitted on the load that existing power lines can withstand and, secondly, the need for additional power line construction due to the power line that is the subject to the application.
2. The voltage for which the power line is designed.
3. If the power line is designed for a voltage not exceeding the maximum voltage permitted for the network concession areas affected by the power line, the special reasons invoked for the application must be stated.
4. How the general consideration rules in Chapter 2 of the Environmental Act are observed.
5. Alternative power line routes that the applicant has investigated.

An application for a network concession for a power line must be made in writing and submitted to the network authority. It must contain the environmental impact assessment required in accordance with Chapter 2, § 8 a second paragraph 2 or 3 Electricity Act (1997:857), *the cost-benefit analysis required in accordance with Chapter 2, § 6 a third paragraph Electricity Act* as well as information on the following:
1. The transmission needs that the power line is designed to meet. If the power line is intended to reinforce existing lines, this must be stated as well as information submitted on the load that existing power lines can withstand and, secondly, the need for additional power line construction due to the power line that is the subject to the application.
2. The voltage for which the power line is designed.
3. If the power line is designed for a voltage not exceeding the maximum voltage permitted for the network concession areas affected by the power line, the special reasons invoked for the application must be stated.
4. How the general consideration rules in Chapter 2 of the Environmental Act are observed.
5. Alternative power line routes that the applicant has investigated.

Cost-benefit analyses

§ 14 a

The network authority may issue further instructions on
1. Requirements on the content of cost-benefit analyses for investments in a transmission power line,
2. Detailed guidelines on the effects that should be included in the cost-benefit analysis and how they should be quantified and monetised,
3. How and with which stakeholders the consultation should be conducted, as well as
4. Publication of cost-benefit analyses for investments in a transmission power line.

Summary

On 29 June 2017, the Swedish Energy Markets Inspectorate (Ei) was commissioned by the Government to establish guidelines for cost-benefit analyses of investments in the transmission network for electricity. The overall purpose of the assignment is to improve the basis for decision-making on investments in the transmission network so that the projects implemented are welfare-improving for society. According to the assignment, Ei shall investigate the effects that should be included in a cost-benefit analysis and how the geographical scope and other delimitations should be defined. In addition, Ei shall provide proposals for how these identified effects should be quantified and monetised. Furthermore, Ei shall analyse whether it is appropriate to use regulation as a measure for implementing the guidelines for the cost-benefit analysis, the purpose of which is to improve the decision-making processes for investments in the transmission network. The assignment also includes analysing the need for an independent third party to carry out "shadow analyses" in addition to Svenska kraftnät's analyses, as well as to analyse whether alternative investments such as energy storage, production capacity or demand-side measures can be a cost-efficient way to achieve the same objective.

Ei proposes that investments in the transmission network should be welfare-improving for society

It is important that investments in transmission capacity for electricity are economically justifiable. Today, it is also clear from Svenska kraftnät's instructions issued by the Swedish Government that they shall build the transmission network for electricity based on cost-benefit analyses. However, at present, there is no requirement in the Electricity Act (ellagen) that a transmission power line should be welfare-improving or that a cost-benefit analysis should be included in the application for a network concession, even though the regulatory process of granting network concessions aim at preventing inefficient investments in the transmission network (prop. 1996/97:136, p. 123).

Ei therefore proposes amendments to the current Electricity Act (1997:857) and a resulting amendment to the Electricity Code (2013:208). The proposed amendment implies that a network concession for a transmission power line can only be issued if the installation is welfare-improving, provided there are no special reasons to waive this requirement. In order for the permit-issuing authority, in practice Ei, to be able to verify that the installation is welfare-improving, the Svenska kraftnät must include a detailed cost-benefit analysis when applying for a network concession for a transmission power line. The analysis must be based on a general economic assessment that has been developed following consultation, published, and audited by an independent third party.

Ei's proposed amendment in the Electricity Act also contains an authorisation to the Government, or authority appointed by the Government, to issue regulations on how to design the cost-benefit analysis, what effects should be included in the analysis, how the consultation shall be conducted and how the cost-benefit

analysis shall be published. These instructions need to be detailed and may need to be modified as the methodology for cost-benefit analyses is developed.

Ei also proposes that a general cost-benefit analysis should be conducted at an early stage in Svenska kraftnät's decision making process and that it should be known to the general public. For this reason, the general cost-benefit analysis should be published before an application for a network concession is submitted to Ei. The following section describes Ei's proposal on the design for the specific cost-benefit analysis and the effects that should be included in the assessment.

Ei proposes a clear and transparent framework for cost-benefit analyses

To enable comparisons between different investment options, each cost-benefit analysis is made with a common set of assumptions. Different frameworks are currently available, depending on whether the cost-benefit analysis complies with international or national guidelines. For investments in the transmission network made by Svenska kraftnät, Ei proposes that

- there should be no general exceptions from the requirement of a cost-benefit analysis
- the geographical scope of the cost-benefit analysis is not limited to Sweden but shall include costs and benefits for the geographical areas where significant effects are expected
- if the net benefit of several projects is dependent on each other, all relevant projects must be included in the analysis
- alternatives to increased transmission capacity must be analysed and included in the cost-benefit analysis.

Ei also proposes that the time period for the evaluation of effects is 40 years from the decision date for the network concession. No residual value should be included in the analysis. For the 40-year time period, Ei proposes that a constant real discount rate of 3.5 per cent should be used in line with national and international recommendations.

Ei proposes guidelines on the effects to be quantified and monetised

A cost-benefit analysis can answer the question of whether an investment is beneficial for society by identifying, quantifying and monetising the effects (costs and benefits) that are expected to arise as a result of the proposed investment. The result of the cost-benefit analysis may vary considerably depending on the effects that are included or excluded and how the effects are quantified and monetised. In order to minimise uncertainties linked to the cost-benefit analysis, it is of great importance that clear guidelines are drawn up for the effects that should be included in the analysis and how these should be quantified and monetised. Ei's proposal is presented below.

Welfare effects arising in the day-ahead market

Increased transmission capacity between bidding zones affects the welfare by means of a more efficient allocation of resources. Part of this effect occurs in the day-ahead market and can be analysed by studying how welfare effects in the day-ahead market change with the investment in the transmission network. Changes in welfare in the day-ahead market consist of net changes in producer and consumer surpluses as well as congestion charges. Ei proposes that welfare effects in the day-ahead market should be included in the cost-benefit analysis and that the evaluation of welfare effects in the day-ahead should be conducted using at least two established and available electricity market models.

Market power

Market power means, amongst other things, that market participants can cause the price of electricity to deviate from the prices that had existed in perfect competition. For example, if electricity producers have market power and there are barriers for new electricity producers to enter the market, it tends to lead to higher prices. Prices that deviate from perfect competition lead to reduced welfare in society. Ei proposes that the cost-benefit analysis should include a qualitative analysis of the effects of increased interconnector capacity on the potential market power of electricity producers. The analysis should be based on one or more indexes for market concentration. The index may be, for example, the Residual Supply Index or the Herfindahl-Hirschman Index. Market concentration should be calculated with and without the proposed network investment. The change in potential market power shall then be included in the cost-benefit analysis. Since it is not possible to evaluate this change in monetary terms based on these indexes, the result needs to be handled qualitatively in the analysis.

System adequacy

System adequacy is determined by both generation adequacy and network adequacy. Changes in system adequacy affect the system's security of supply. Ei proposes that the effect of an investment in the transmission network on the expected energy not served (EENS) should be quantified using simulations. This effect should then be monetised using the value of lost load (VOLL). Ei also proposes that any cost saving associated with reducing or completely removing capacity reserves should be included in the analysis.

Power quality

By power quality, we mean the quality of the product that has been delivered (with regard to voltage, frequency, etc.). The power quality is a result of the network's dimensioning, technical solutions and the electrical installations connected to the network. Deficiencies in power quality can have significant consequences for those connected to the network. Ei therefore proposes that the cost-benefit analysis should always contain a qualitative analysis of how an investment is expected to affect the power quality. For investments that may result in a significant effect on the voltage quality in the underlying networks, a quantification and monetisation of the effect must also be made.

Operational reliability

Operational reliability denotes the system’s ability to accommodate an unexpected fault in the grid, without exceeding the network’s security limits. Changes in operational reliability affects the system's security of supply. Ei proposes that the effect of an investment in an electricity grid on operational reliability is monetised in terms of the costs for other measures (e.g. counter trade or reduced interconnector capacity) that are necessary to maintain operational reliability and which can then be avoided if an investment is made in the transmission network. Ei also proposes that Svenska kraftnät should include in the analysis how the costs of maintaining safety margins in the transmission network are affected in the event of an investment. The costs should be expressed in terms of welfare effects in the day-ahead market and monetised using an electricity market model.

Frequency control

Svenska kraftnät is the system operator for electricity in Sweden. This means that they, together with other TSOs within the synchronous area, have an overall responsibility of balancing production and consumption of electricity in real time. This is achieved by procuring balancing reserves in the balancing market. Balancing reserves, primarily consist of hydropower, but in principle, they can also consist of flexible electricity users, wind power or other controllable flexible resources. Ei proposes that the cost-benefit analysis should include a qualitative analysis of the value of the capacity expansion *in addition to the* welfare effects arising in the day-ahead market. Moreover, Ei proposes that any other balancing service being enabled by the investment is monetised and included in the cost-benefit analysis.

Cost-efficient achievement of political objectives

An investment in the transmission network can affect the cost of achieving policy objectives. A challenge to quantifying how the infrastructure affects this cost is the risk of double counting (for example, climate effects are already internalised in the welfare in the day-ahead market through the price for carbon dioxide in the EU's emissions trading system). Infrastructure development projects can also lead to - renewable electricity generation following a lower cost trajectory. Regardless of whether it is possible to quantify these effects, Ei proposes that, in the cost-benefit analysis, Svenska kraftnät should include a qualitative analysis of how the investment is expected to affect the cost of achieving different policy objectives.

Network losses

Network losses refer to the losses that arise in the transmission of electricity and are defined as the difference between the amount of electricity supplied and the amount taken out of the network. Ei proposes that Svenska kraftnät should use a network model (for example, the model they use today - Samlast) in order to quantify how the network losses are affected by an investment in the transmission network. After that, Svenska kraftnät should also monetise the effect using one of the electricity market models used in analysing welfare in the day-ahead market.

Construction, maintenance and reinvestment costs

The cost-benefit analysis must include all direct construction costs, field planning costs and costs related to consultation and permit processes, transition costs, operating and maintenance costs, as well as decommissioning costs. It is only society's real resource use that should be included in the calculation, which means that all costs (or revenues) that can be considered as transfers should be excluded.

Accounting depreciations should not be included, nor interest costs. In order to assess costs related to field planning and consultation and permit processes, Ei proposes that the working hours for this are estimated and priced at an average hourly rate. Additional costs (related, for example, to public consultations) are added to the cost of labour.

Ei proposes that any transition costs are monetised by estimating the working hours involved for potential process transition together with direct costs for training, equipment and inventories. Working hours are priced at an average hourly rate and are added up with the direct costs. Operating and maintenance costs, including necessary reinvestments throughout the discounting period, shall be included in the cost-benefit analysis. Decommissioning costs, including recycling costs and any landfill costs, that may arise in connection with the decommissioning of an installation, shall be included.

Local encroachment effects

Encroachment refers to both pure physical encroachment and encroachment that manifests itself as visual or emotional encroachment, and which results in a changed experience of a particular environment. Ei proposes that the Lantmäteriet (Real Property Register) Valuation Handbook provides a starting point for the monetisation of local encroachment effects arising from investments in the transmission network but that the discounting period, discount rate and value of any production loss should be adjusted to reflect the socio-economic value of the land. Ei proposes that the discounting period should be 40 years and the discount rate 3.5 per cent according to other proposals. Costs due to visual impact and psychological immissions for properties directly affected by the power line are already included in the project costs for the power line and should therefore not be reported as a single item. Costs associated with land encroachment for nearby properties being indirectly affected by the investment, e.g. visually, should be reported as a separate item.

Local environmental impacts

The majority of the local environmental impacts arising from an investment in the electricity grid are described in the environmental impact assessment that is drawn up in connection with the application for a network concession. Examples of local environmental impacts are effects on reindeer husbandry, on the function of the ground as a carbon sink, on cultural values, on biodiversity, the partitioning of habitats or that birds are injured or killed in contact with overhead transmission lines.

The Environmental Act contains rules aimed at limiting the environmental impacts of an installation on the environment. The adjustments required by the Environmental Act affect the cost of the project. External effects consist of any residual environmental impact that is not internalised in the cost of the project. As far as possible, these effects should be quantified and monetised in the cost-benefit analysis. The effects that cannot be quantified and monetised should be described qualitatively.

Emissions

The construction, operation and decommissioning of an electricity grid involves the use of natural resources and results in emissions and noise. Emissions to air and water should be quantified and monetised separately. Damage caused by local emissions of nitrogen oxide, nitrogen dioxide, sulphur dioxide, hydrocarbons and particulate matter from work machines can be calculated, for example, using Svenska kraftnät's environmental assessment tool.

Ei proposes that alternatives to increased transmission capacity should be analysed and included in the cost-benefit analysis.

Currently, there are alternative measures available to meet the increased need for transmission capacity in the transmission network. For example, demand-side flexibility, flexible production, energy storage or relocation of consumers and production units can help to remedy temporary congestions in the transmission network. Continued market and technology development means that alternative measures are becoming more cost-effective compared to conventional investments in increasing transmission capacity. When performing a cost-benefit analysis, it is therefore important to also compare increased transmission capacity with alternatives that have the potential to be a more economically efficient way of achieving the same objective. Ei therefore proposes that alternatives to increased transmission capacity should always be included and monetised in cost-benefit analyses of investments in the transmission network.

Depending on the type of investment in the transmission network, such as connection of a new electrical facility, reinvestment, system expansion or market integration, different alternative measures may be of relevance. Ei has engaged two consultancy companies in order to compile background reports that describe alternatives to conventional investments in increased transmission capacity. The alternatives presented in the report can be largely divided into two main categories: adapting the need for electricity transmission to existing network capacity by reducing demand for electricity or generating electricity near the end consumer, or using the existing electricity infrastructure more efficiently.

The two reports and experiences from other parties show that in some cases it is possible to use alternative measures to postpone expansion of the transmission network. The possibility of using alternative measures cannot be described in general, i.e. no universal alternatives for all types of investment in the transmission network have been identified. It is also rare that a measure can replace the entire need for increased transmission capacity. However, it may be that several measures combined can complement or postpone an expansion of transmission capacity.

1 Introduction

1.1 Background

The European electricity market for electrical energy is undergoing a major structural change. This change places new demands on both market participants and electricity grids. Amongst other things, the electricity grids need to be adapted to more renewable electricity generation, both large and small-scale generation, which can sometimes take place in geographically dispersed installations. Renewable energy sources are often weather-dependent and thus more difficult to plan than for example nuclear power. Another difference to traditional electricity generation that may create challenges is that small-scale renewable electricity generation such as photovoltaic (PV) may be connected to electricity grids at lower voltage levels.

The Swedish electricity grid can be divided into three levels: transmission network, regional grid and local grid. The focus for this assignment is the first level, the transmission network. The Swedish transmission network is defined as installations of 220 kV and upwards. A transmission network company is defined according to the Electricity Act (1997:857) as one that holds the concession for the transmission network or owns the majority of the transmission network. The state enterprise, Svenska kraftnät, is the transmission system operator in Sweden. Svenska kraftnät is also a certified transmission network company in accordance with the Act (2011:710) on the Certification of Transmission Network Undertakings for Electricity. In its role as transmission network company, Svenska kraftnät manages and develops the Swedish transmission network. Transmission capacity in Sweden and neighbouring countries is of major importance for Swedish economic development and a well-developed transmission network promotes trade in electricity, both in normal operation and in difficult situations. Svenska kraftnät is also the system operator for electricity and is thus responsible for maintaining the balance between the generation and consumption of electricity at the moment of operation, i.e. to make sure there is sufficient power to meet the needs of the consumers in real time.

The combination of an outdated transmission network, switching of energy sources and a political will to achieve increased market integration within the EU has led to increased needs for investment. Svenska kraftnät's investments have increased from about SEK 400 million per year in the 1990s to SEK 4-5 billion per year in the 2010s. Svenska kraftnät plans to continue investing as much until 2027. (Swedish National Audit Office (Riksrevisionen), 2016; Svenska kraftnät, 2017)

The Swedish National Audit Office (Riksrevisionen) has audited the Government's and the Parliament's governance of Svenska kraftnät and how Svenska kraftnät in turn manages the activities to achieve secure electricity transmission and distribution at economically justifiable costs, given the switching towards more renewable electricity generation. Amongst other things, the audit showed that there were shortcomings in Svenska kraftnät's basis for decision-making in the form of cost-benefit analyses. These shortcomings risk negatively affecting efficiency, which in the long run can contribute to higher costs for Swedish electricity grid customers. (Swedish National Audit Office (Riksrevisionen), 2016)

1.2 Purpose

Against the background of the report from the Swedish National Audit Office (Riksrevisionen), on 29 June 2017, Swedish Energy Markets Inspectorate (Ei) was commissioned by the Government to establish guidelines for cost-benefit analyses for the construction of transmission capacity for electricity. The assignment includes more closely identifying the types of effects that should be analysed in the context of a cost-benefit analysis, as well as proposing guidelines for how these effects should be calculated for decisions on investment in transmission capacity for electricity. According to the assignment, Ei shall investigate the following

- What effects should be included in a cost-benefit analysis for decisions on investments in the transmission network and how the geographical demarcation should be done, as well as how the effects should be quantified and monetised.
- Whether general exceptions should be allowed to the cost-benefit analysis of investments in the transmission network
- Whether it is appropriate to use regulation as a measure for implementing the guidelines for the cost-benefit analysis
- Whether there is a need for an independent third party to perform cost-benefit analyses on investments in the transmission network as a complement to Svenska kraftnät's own analyses.
- Whether alternative investments such as energy storage, production capacity or demand-side measures are cost-effective ways to achieve the same objective.

In the event of implementation, the Swedish Energy Markets Inspectorate shall take into account the knowledge and experience at Svenska kraftnät and the Swedish Agency for Public Management.

The analyses and proposals presented in this report are aimed both at improving the basis for decision-making on investments in the transmission network and at facilitating a transparent, involved decision-making process for stakeholders and decision-makers on investments in the transmission network.

1.3 Limitations

Ei has not analysed whether the financial governance of Svenska kraftnät or the current network regulation creates incentives for a socio-economically efficient expansion of the transmission network. Ei has also not analysed whether the current tariff structure or subdivision in bidding zones is a socio-economically efficient price signal for locating new electricity generation capacity or demand facilities.

1.4 Dialogue meeting with electricity market participants and stakeholders

During the investigation, Ei organised a dialogue meeting in which market participants and stakeholders were invited to give their comments. We have also had a project page on www.ei.se where the participants have been able to submit written comments to the project group.

The interest in the dialogue meeting has been great and about 40 representatives from network companies, consultants, landowners affected, wind power owners and forest industry participated. During the investigation, the representatives submitted their own proposals for guidelines and commented on the options presented by the project group. In total, approximately 15 market participants and stakeholders affected have submitted written comments and proposals. In addition, Ei has held individual meetings with Svenska kraftnät, the Swedish Agency for Public Management, Lantmäteriet (Real Property Register), regional network owners, wind power producers, the Federation of Swedish Farmers and Södra Skogsägarna (Forest Owners in Southern Sweden).

1.5 Method and implementation

The proposals presented in this report have been based on a review of the current legal framework in Sweden and the EU, as well as a literature study and analysis of how cost-benefit analyses are carried out in infrastructure projects in other areas and in other countries. This has been supplemented with interviews of, amongst others, representatives of the Norwegian Ministry of Petroleum and Energy (OED). In order to highlight issues related to cost-effectiveness and the feasibility of alternative investments, Ei has engaged two consultancy agencies. For support and quality assurance in method and process issues, Ei has engaged a reference group consisting of Ficre Zehaie (Swedish Environmental Protection Agency), Gunnel Bångman (Swedish Transport Administration) and Kerstin Grandelius (Swedish Transport Agency).

1.6 Report structure

The report layout is as follows. Chapter 2 describes the roles and responsibilities of Svenska kraftnät and the transmission network in Sweden. In Chapter 3, we focus on the decision-making processes that precede an investment in the transmission network and Ei's proposed amendment related to the decision-making process. In Chapter 4, we present a proposal for a framework for making cost-benefit analyses of investments in electricity grids. Chapter 5 contains suggestions on the effects in terms of costs and benefits that should be included in a cost-benefit analysis of investments in the transmission network. This chapter also contains concrete proposals for how these effects should be quantified and monetised. Chapter 6 contains an analysis of alternatives to increased transmission capacity in the transmission network. In conclusion, Chapter 7 contains an impact assessment of our proposed amendments. Finally, there is a more detailed account in Appendix 1 of the provisions of the Electricity Act and the Environmental Act relating to network concessions.

Chapter 3 contains binding proposed amendments and therefore has the same structure as propositions. The proposals presented in Chapters 4-6 are linked to future regulations and describe how the cost-benefit analysis should be designed. The presentation of Ei's draft regulations in Chapters 4-6 differs from the proposed amendments in Chapter 3.

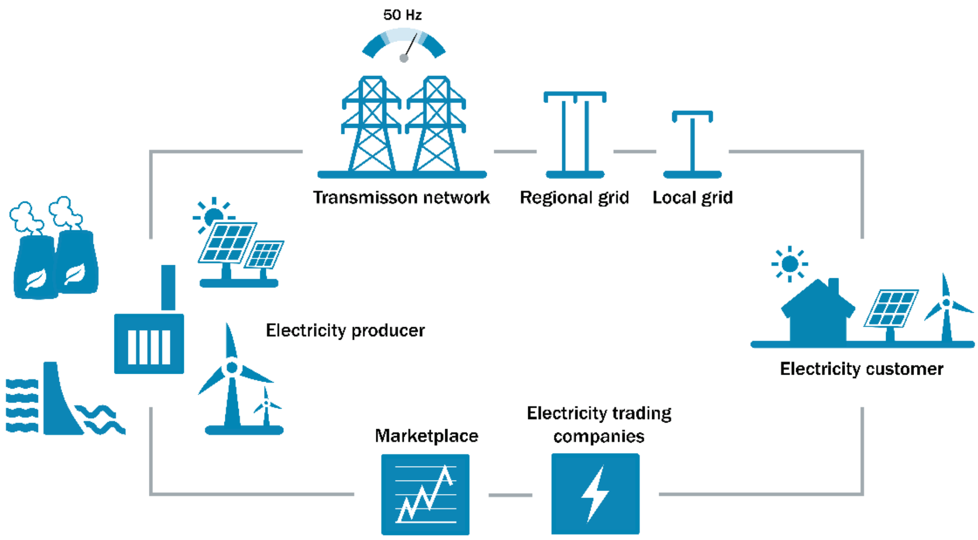
2 The transmission network in Sweden

This chapter describes how the Swedish electricity system is structured with focus on the transmission network and its function. Furthermore, there is a description of the role of Svenska kraftnät as a system operator and how its responsibilities are influenced by policy objectives at national as well as European level. Central policy objectives are increased market integration within the EU and a national target of switching to 100 per cent renewable electricity energy sources by 2040. Finally, there is a description of Svenska kraftnät's financial governance and economic framework conditions.

2.1 The function of the transmission network in the Swedish electricity system

The Swedish electricity grid has three levels: The transmission network transports electricity from electricity producers to the regional electricity grids. The regional grids transport electricity from the transmission network to local grids and to major industrial customers. The local grids then transport electricity to households, smaller industries and other users. Figure 1 gives an overview of different parties in the electricity system and the different levels in the electricity grid.

Figure 1. Overview of the electricity system.



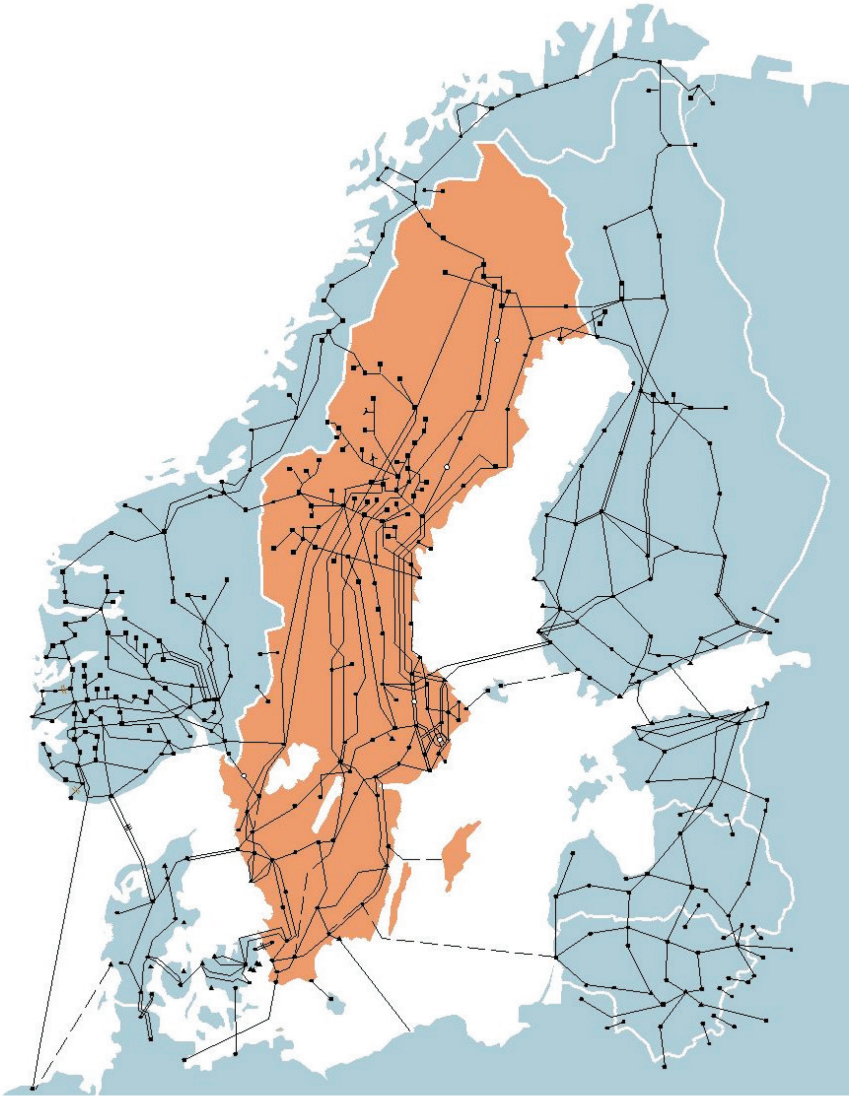
Source: Ei.

On 1 January 1996, the electricity market in Sweden was deregulated. The production of electricity was opened up to competition and regulations that prevented trade in electricity were abolished. Amongst other things, the aim was to increase the choice for electricity customers and to facilitate increased competition. Electricity grid operations remained regulated monopolies. The high investment costs for electricity grids result in significant economies of scale in electricity grid operations. Economies of scale mean that the average cost decreases as grid supplies increase, and the investment cost is spread over several kilowatt hours. This means that the network operation is a so-called natural monopoly, which in turn means that more than one operator in a certain area results in more expensive electricity supply. Consequently, it is not socio-economically justifiable to open up the electricity grid operation to competition. To prevent inefficient entry, it is common to create a legal monopoly for electricity grids (Joskow P. L., 2007).

The transmission capacity of the transmission network in Sweden as well as to and from neighbouring countries is of great importance for a well-functioning electricity market. Figure 2 presents a simplified illustration of the Nordic-Baltic transmission system. The Swedish transmission network for electricity consists of 15 000 km of power lines, 160 substations and switching stations and 16 international connections (Svenska kraftnät, 2015; Swedish National Audit Office (Riksrevisionen), 2016). The transmission network in Sweden is synchronously[1] interconnected with the Nordic region apart from western Denmark. The total capacity of the international connections is equivalent to approximately 40 per cent of the maximum consumption during the year. Further connections are planned, including the so-called Hansa Power Bridge to Germany.

[1] Synchronous means that the electricity systems have the same frequency.

Figure 2. A simplified description of the Nordic-Baltic transmission system.



Source: Svenska kraftnät.

2.2 The role of Svenska kraftnät in the electricity system

Svenska kraftnät is owned by the Swedish state and is thus directly under the authority of the Government. Since Sweden is a member of the EU, European legislation and policy objectives at European level need to be considered. This section describes the roles and responsibilities of Svenska kraftnät in the Swedish electricity market and how these relate to other electricity market participants.

The assignment of Svenska kraftnät is to manage, operate and develop a cost-effective, reliable and environmentally-adapted power transmission system on a commercial basis. Additional assignments are to sell transmission capacity and, in the instruction's wording, "conducting activities connected to the power transmission system" and "expand the transmission network for electricity based on cost-benefit analyses" (Code (2007:1119) with instruction for the State Enterprise, Svenska kraftnät).

Svenska kraftnät is the system operator, which implies an overall responsibility for maintaining a balance between the generation and consumption of electricity (Chapter 8, § 1 Electricity Act). Svenska kraftnät is also the electricity emergency response authority, which involves responsibility for the measures needed to prevent, resist and manage disruptions in electricity supply that can cause severe strains on society (Power Contingency Act (1997: 288)).

Roles for maintaining the electricity system's security of supply

The electricity system's security of supply is a general term for the system's ability to receive, transmit and supply electricity to the system's end customer. Svenska kraftnät has an important function in maintaining this security of supply. It depends on many factors, such as energy adequacy, system adequacy, operational reliability and frequency control. If one of these factors is below a critical limit, it may lead to an interruption in the electricity supply at regional, national or even Nordic level. Svenska kraftnät does not have direct influence over all the factors. Section 5.4 contains a more detailed description of the factors that determine security of supply.

In the real time, Svenska kraftnät is responsible for the frequency and balance in the system. The network customers, in the form of producers and electricity users, must comply with the connection requirements set by Svenska kraftnät. Amongst other things, the connection requirements mean that the balance responsible party (BRP) from the network customers is obliged to plan for balance prior to the operating hours. Amongst other things, the BRPs use trade on the day-ahead market and intraday market to be in balance. The better the BRPs are at planning in balance, the fewer the discrepancies that remain for Svenska kraftnät to handle in real time. The market's time resolution for trading in electricity also affects Svenska kraftnät's balancing needs in real time. At the time of this report, electricity is traded per hour, which can result in real time imbalances due to the fact that production or consumption varies over the hour. According to Article 53 (1) of Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline for electricity balancing, time resolution within Europe will eventually be harmonised to 15 minutes, which may affect Svenska kraftnät's need to trade in balancing services. [2]

All electricity network companies are also responsible for maintaining quality of supply and customer connections, i.e. a robust electricity distribution to and from connected customers. In the medium term, the network companies perform planned interruptions and switchings to be able to perform maintenance and renewals, preferably without outages (by temporarily supplying electricity via other routes or by live-line working, i.e. performing work on live network components). The electricity network companies shall manage the expansion and renewal of the electricity grid, with the help of forecasts on market development and appropriate incentives in, for example, network regulation.

[2] Within three years of this Regulation the entering into force, all system operators of electricity transmission systems shall apply the 15-minute imbalance settlement period in all planning areas while ensuring that all market-time unit limits coincide with the limits of the imbalance settlement periods.

2.3 Svenska kraftnät's planned investments

This section first describes Svenska kraftnät's overall driving forces with regard to investment and then the driving forces illustrated in the network and system development plans.

Overall driving forces

At an overall level, there are clear political drivers for Svenska kraftnät's investments. At European level, it primarily concerns the European Commission's strategy for a common energy union, according to which all member states will have cross-border capacity by 2030 at the latest, equivalent to 15 per cent of installed production capacity.[3] Sweden has good cross-border capacity and by 2030, the installed capacity is expected to amount to approximately 50 per cent of peak power during the year (European Commission's expert group on electricity interconnection targets, 2017).

Swedish energy policy is also important for Svenska kraftnät's activities. Of particular importance is the so-called energy policy agreement. The agreement meant that the political parties Social Democrats, the Moderates, the Green Party, the Centre Party and the Christian Democrats reached a framework agreement in the summer of 2016 which, amongst other things, resulted in targets for Sweden to have 100 per cent renewable electricity generation[4] by 2040 and 50 per cent more efficient energy use by 2030. In addition, the Parliament has decided on a target of zero net greenhouse gas emissions by 2045.

The energy policy agreement states that the electricity certificate system shall be extended and increased by 18 TWh of new[5] electricity certificates by 2030, and that the connection fees for offshore wind power should be abolished. In total, this means that the electricity certificate system will finance 48 TWh of renewable electricity by 2030 compared with 2002. Stronger market integration with the Nordic region and the rest of Europe through increased cross-border capacity is also highlighted as an important starting point for reaching solutions to the challenges posed by the common electricity market.

System development plan

Svenska kraftnät has drawn up a system development plan describing its views on the challenges facing the electricity system. The plan also points out possible solutions. It builds on the previous network development plan, as described below, but has a broader perspective and includes, in addition to network development, issues of operating conditions and market design.

The plan is aimed at larger transmission network customers and BRPs, major suppliers of services to Svenska kraftnät as well as to authorities and ministerial departments. Amongst other things, it presents a reference scenario for the electricity system in 2040 and the electricity system's challenges and network

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[3] Commission Decision of 9 March 2016 setting up a Commission expert group on electricity interconnection targets (2016/C 94/02).

[4] This is a target, not a deadline to prohibit nuclear energy, nor does it mean stopping nuclear energy with political decisions.

[5] In addition to 30 TWh of renewable electricity by 2020 compared to 2002.

development over time. The system development plan 2018-2027 broadens the perspective over a 10-year planning period. In many respects, the system development plan looks ahead to 2040, since the consequences from switching energy sources must be seen in a longer perspective.

Network development plan

Every two years, Svenska kraftnät draws up an investment plan in the form of a so-called network development plan for the following ten years. The latest network development plan is part of the System Development Plan 2018-2027. The network development plan constitutes Sweden's national starting point in the work on the common European ten-year plan for network investments (Svenska kraftnät, 2015).

The plan categorises and describes the driving forces behind Svenska kraftnät's investment decisions. The categorisation of the driving forces into the four areas of *connections, market integration*, *system expansion* and *reinvestments* is a model that compiles the various reasons behind the network measures implemented by Svenska kraftnät. The same categorisation is also used in the internal work to facilitate planning and management of all ongoing and upcoming projects. The four different driving forces are described below, as well as how they affect the development of the transmission network.

Connections

Connections of new or increased generation or consumption always involve more or less extensive adaptations of the transmission network. This applies to connecting both new wind power generation and larger customers, such as server halls. The adaptations can consist of everything from minor adjustments in an existing transmission network station to brand new power lines and stations. Like all other network owners, Svenska kraftnät has a statutory obligation to connect generation and consumption if there are no particular reasons to deny a connection.

The major uncertainties with regard to the future need to connect new generation and consumption are a significant challenge for Svenska kraftnät in the development of network development plans. Not least considering the long lead times for permits to build new power lines.

Market integration

This category of network investments aims at increasing or maintaining the interconnector capacity between the Swedish bidding zones[6] and between Sweden and its neighbouring countries. The aim is to contribute to an integrated Nordic and European electricity market. The benefits of these projects are primarily more efficient utilisation of production resources and increased security of supply by increasing the capacity for transmitting electricity from surplus to deficit areas.

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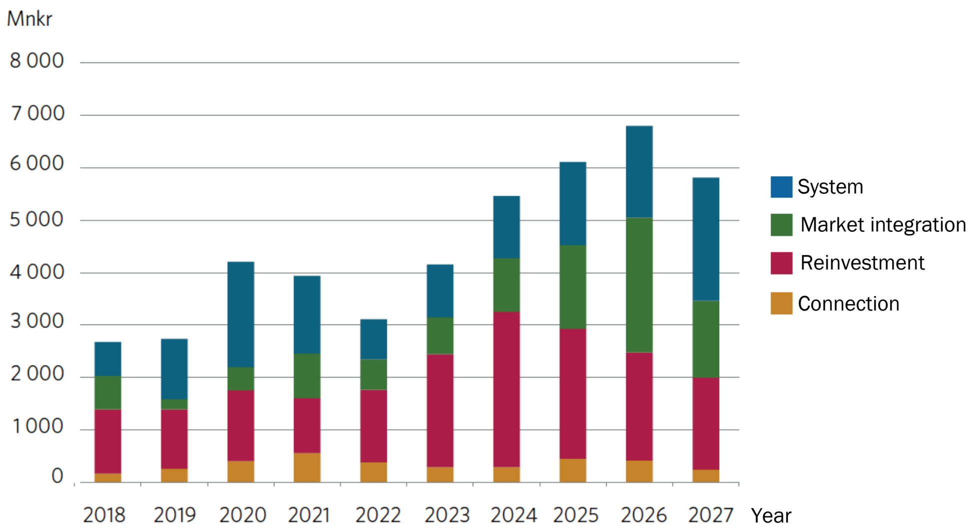
[6] Since 2011, Sweden has been divided into four bidding zones. The division of bidding zones aims to make congestion in the transmission network visible to the market participants, where price differences occur when transmission capacity is fully utilised.

System expansion
System expansion consists of investments in the transmission network that are made to strengthen or maintain operational reliability and thus long-term security of supply in the electricity system, even if the investments cannot be related to any specific connection or any specific market need. The need for these investments arises as a result of ongoing changes in, for example, generating mix, consumption patterns and power flows.

Reinvestments
Svenska kraftnät is responsible for meeting society's needs for a robust transmission network by maintaining the technical function with continued high personal safety, high availability and low environmental impact.

Figure 3 shows Svenska kraftnät's overall assessment of how the investment need for the transmission network will develop during the period 2018-2027. The costs of market integration and reinvestments are expected to increase slightly from 2023.

Figure 3. Svenska kraftnät's investment needs 2018-2027 linked to system expansion, market integration, reinvestment and connection of new electricity generation, expressed in SEK millions.



Source: Svenska kraftnät (2017).

2.4 Svenska kraftnät's financial framework

This section describes the commercial framework that affect Svenska kraftnät's activities.

Required rate of return on investment and investment and borrowing framework

The required rate of return on investment determined by the state for Svenska kraftnät is formulated so that Svenska kraftnät should achieve a return on adjusted equity after tax equivalence of 6 per cent over one economic cycle and a debt to equity ratio of no more than 115 per cent for 2017. Since 2010, Svenska kraftnät has achieved a return on investment higher than six per cent[7] every year to 2016 and in 2013-2017, the return on investment was 7.9 per cent on average. [8] This means that the stipulated required rate of return on investment has been achieved with a good margin.

As currently formulated, the required rate of return on investment stipulated by the state does not take the instruction that the transmission network should be expanded based on cost-benefit analyses into account. This could lead to Svenska kraftnät choosing not to carry out investments that are welfare-improving for society unless they also meet Svenska kraftnät's required rate of return on investment.

Every year, the Parliament takes decisions on the investment and borrowing framework for Svenska kraftnät on proposals from the Government. The basis for the decision is Svenska kraftnät's investment and financing plan, which outlines the investments planned for the following four years and how these shall be financed. Investments over SEK 100 million are described in brief. Results from the cost-benefit analyses that Svenska kraftnät is commissioned to carry out are not reported, nor is there any other supporting information to justify the investments (Swedish National Audit Office (Riksrevisionen), 2016). The Swedish National Audit Office (Riksrevisionen) states that the Parliament and the Government have so far approved the investment plans and loan frameworks that Svenska kraftnät has proposed without a thorough review, and thereby considers that, in practice, Svenska kraftnät has not had any binding investment or loan restrictions (Riksrevisionen 2016). Furthermore, the Swedish National Audit Office (Riksrevisionen) states that the investment framework that the Parliament makes decisions on includes investments that are at the planning stage, where the conditions have not been fully investigated. The levels requested by Svenska kraftnät will not be adjusted down, even if the investments are delayed or cancelled.

Revenue cap regulation and congestion charges

Ei makes decisions on revenue caps according to the revenue cap regulation. Exactly as with other electricity grids, the transmission network is a natural monopoly. The purpose of the revenue cap regulation is that the electricity network companies will receive coverage for the costs incurred for running an efficient electricity grid business without the customers having to pay too much for the network service. The revenue cap is based on the capital base and the relevant costs that Svenska kraftnät has during the supervisory period, including investments. In the revenue cap, the regulatory capital base is calculated based on the current market value or replacement value, while the Government's required rate of return on investment for Svenska kraftnät are based on the historical book value after depreciation. The historical book value of the largely decades-old transmission network is approximately SEK 21 billion, while the replacement value is approximately SEK 57 billion. This means that the regulated revenue cap will be high and not fully utilised (Swedish National Audit Office (Riksrevisionen), 2016).

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[7] Svenska kraftnät's Annual Report for 2016 (Svenska kraftnät, 2017).

[8] Svenska kraftnät's Annual Report for 2017 (Svenska kraftnät, 2018).

Congestion charges

Svenska kraftnät also has revenues from congestion charges that arise when the demand for transmission capacity between bidding zones is greater than the allocated transmission capacity. These revenues should together with direct costs caused by counter trade in order to ensure the operational reliability of the electricity system be reported separately. According to Article 16 (6) of Regulation (EC) No. 714/2009 of the European Parliament and of the Council, congestion charges must mainly be used for the following purposes:

a) to guarantee that the allocated cross-border capacity is actually available, and/or
b) network investments to maintain or increase transmission capacity, in particular those relating to new interconnections.

In theory, this mechanism ensures that investments in new transmission capacity between bidding zones are carried out until the price differential (i.e. the marginal increase in the congestion revenue at increased transmission capacity) is equal to the marginal cost of the new transmission capacity.[9] Svenska kraftnät's incentives for transmission network expansions between bidding zones therefore differ from internal network expansions within bidding zones. Congestion charges may provide incentives in the first case, while the revenue cap combined with system responsibility creates incentives in the latter.

[9] In practice, investments in increased transmission capacity take place at intervals of many years. When the investments finally take place, they tend to be large, and therefore anything but marginal. The increased transmission capacity will affect the price differential, and thus the congestion charges between bidding zones. (Joskow & Tirole, 2005; Hogan, 2018)

3 When should a cost-benefit analysis be carried out, audited and considered?

In this chapter, we describe Svenska kraftnät's decision-making process for investments in the transmission network and Ei's permit granting process when considering an application for a network concession. A central issue is the extent to which a cost-benefit analysis forms the basis for decision-making throughout the process. The review of the decision-making process is followed by a comparative analysis of other countries and how their respective permit-issuing authorities proceed in order to ensure that the investments are welfare-improving for society.

After that follows a section containing Ei's proposals for when cost-benefit analyses should be performed and then considered in the context of the permit granting process for a network concession. Since it is a question of binding proposed amendments, the section has the same structure as propositions.

3.1 Svenska kraftnät's decision-making process

In 2016, the Swedish National Audit Office (Riksrevisionen) found shortcomings in Svenska kraftnät's decision-making process and recommended that the Government clarify the role and responsibility of the Board in investment decisions. The Swedish National Audit Office (Riksrevisionen) also recommended that the Board should base its investment decisions on cost-benefit analyses to an increasing extent.

At the end of 2017, Svenska kraftnät's Board approved a new decision-making procedure for the investment process.[10] The purpose of the new procedure is to strengthen the role of the Board and ensure earlier transparency of the decision-making process. This is expected to lead to a greater scope for the Board to discuss benefit assessments and alternative solutions for strategic investments. The Board shall also be supported by giving the Director General more power to make decisions on investments not deemed to be of a strategic nature for Svenska kraftnät.

The new decision-making procedure involves two main changes in Svenska kraftnät's decision-making process.[11] First of all, the criteria for which projects require Board decisions and which can be delegated to the Director General have been changed. The categorisation was previously based on a financial limit of SEK

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[10] Svenska kraftnät, Case no. 2017/3204.
[11] See the Swedish National Audit Office (Riksrevisionen) (2016), Appendix 8 for a description of the decision-making process prior to the new decision-making procedure introduced at the end of 2017.

25 million but will continue to be evaluated based on whether or not the project is of a strategic nature. In accordance with the new decision-making procedure, the Board shall decide on projects such as "*investments in new power lines*[12]*, reinvesting in power lines with sensitive accessibility, projects of a strategic nature, and investments in new technology of a significant character*". (Svenska kraftnät, Case No. 2017/3204)

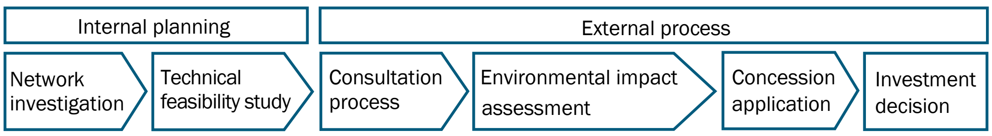
Projects that include *"reinvesting in power lines with sensitive accessibility"* have been included because they can have a major impact on the general public and other external parties. Projects that are not considered to be of strategic importance normally include connection cases, renewal of stations, renewal of power lines with uncomplicated accessibility, management projects, cost projects and similar projects.

Secondly, the number of decision-making points is increased for projects that are assessed as strategic from the previous two to three occasions per project. The new decision-making procedure consists of:

1 a policy decision,
2 decision on a concession application (new), and
3 an investment decision.

As the number of decision-making points has been increased, the initial policy decision can be made earlier in the process. Figure 4 provides an overview of Svenska kraftnät's decision-making process for investments in the transmission network.

Figure 4. An overview of Svenska kraftnät's decision-making process for investments in the transmission network.



Source: Own processing, the figure has been checked with Svenska kraftnät.

Previously, policy decisions were normally only made after a detailed technical feasibility study had been carried out. This meant that Svenska kraftnät officials had already investigated what should be done as well as how it should be implemented. An early submission so that the policy decision is taken before the technical feasibility study in Figure 4 means that the board has a greater influence over the impact of a project and what alternative solutions should be considered. Also new is that a complete cost-benefit analysis shall form the basis as early as the policy decision.

By introducing a decision on a concession application, the Board confirms the conclusions of the consultation, and any significant comments made during its

[12] The term "power lines" refers to transmission network connections of all types of technical design, such as overhead power lines, underground cables or sea cables. In addition, the installations required for connecting the power lines to the rest of the transmission network are also included, such as station operations, terminal location or converter station.

progress, and acknowledge that the application for a concession can be submitted. A decision on a concession application also means that the Board confirms that the project's purpose and objectives are still relevant and that the benefits exceed the costs. As a basis for this, an updated cost-benefit analysis and cost estimate are presented, based on results from the consultation and other planning work.

With the investment decision, the Board approves the signing of a contract with the contractor(s) awarded the contract during the procurement. An investment decision means that the Board confirms that the project's purpose and objectives are still relevant and that the benefits exceed the costs. The supporting information consists of an updated cost-benefit analysis and cost estimate based on results from, for example, supplementary surveys and the completed procurement.

Svenska kraftnät's financial management and economic framework conditions.

Svenska kraftnät is a state enterprise that aims to carry out socially useful transmission network activities and generate returns on investment for the treasury. The Government exercises its authority by means of instructions and assignments to the public authorities, and also decides on financial targets, dividends and debt to equity ratios. The Government also appoints the Board and Director General. Svenska kraftnät's Board of Directors makes decisions on the budget for future new investments and reinvestments, within the framework of Svenska kraftnät's investment plan. According to the Swedish National Audit Office (Riksrevisionen) review (2016) the Government Offices consider that it is the responsibility of the Board to ensure that there is a sound and sufficient basis for decision-making on investments.

Svenska kraftnät's guidelines for cost-benefit analyses

According to the instructions from the Government, Svenska kraftnät shall develop the transmission network for electricity based on cost-benefit analyses, § 3, 1 Code (2007:1119), with instructions for the state enterprise, Svenska kraftnät. In 2014, Svenska kraftnät drew up internal guidelines for how cost-benefit analyses should be designed and started work during 2017 to draw up formal guidelines. Svenska kraftnät states that it is awaiting the results of Ei's investigation before defining the final guidelines.[13]

In its new decision-making procedure that came into force at the end of 2017, Svenska kraftnät states that it systematically uses cost-benefit analyses for projects that are considered to be of a strategic nature. If the project is assessed to be of a strategic nature, the cost-benefit analysis is carried out during an early stage of the decision-making process. The cost-benefit analysis will then be updated based on the results of the consultation. Since it has not yet been determined where a certain power line will be routed, the environmental impacts can only be described in general terms. In conjunction with an application for a concession, an environmental impact assessment (EIA) is conducted of the final route of the power line, but as a rule the cost-benefit analysis is not updated.

[13] E-mail conversation with Mira Rosengren Keijser and Hilda Dahlsten, Svenska kraftnät.

The new decision-making process has no formal guidelines for how cost-benefit analysis should be used for investments that are not of a strategic nature. Examples of such investments are the renewal of power lines and stations approaching the end of their service life, provided that the power line does not have "*sensitive accessibility*". Svenska kraftnät has previously stated that "it is usually quite clear that reinvestment can be justified from a socio-economic perspective" (Svenska kraftnät, 2015, p. 20). Based on this, Ei cannot rule out the fact that investment decisions are taken based on the project's potential for welfare-improving, but the statement suggests that a thorough analysis has not been carried out. Expansions aimed at facilitating connections to new generation are managed in a similar way, where the network company is obliged to connect in accordance with Chapter 3. § 6, first paragraph of the Electricity Act. Svenska kraftnät states that it cannot make its own assessment of the potential for welfare-improving of the generation connection. In these cases, Svenska kraftnät's analysis is aimed at identifying the measures that facilitate the connection of the new generation at the lowest socio-economic cost but with maintained operational reliability (Svenska kraftnät, 2015).

Svenska kraftnät states that cost-benefit analyses have gained greater influence in its decisions in recent years. However, guidelines for how the cost-benefit analysis should be designed are not governed by any regulations or instructions. On the other hand, Svenska kraftnät follows the statements of the Nordic Council of Ministers that the Nordic system operators should make investments that are welfare-improving from a Nordic perspective.

The decision-making process for joint investments within the EU

European Union law constitutes a framework that Svenska kraftnät must comply with for certain types of investment in increased transmission capacity. All system operators of electricity transmission systems shall cooperate at Community level through ENTSO-E[14] in order to ensure that the internal electricity market in the EU is fully operational and to promote cross-border trade and ensure optimal management, coordinated operation and sound technical development of the European electricity transmission network (Article 4 Regulation (EC) No. 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges of electricity and repealing Regulation (EC) No. 1228/2003).

Every two years, ENTSO-E draws up a community-wide network development plan for the transmission network (Ten Year Network Development Plan - TYNDP). The purpose of the ten-year plan is to identify which investments in the transmission network are welfare-improving for Europe and is based on common model descriptions of the integrated network, development scenarios and a European supply forecast (Swedish National Audit Office (Riksrevisionen) 2016, Appendix 8).

[14] European Network of Transmission System Operators for Electricity - ENTSO-E.

Projects listed in TYNDP can be named as projects of common interest (PCI). According to Regulation (EU) No. 347/2013[15], ENTSO-E shall establish a method for a harmonised energy system-wide cost-benefit analysis at EU level for projects of common interest in the EU. Amongst other things, this relates to investments in the transmission grid for electricity if they are of cross-border importance. ENTSO-E has developed guidelines in accordance with the purpose of establishing a common framework for cost benefit analyses (ENTSO-E, 2015; ENTSO-E, 2016). Svenska kraftnät's international projects are included in the ten-year plan for the transmission network for electricity.

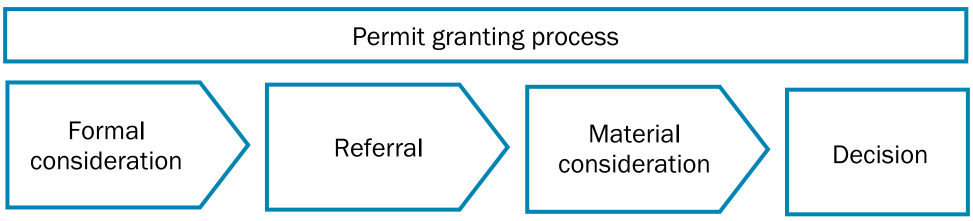
3.2 Ei's process of granting network concessions

To be allowed to build a transmission power line requires a network concession, i.e. a permit to build and use electrical mains power lines. The application for network concession can be made by power line or by area. Power lines with lower voltage levels are normally built based on network concession by area, while higher voltage levels are subject to network concession requirements by power line. Ei is the authority that considers applications for network concessions and in most cases has to decide whether to issue network concessions.

The permit granting process aims to ensure that the power line is appropriate, that the applicant company is suitable for conducting electricity grid operations and that transmission power lines are not constructed in such a way as to be harmful to people, animals or nature. The permit granting process includes both a legal review against the Electricity Act and a legal review against the rules of the Environmental Act. This section describes Ei's permit granting process. The relevant legal provisions of the Electricity Act and the Environmental Act are presented in Appendix 1.

Ei's permit granting process is divided into several steps. Figure 5 provides a simplified description of the different steps.

Figure 5. Permit granting process.



Source: Own processing.

Legal review

The legal review means that the application is considered against the contents of the statutory requirements in order to check that it is complete. What an application should contain is primarily governed by the Electricity Act and the

[15] Regulation (EU) No. 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans-European energy infrastructures and repealing Decision No. 1364/2006/EC and amending Regulations (EC) No. 713/2009, (EC) No. 714/2009 and (EC) No. 715/2009.

Electricity Code (2013:208). Amongst other things, the application must be in writing and include a technical description, a map and a cost calculation of the planned power line. Since a legal review must be made against the Environmental Act, the application must also contain information that facilitates such a review. The application must therefore contain an environmental impact assessment and information on how the general considerations in Chapter 2 of the Environmental Act will be managed.

The legal review can lead to three different outcomes:

1 The application is complete and no supplements are required.
2 The application is incomplete but the deficiency can be rectified by means of supplements.
3 The application is incomplete and the deficiency cannot be rectified.

Outcome 1 means that the case can be submitted. In outcome 2, Ei may request that the applicant company supplements the application. When a supplement is received, it is examined if the applicant has answered the questions Ei has asked or has submitted the requested material. When Ei has received all the material required for the application to be considered complete, the legal review will be concluded, and the case may be submitted. Outcome 3 means that Ei makes a decision on rejection. A deficiency that is due to inadequate or incorrect preparation of the application is difficult to rectify by means of supplements. For example, there may be deficient or incorrectly conducted consultation.

Referral

When a case has undergone the legal review, it shall be sent for referral. Some referral bodies are mandatory in accordance with the Electricity Code and must always receive an application for referral. Ei also takes a position on whether the case needs to be submitted to additional stakeholders. The additional stakeholders in question depend on the interests involved in the individual case, for example, the National Electrical Safety Board for technical safety issues. If the activities can be expected to have significant environmental impact, the application must also be published in an announcement. Ei can also choose to ask targeted questions to any of the referral bodies if there is something in particular in the application that Ei wants them to give an opinion on. In this way, Ei can take into account the expert competence of the referral bodies in certain areas as well as their local knowledge.

Material review

The material review means that the content of the application is considered. Ei examines the actual circumstances of the case, such as the need for the power line, affected third parties and the way in which they are affected. Ei also examines the expected consequences that arises from the power line, which damage prevention measures are planned, what the referral bodies have said, etc. The material review also includes allowing the applicant company to respond to the referral opinions received if they have added something new to the case. Ei also takes a position as to whether additional information is needed to allow the application to be considered. In such cases, Ei requests the company to supplement the application.

It is primarily during the material review that the environmental assessment is concluded.

Decision

When the material review has been completed, a decision can be made on the case. In addition to the general condition that the company is bound to take all the measures it has undertaken in the application documents, Ei has the opportunity to introduce additional conditions into the decision. If the application relates to a cross-border connection, Ei cannot make a decision. Ei then submits an opinion to the Government that decides on the case.

If the activities can be considered to lead to a significant environmental impact, the decision is published in an announcement. A decision on a network concession for a transmission network power line is appealed to the Government. Decisions regarding network concessions for cases not related to a transmission power line are appealed to the Land and Environment Court.

3.3 Decision-making and permit granting processes in other countries

An international comparison shows that there are several ways of using cost-benefit analyses in the decision-making process for investments in the transmission network and in the process of granting network concessions. Requirements for cost-benefit analyses are varied to a degree in the decision-making and permit granting processes. Ei has chosen to analyse the same countries as the Swedish National Audit Office (Riksrevisionen) in its report (Riksrevisionen, 2016). The reason for this is that in the decision-making or permit granting processes in selected countries, a cost-benefit analysis is carried out with a clear purpose.

The decision-making process in Norway

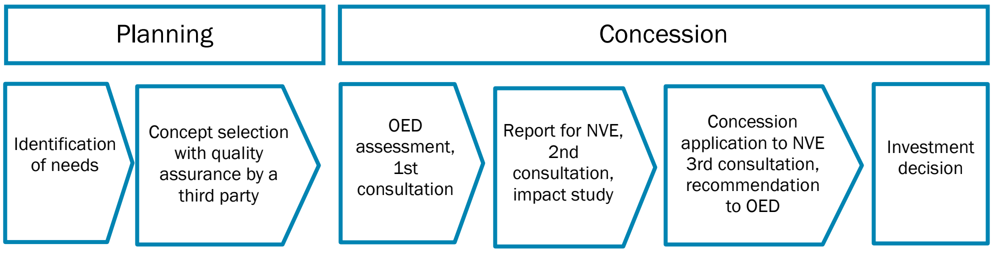
Statnett is both owner and system operator of the Norwegian electricity transmission system. Statnett is wholly owned by the Norwegian state. The supervisory authority is the Norwegian Water Resources and Energy Directorate (NVE). Amongst other things, Statnett's activities are regulated in the Energy Act which prescribes that generation, conversion, transmission, trade, distribution and use of energy takes place in an economically efficient manner, taking into account how public and private interests are affected. The Ministry of Petroleum and Energy (OED) is the permit-issuing authority for concessions.

Norway has introduced a so-called public concept selection investigation in which various options for solving an investment need are evaluated (Concept Selection Investigation, KVU). The purpose of the KVU is to facilitate early transparency for stakeholders and decision-makers in order to allow them to influence which project is implemented. In this way, only projects that are assessed as feasible will undergo the entire decision-making process. The KVU also contains requirements for an independent third party to assure the quality of public concept selection investigations that concern major investments in the transmission network. A major investment in the transmission network refers to investments on the 300 kV network, with a distance of at least 20 km. The Norwegian Parliament has also requested a development plan for the transmission network, presented once per parliamentary term, i.e. every four years.

The Norwegian legislature has given OED an authorisation to determine how the public presentation should be conducted and what the concept selection should include, including an opportunity to demand an independent auditor to assure its quality. OED has therefore drawn up guidelines for how an independent audit should be conducted for major investments in the transmission network (Ministry of Petroleum and Energy, 2013). Amongst other things, the guidelines mean that network companies are responsible for the auditing of the KVU. In practice, this means that the network companies procure a consultant with the specific competence required for conducting the audit.

The decision-making process in Norway starts by identifying needs and the concept selection, see Figure 6. Before submitting an application to the ministry, the applicant (in practice Statnett) must conduct a conceptual evaluation with quality assurance by an independent auditor. Following this, the concession procedure begins by means of a first consultation with the ministry. After that, a consultation will take place with NVE. The notification to NVE must include a plan for implementing the project, a statement of possible alternatives, a summary of the KVU and an environmental impact investigation. After this, the application is

Figure 6. Chart of Norway's decision-making process for investments in the transmission network.



Source: Swedish National Audit Office (Riksrevisionen) (2016), own processing.

submitted to the OED for consultation before the Government takes a decision on a concession. Statnett's Board takes the final investment decision.

The independent auditor will audit the network company's investigations and make a separate analysis where the various options are evaluated in relation to each other (Ministry of Petroleum and Energy, 2012). The work shall take place in dialogue with the network company and the company shall have the opportunity to make changes to its KVU, based on comments from the auditor before the audit report is submitted to the OED. The final audit report shall include any changes the network company has made in its KVU.

In a telephone interview conducted by Ei with representatives of OED (26 October 2017) it emerged that the quality of Statnett's cost-benefit analyses has improved after the introduction of quality assurance by an independent auditor. However, the quality assurance has generally not resulted in any significant changes to the proposals. Whether or not the improvements in the supporting documentation are a direct result of the input during the quality assurance process, or whether Statnett has conducted improvement work in the knowledge that the investigations will be subject to legal review, is not established. There are concerns that the auditors, who are private consultants, are not sufficiently independent in relation to Statnett.

The decision-making process in the Netherlands

TenneT is a group that owns and operates a transmission network of more than 22 000 km in Germany and the Netherlands. TenneT's assignment in the Netherlands is to ensure reliable and safe transmission of electricity. The Government in the Netherlands is responsible that investments in the network is for the benefit of the public interest, i.e. that they ensure a reliable, affordable and sustainable power supply.

The decision-making procedure can be briefly divided into a planning phase and a project phase. What is worth noting is that the planning phase begins with centralised planning, which is justified by the shortage of land and the need for collaborative planning of multiple infrastructures. The centralised planning also includes a preliminary environmental impact assessment for the various sites.

Once the planning phase is complete, the project phase begins with the concession and permit granting process. Also conducted at this stage is a more detailed environmental impact analysis as well as consultations with regional authorities and stakeholders, amongst others. After the project has been completed, the Dutch regulatory authority evaluates whether TenneT has chosen the most economical solution based on certain general guidelines and whether the measures could have been implemented in a more cost-effective way.

The Dutch equivalent to the Swedish National Audit Office (Riksrevisionen), the Dutch Algemene Rekenkamer, has criticised the decision-making processes that precede an investment in the transmission network, where the ministerial department and supervisory department have demonstrated deficiencies in their evaluation of cost-effectiveness, amongst other things, according to the audit. The decision-making processes have undergone a review that can be expected to lead to new legislation. (www.tennet.eu)

The decision-making process in the UK

National Grid PLC is a private company that owns the transmission network in England and Wales. In Scotland, the transmission network is owned by Scottish Power and Scottish Hydro Electric. National Grid is system operator of the electricity transmission system and is responsible for efficient operation, development and planning of the UK transmission network.

The supervisory authority in the UK, Office of Gas and Electricity Markets (Ofgem), develops an overall plan for National Grid. The aim of the plan is to ensure transparency and commitment from stakeholders on issues regarding the development of future system requirements and the investments necessary to meet these requirements. Each year, in cooperation with other stakeholders and market participants, National Grid goes through three processes which involve the following:

1 develop four long-term scenarios
2 draw up a ten-year plan
3 identify operational challenges in the medium term.

The decision-making process begins with a planning phase with an analysis of future needs for power transmission and the policy objectives to be met. Based on Processes 1 and 2 above, a needs analysis is conducted and when completed, National Grid develops an overall investment concept which is presented to the owner of the transmission network.

The implementation phase begins with detailed planning based on the concept developed by National Grid. In this stage, the planning consists of the transmission network owner developing detailed investment options as well as a cost-benefit analysis for each one. The cost benefit analysis takes into account alternative measures, such as alternative routes, technology options, etc.

The investment plans of the owners of the transmission network must be approved by Ofgem and in connection with the consideration of the revenue cap, Ofgem takes a position on whether the cost-benefit analyses, environmental impact analyses and, where appropriate, cost-benefit analyses are adequate. Ofgem then conducts its own analysis and, in the case of major investments, the authority also conducts a more comprehensive analysis of needs and measures. After the investment plan has been approved, supervision of the implementation is performed by Ofgem. There is no specific requirement that National Grid or the owners of the transmission network conduct a cost-benefit analysis, but Ofgem requires that all investments must be supported by cost-benefit analysis, environmental impact analysis and technical analyses.

The decision-making process in California, USA

The Federal Energy Regulatory Commission (FERC) is the federal authority that regulates the transmission network and wholesale trade between the states. FERC also issues concessions for certain intergovernmental transmission network power lines. The European equivalent of FERC is ACER where the difference is that FERC is governing and ACER is only indicative.

The North American Electric Reliability Corporation (NERC) is a non-profit company that works with electricity market participants and stakeholders to set standards for safety margins in the electricity system, accrediting and training network operators across North America (i.e. also Canada and Mexico). NERC has a mandate from FERC to ensure that these standards are followed in the USA.

Western Electric Coordination Council (WECC) coordinates the electricity grid across western USA, which is synchronously interconnected across state borders. Amongst other things, this means that WECC coordinates long-term transmission network planning with regional system operators, market participants and regulatory authorities.

California Public Utilities Commission (CPUC) approves concession applications for transmission power lines in California as well as regulates generation and approves network tariffs for distribution networks.

The system operator for California's transmission network, the California Independent System Operator Corporation (CAISO), is a publicly non-profit utility company responsible for the electricity supply to 30 million end customers. CAISO owns neither electricity grid nor production capacity but is responsible for how the transmission network is organised. Several authorities interact with CAISO to ensure security of supply and market efficiency, and to achieve the energy policy goals for California. In the planning of the transmission network, CAISO follows the guidelines set by NERC and WECC, but interprets and adapts these to the conditions prevailing in California.

CAISO's internal decision-making process consists of three phases. The first phase aims at determining how the need for investment should be investigated and what general objectives should govern the planning. In the second phase, more concrete technical studies are conducted and CAISO gives opportunities to the general public to comment on significant issues. After the Board has taken a decision on the investment to be made, phase three begins, which can be described as a procurement phase. (California ISO, 2017)

Before CAISO applies for a concession, a cost-benefit analysis is conducted. According to CAISO's guidelines, it should contain the largest consumption at risk of disconnection, how long outages are expected to be, when outages may occur, total power demand that cannot be supplied, number of affected customers, and customer willingness to pay in order to avoid outages.

CPUC decides on concessions. Once an application for a concession has been submitted, the investment is subject to a mandatory independent audit and consideration of needs. CPUC conducts an environmental impact investigation, consisting of an audit of the need and including a cost benefit analysis. A judge at the administrative court monitors CPUC's evaluation of the need and investment costs. The judge can decide on consultation, where the general public can submit comments, but also decide whether a process is needed to consider certain questions.

CPUC submits a written statement of the environmental impact investigation to the judge and then prepares a supporting documentation for decision-making that contains information from the environmental impact investigation as well as information on the effects of the proposed project and the project options evaluated by CAISO. After a referral and comment period, CPUC votes on whether the main proposal or any alternative should be granted a permit. (www.caiso.com)

Summary of the permit granting process in other countries

The countries studied have chosen different solutions in order to ensure that the cost-benefit analysis is conducted. An independent audit is included in most of the countries, e.g. in Norway and in California. In the UK, the process takes account of stakeholder comments on a regular basis by making it a formal part of the decision-making process.

3.4 Ei's proposal on timing and process

This section describes the proposals for legislative regulation of when cost-benefit analyses should be conducted on investments in the transmission network and what considerations have been made. The proposals are drawn up based on the review of the current decision-making process for investments in the transmission network and how it is done in other countries. There is no obvious model to follow from the international comparison and the proposals have been adapted to Swedish conditions. The purpose of Ei's proposals is to ensure that:

- investments in the transmission network are welfare-improving
- the cost-benefit analysis is of high quality
- an audit is conducted of the cost-benefit analysis at an early stage in Svenska kraftnät's decision-making process, and
- Svenska kraftnät's investment plans undergo public scrutiny.

A permit-issuing authority should generally be restrictive in giving advance notice. For this reason, Ei is limited in how early in the decision-making process the authority can conduct assessments. Ei can therefore not take on a similar role as NVE has in Norway. In order to ensure that Svenska kraftnät conducts a cost-benefit analysis at an early stage in the decision-making process, the timing should therefore be regulated in Svenska kraftnät's own guidelines.

Coordination of major infrastructure projects does not currently take place to the extent desired (compare with the Netherlands, for example). Exactly how such coordination should take place is beyond the scope of the assignment, but Ei recommends the Government to continue with the issue and commission the authorities and state enterprises affected (e.g. the Swedish Transport Administration and Svenska kraftnät) to design and implement a method for this. Our recommendation is that coordination and dialogue meetings take place as early as possible in the planning process.

How does the cost-benefit analysis relate to the environmental assessment?

The permit granting process for network concessions includes parallel assessments resulting from different regulatory frameworks. The Environmental Act and Electricity Act apply in parallel, and a decision on a network concession in accordance with the Electricity Act does not prevent a legal review based on other regulations in the Environmental Act or other legislation. Amongst other things, this means that a decision in accordance with the Electricity the Act does not affect other assessments in accordance with the Environmental Act and that the supervisory authorities, based on Chapter 26, § 9 of the Environmental Act may issue injunctions and prohibitions even if Ei has accepted certain conditions in the permit granting process (compare prop. 1997/98:90 pp. 147, 150 f and 200, amongst others). The cost-benefit analysis can therefore not be weighed against the environmental assessment, as they consist of two separate assessments. The environmental assessment follows the rules of the Environmental Act and the cost-benefit analysis would be part of the consideration of the power line's potential for welfare-improving according to the Electricity Act. The power line must meet the requirements in both the Environmental Act and the Electricity Act for an application for a network concession to be granted. However, this does not prevent the inclusion of environmental impacts in the cost-benefit analysis.

What requirements should there be for cost-benefit analyses when considering a network concession?

Ei's proposal: A requirement is introduced that cost-benefit analyses should be included when an application for a network concession for transmission network power lines is submitted to Ei.

A network concession may only be granted for a transmission power line on condition that the investment is welfare-improving, with the option for exemption if special reasons exist. The same also applies for a reassessment of an existing network concession.

The Government or other authority is authorised to issue regulations on requirements for the content of the cost-benefit analysis, the effects to be included in the assessment, and how it should be presented to the public.

The Electricity Act's requirements for a power line to be suitable from a public point of view can be interpreted as meaning that Ei could require a power line to be welfare-improving in order to grant an application for a network concession. However, there is no regulation or instruction that guarantees that Ei may use or examine any cost-benefit analysis as a basis for decision-making in the consideration of an application for a network concession for a power line.

Ei therefore proposes the introduction a provision in the Electricity Act so that it is clear that a network concession for a transmission power line can only be granted if the investment is welfare-improving, unless special reasons exist. Special reasons may be that there is a connection obligation or that the investment is required to meet the criterion for operational reliability (N-1 criterion[16]). In these cases, the cost-benefit analysis should also show that the legal requirement is met at the lowest possible cost to society, even if the investment is not welfare-improving. A requirement for special reasons is assessed to be adequate protection since a requirement for exceptional circumstances would lead to the possibility for an exemption to be far too restrictive.

The requirements set for the application for a new network concession should also apply for a reassessment of an existing network concession.

If the requirement of potential for welfare-improving is not met and no special reasons exist, the application for a network concession must be rejected. However,

[16] N-1 is an expression of an operational reliability level, which means that an electricity system can withstand a sudden loss of one individual main component (production unit, power line, transformer, busbar, consumption, etc.). Similarly, N-2 means the failure of two individual main components.

there must be the opportunity to rectify shortcomings in the cost-benefit analysis as far as possible by means of supplementing.

Ei proposes an authorisation to the Government or authority appointed by the Government to issue regulations on how the cost-benefit analysis should be designed, what effects should be included in the assessment, and how it should be presented to the public. Ei considers that the right to issue regulations should be re-delegated to Ei, as these rules will be quite detailed. In addition, the rules will need to be amended with the development of the methods for cost-benefit analyses. Therefore, it is more appropriate that this governance takes place in the form of an instruction rather than by means of a regulation.

When should a cost-benefit analysis be drawn up and subject to consideration?

Ei's proposal: A general cost-benefit analysis should be conducted before Svenska kraftnät undertakes the technical feasibility study. A more detailed cost-benefit analysis based on the general cost-benefit analysis should also be submitted and subject to consideration by Ei in connection with the application for a network concession.

Several stakeholders have suggested that Svenska kraftnät's process is perceived as non-transparent and that public environmental considerations are not considered when making decisions on investment projects. A cost-benefit analysis should therefore be conducted at an early stage.

Ei proposes that two cost-benefit analyses should be carried out: a general cost-benefit analysis before the technical feasibility study mentioned by Svenska kraftnät in the internal decision-making process, and a detailed cost-benefit analysis that is submitted to Ei as part of the application for a network concession.

We have considered two different options for how the specific cost-benefit analysis should be subject to consideration by Ei.

The option "assessment within the framework of granting network concessions" means that the assessment of the cost-benefit analysis will be an integral part of the granting process. Parallels can be drawn to how the environmental assessment is designed (see Appendix 1). In the same way as the applicant is responsible for conducting consultations and drawing up the environmental impact assessment before submitting an application for a network concession, Svenska kraftnät should be responsible for carrying out the cost-benefit analysis before submitting the application for a network concession to Ei. All parts are then assessed within the granting process in a similar way to how the environmental assessment and the approval of the environmental impact assessment are performed today.

The option "assessment prior to the process of granting network concessions" means that the cost-benefit analysis is assessed and approved in a separate process before the application for a network concession is submitted to Ei. An approved cost-benefit analysis will then be a requirement for an application for a network concession to be subject to consideration by Ei. Parallels can be drawn with the function currently filled by the county administrative board's decisions on significant environmental impact. The decision on significant environmental impact is taken before the application for a network concession is submitted to Ei. There is also a requirement that the decision must have been taken in order for the process of granting network concession to start.

The latter option means that a predefined and approved cost-benefit analysis will be a formal requirement for what an application for a network concession should contain. However, prior assessment of the cost-benefit analysis may conflict with the Environmental Act's rules on consultation. In addition, a division of the assessment risks becoming less time-efficient. Ei therefore considers that the option "assessment within the framework of granting network concessions " is the most appropriate.

Since the proposal is for the general analysis to be performed before the application for network concession is submitted, and since this analysis will never be reviewed by Ei, we do not submit any proposal for the regulation of this analysis in the Electricity Act or Electricity Code. How this analysis should be conducted should instead be determined by Svenska kraftnät's internal guidelines.

How should a cost-benefit analysis be audited and presented to the public?

Ei's proposal: The general cost-benefit analysis should be audited by a third party that is independent of Svenska kraftnät. Any requirement that the independent third party should submit a formal approval of the cost-benefit analysis has not been introduced.

Svenska kraftnät should present the general cost-benefit analysis and the auditor's report to the public, where any deviating assessments should be included.

According to the assignment, Ei should investigate whether there is a need for an independent third party to perform cost-benefit analyses as a complement to Svenska kraftnät's assessments.

It is important that decisions on major investments for increased transmission capacity for the transmission network are based on good data. In the current situation, it is undoubtedly Svenska kraftnät and Ei that have the greatest competence and experience in cost-benefit analyses for different types of network investments. Against this background, it has also been proposed that Ei could be a suitable party for implementing complementary cost-benefit analyses in Motion 2016/17:3675: "Parliament supports what is stated in the motion, that the Government should commission an independent third party such as the Swedish Energy Markets Inspectorate to perform cost-benefit analyses for network investments, and gives notice of this to the Government."

Our assessment is that Ei should not assess the general cost-benefit analysis. The analysis is conducted at an early stage in Svenska kraftnät's decision-making process and the result may be subject to change during the course of the process. It is important that Ei gives consideration to the issue of the potential for welfare-improving only on one occasion, and that the consideration then concerns a cost-benefit analysis that is specific to the planned route.

The question is whether there is any other authority that can perform complementary cost-benefit analyses at an early stage in Svenska kraftnät's decision-making process. There are, without doubt, several authorities with the knowledge and competence on cost-benefit analyses, but there is no authority that has more in-depth and more specific knowledge on cost-benefit analyses for investments in the transmission network than Svenska kraftnät and Ei. Both Svenska kraftnät and Ei work continuously with these issues, both nationally and internationally.

In order for the benefits of the complementary cost benefit analyses to outweigh its costs, they need to be performed with at least the same, but preferably more knowledge and insights than already possessed by Svenska kraftnät and Ei, which will, in all likelihood, perform and assess the cost-benefit analyses.

In addition to the competence issue, there are a number of challenges related to an independent third party making its own estimates for investments in the transmission network. These challenges include which third party has the final preferential right of interpretation if the cost-benefit analyses come to different conclusions? Another challenge is the risk of a cumbersome and complex process with few gains if an independent third party is engaged in further calculations when Ei, despite the proposals now presented in detail, gives consideration to Svenska kraftnät's cost-benefit analyses in the process of granting network concessions.

The issue has also been discussed with the Swedish Agency for Public Management. In the report, Evaluation of different areas - An analysis of sector-specific evaluation agencies, the Swedish Agency for Public Management has analysed the conditions under which autonomous sector-specific evaluation agencies can be a cost-effective and efficient use of state evaluation resources (Swedish Agency for Public Management, 2014)[17].

The Swedish Agency for Public Management's assessment is that an independent third party for cost-benefit analyses may only be suitable if it can contribute to long-term knowledge development regarding cost-benefit analyses, if there is a need to continuously perform this type of cost-benefit analysis in a certain quantity sufficient to justify the additional costs, and if it is important to have additional access to independent and consistent analytical capacity in cost-benefit analyses. A prerequisite is that the analyses can be perceived as relevant, credible and useful.

Based on the analyses and interviews conducted, it is Ei's assessment that there is inadequate justification for establishing a whole new organisation in the form of a single evaluation authority to audit cost-benefit analyses for investments in the transmission network. On the other hand, we can see that there may be clear

[17] In Sweden, there are several autonomous evaluation authorities, such as IFAU (Institute for Evaluation of Labour Market and Education Policy), the Swedish Agency for Health and Care Analysis, the Swedish National Council for Crime Prevention, the Swedish Fiscal Policy Council, the Swedish Agency for Cultural Policy Analysis, the Swedish Social Insurance Inspectorate, the Swedish Agency for Growth Policy Analysis, the Swedish Council on Health Technology Assessment and Transport Analysis.

justification for an independent third party to audit Svenska kraftnät's cost-benefit analyses.

The advantages of an independent third party auditing the cost-benefit analyses are that it provides a control body for quality assurance of Svenska kraftnät's analyses. The independent third party should audit the analysis but not give any formal approval, since the final assessment should take place in the process of granting network concessions.

Ei should therefore not be involved in the selection of the independent auditor. This means that Svenska kraftnät should procure the third party that shall audit the cost-benefit analyses. Ei considers that this procedure will reduce bureaucracy, compared to the option where Ei appoints the auditor. It is important that the procurement is conducted in such a way that the auditor is independent of Svenska kraftnät. The fact that Ei will assess the cost-benefit analysis and the options that are evaluated should provide Svenska kraftnät with the incentive to set requirements for the independent third party so that the audit is of high quality.

In order to ensure transparency early on, the cost-benefit analysis and the auditor's report should be made known to the public at an early stage. Svenska kraftnät should therefore publish these before the application for a network concession is submitted to Ei. For example, the publication can be made on Svenska kraftnät's website.

Ei therefore proposes that Svenska kraftnät should publish the analysis and the auditor's report where any deviating assessments should be included.

Should consultation take place and in what way?

Ei's proposal: The specific cost-benefit analysis should be performed after consultation with the stakeholders affected.

How the consultation should take place may be further regulated by regulation or instruction.

During the work on this investigation, Ei has received several requests and suggestions for external parties to have the opportunity for insight into the process earlier than is the case today. Several stakeholders have suggested that they perceive Svenska kraftnät's process as non-transparent. From the international perspective in section 3.3, what is also evident is that a factor common to the countries that systematically use cost-benefit analyses in their decision-making processes is that they use various means to ensure an early insight into the process. Not only is it important that Svenska kraftnät has clear internal guidelines for how and when the cost-benefit analysis should be performed, it is also important to have a more open decision-making process at Svenska kraftnät.

Ei therefore proposes that the specific cost-benefit analysis should be drawn up after consultation. The consultation may include, for example, relevant market participants and stakeholders, owners of other infrastructure, county administrative boards and authorities.

Should there be exceptions from requirements for the potential for welfare-improving?

Ei's proposal: There should not be any general exceptions from the requirement of a cost-benefit analysis.

In its proposal for guidelines for cost-benefit analysis (2017), Svenska kraftnät states that "an overall assessment with cost-benefit analysis does not always need to be drawn up for investment. Exceptions apply to investments that are necessary to meet the criterion for operational reliability (N-1 criterion), connection obligation for new production, and when the investment amounts are so small that the resource requirements for implementing an overall assessment are unjustified." (Svenska kraftnät 2015, page 20).

Ei considers that there should not be any general exceptions from the requirement of a cost-benefit analysis. The purpose of the cost-benefit analyses is that decision-makers, permit issuers and other stakeholders should have access to transparent bases for decision-making.

For this reason, a cost-benefit analysis should always be included in the supporting documentation, even though the scope and focus of the analysis may differ from case to case. In some cases, the focus of the analysis will not be whether the measure should be implemented at all, but to answer the question of *how* the measure should be implemented in the most cost-efficient manner. This applies to connection obligation, for example, where there may be several different route options that give rise to different effects. The different options should then be analysed from an economic perspective. The most welfare-improving option should then be chosen. Even for the investments that Svenska kraftnät assesses as necessary to meet the N-1 criterion, there is likely to be a range of alternative solutions that should be analysed from a socio-economic perspective. In these cases, it may be appropriate to also consider alternatives to increased transmission capacity.

For reinvestments, there is reason to conduct an analysis of alternative solutions in order to assess the most economically efficient solution. An additional argument for why cost-benefit analyses should be performed even for reinvestments is that some reinvestments involve the need to build stand-by power supply in the form of completely new power lines that are only used for a short period of time.

There is an obvious risk that a threshold value linked to the requirement for when a cost-benefit analysis should be performed could be used strategically by means of the applicant underestimating the investment cost, or dividing the investment into several sub-projects in order to avoid the requirement that a cost-benefit analysis should be performed.

The cost-benefit analysis should therefore be performed regardless of the size of the potential investment. However, the scope of the analysis should be adapted to the investment to be made. For small investments, with negligible socio-economic consequences, the value of the majority of effects will be lower than the cost of the labour to analyse them. A cost-benefit analysis can then contain such a statement, with a clear justification for the measures not having any significant socio-economic consequences. This procedure also contributes to a transparent basis for decision-making.

4 Analysis framework

In this chapter we propose a framework to facilitate cost-benefit analyses of investments in the transmission network. We start by describing basic economic concepts and going through the theory, and then Ei's proposal is presented.

4.1 Socio-economic analysis

Socio-economic analysis is a broad category of analyses that are made to investigate the overall impact on society of various measures and changes, such as investment in infrastructure. Whereas private investors normally take into account only the accounting costs and revenue that the investment is expected to generate, a cost-benefit analysis aims to include non-priced effects of economic activities as well as correct the market prices if warranted (for example, regulated prices, administrative fees, and monopoly prices).

The purpose of a socio-economic analysis is to provide market participants, citizens, politicians, regulatory authorities and permit-issuing authorities with the basis for making well-founded decisions.

The socio-economic impact assessment is used to analyse the effects of a given proposal on society and how these effects are distributed across different parties in society. As far as possible, the effects should be described in economic terms but can also be expressed qualitatively. A socio-economic impact assessment may include different types of analyses such as a cost-benefit analysis and cost-effectiveness analysis.

A cost-benefit analysis can provide answers whether a measure is welfare-improving for society by identifying, quantifying and monetising the costs and benefits expected as a consequence of the proposed measures. On the other hand, a cost-effectiveness analysis can be used to analyse how a given target can be reached at the lowest possible cost. The cost-effectiveness analysis does not in itself contain an analysis of whether or not the given objective is economically efficient (i.e. the benefits of an objective outweigh its costs).

The bases of a cost-benefit analysis

A cost-benefit analysis is performed in several steps. Initially, investment alternative and reference option, also called status quo, must be defined. The investment option describes the measure planned for implementation. The reference option (status quo) can be either no measure at all or the measure to be taken if the investment option is not employed. The effects to be quantified and monetised for each year during the discounting period are the differences identified between the investment option and the reference option in terms of benefits and costs (see, for example, Boardman, Greenberg, Vining, & Weimer, 2017 and Hultkrantz, 2008).

When all net effects (benefits minus costs) expected to arise during the relevant time period are calculated, they must be expressed in terms of present value. This means that the stream of future costs and benefits must be converted to the value at the time of the investment. This is also called discounting and is calculated using a so-called discount rate. In general, costs that are incurred today are considered more burdensome than costs that occur in the future, and in the same way, benefits that occur today are more valuable than those that occur in the future.

Finally, the discounted costs and benefits are summarised, resulting in a socio-economic profit or loss.

4.2 The different parts of the analysis framework

This section presents the different parts of the analysis framework and describes the considerations made and Ei's proposal.

The discounting period

It must be clear regarding which discounting period is used for the cost-benefit analyses. A discounting period that is too short may mean that all costs are included but probably not all benefits if these occur after the end of the period; and in a discounting period that is too long, the potential for welfare-improvement by the investment may be overestimated.

The duration of the discounting period is often determined by the economic lifespan of the investment. Economic lifespan refers to the time it is expected to be profitable to maintain an installation instead of replacing it with a new one, taking into account operating and maintenance costs, capacity, technology development, functional requirements, etc. In general, the economic lifespan is shorter than the technical lifespan, which reflects the time it takes before the investment is completely unusable (Boardman, Greenberg, Vining, & Weimer, 2017).

It is difficult to specify a discounting period in absolute terms for the relatively wide range of investments facing Svenska kraftnät. For projects of common interest and TYNDP projects, the ENTSO-E Guidelines (ENTSO-E, 2015) state that the cost-benefit analysis should be calculated for a period of 25 years, and that the residual value should then be set to zero. This makes it possible to compare different projects. One problem with the relatively short discounting period is that the economic and technical lifespan of parts of the infrastructure involved is considerably longer, which means there is a risk of the analysis underestimating the benefits of the investment. As a supplement to the discussion about technical lifespan, it can be mentioned that concession decisions in Sweden apply until further notice, but there is also a possibility that the network concession will be reassessed after 40 years. There is thus a possibility that a new concession might not be awarded after 40 years, meaning the value of the asset would become zero. Based on a precautionary principle, the possibility of the concession being reassessed and not extended for some reason means that the discounting period should be set at 40 years, regardless of the economic lifespan of the investment.

The lifespan of different projects and investment options needs to be determined and clearly justified, since it can be assumed that the alternative solutions (for increased transmission capacity), such as batteries, have a significantly different lifespan from the main option. This partly complicates the cost-benefit analysis since re-investments must be made in order for the alternative to match the lifespan of the main option. In these cases, it is important that the analysis includes a discussion about the economic lifespan of different investment options, and assumptions about technological development and future transmission capacity requirements, amongst other things.

Varying depreciation times for different components complicates the cost-benefit analysis. One way to simplify the procedure and make the analysis practically feasible is to standardise the discounting period based on how the concession legislation is written and the risk that a renewed concession will not be issued on reassessment. In which case, this means that the discounting period should be set at 40 years.

Another important issue is how the construction period for the investment should be addressed in the cost-benefit analysis. Construction period means the time between the approval of the investment (when the concession is issued) and when the installation is ready for operation. For investments in the transmission network, the construction period may continue for several years, so it is important that the costs involved in the construction period are included in the analysis. There are rarely any benefits during the construction period and, at the same time, it is the period in which the investment costs for the project are incurred. The network concession period is not affected, even if the actual construction period continues for several years. A network concession thus applies 40 years from the date the network concession is granted, regardless of the construction period. It is therefore reasonable to include the construction period in the period for the socio-economic calculation. Since different options may have different construction periods, the construction period for one option may also affect the present value of the net-benefit of a project compared with its alternatives.

Ei's proposal: The discounting period for the cost-benefit analysis is 40 years from the date the network concession is issued. No residual value should be included in the analysis.

Investments with different lifespans

Different alternatives to conventional investments in increased transmission capacity, i.e. power line construction, often have a shorter economic lifespan compared with the conventional option. Two investments with different lifespans are not directly comparable to each other in the cost-benefit analysis. One way to make them comparable is to repeat the investment with shorter lifespan in the cost-benefit analysis until it has the same discounting period as the investment with the longer lifespan. For example, if investment A has a lifespan of 40 years while investment B has a lifespan of 20 years, investment B must be repeated twice in order to make it comparable to A.

A postponed investment in increased transmission capacity can have a value in itself due to uncertainties about environmental impact, technological development and the way in which the future need for electricity transmission and distribution evolves, which may affect customer valuation of security of supply, amongst other things. A postponed investment can thus be regarded as an option (Hogan, 2018). An evaluation of this "option" to be able to make a more informed decision in the future depends on many assumptions, and this type of option evaluation becomes extremely complex. There may also be additional benefits of temporary solutions because there is not necessarily the need to renew the investment when it expires. The value of this possibility, or "option", is additionally clear when there are uncertainties about which options are available at this particular point in time. For example, technological development may mean that there are better options available in 20 years (see Boardman, 2017, for a more detailed discussion).

Ei's proposal: The different economic lifespans of the investment options are included by repeating investments with a shorter lifespan in the analysis until the lifespans are comparable. The potential value of the option from postponing a conventional investment in the transmission network should be described qualitatively.

Sensitivity analysis

A cost-benefit analysis contains several uncertainties. The cost-benefit analysis should therefore be supplemented by sensitivity analyses that take into account uncertainties regarding future prices and costs, uncertainties regarding the monetisation of external effects, as well as uncertainties about which scenarios best describe the future electricity system and its generating mix, consumption patterns and transmission capacity requirements.

It is important that different scenarios are used to analyse the robustness of the investment with regard to different development trajectories and global macroeconomic factors. A minimum requirement for investments that are expected to affect the integration of the European electricity market is to use similar scenarios already used at European level in ENTSO-E's so-called ten-year plans (TYNDP). Here, however, there may be reason to add a scenario for specific national conditions.

Ei's proposal: Scenarios should be used for sensitivity analysis.

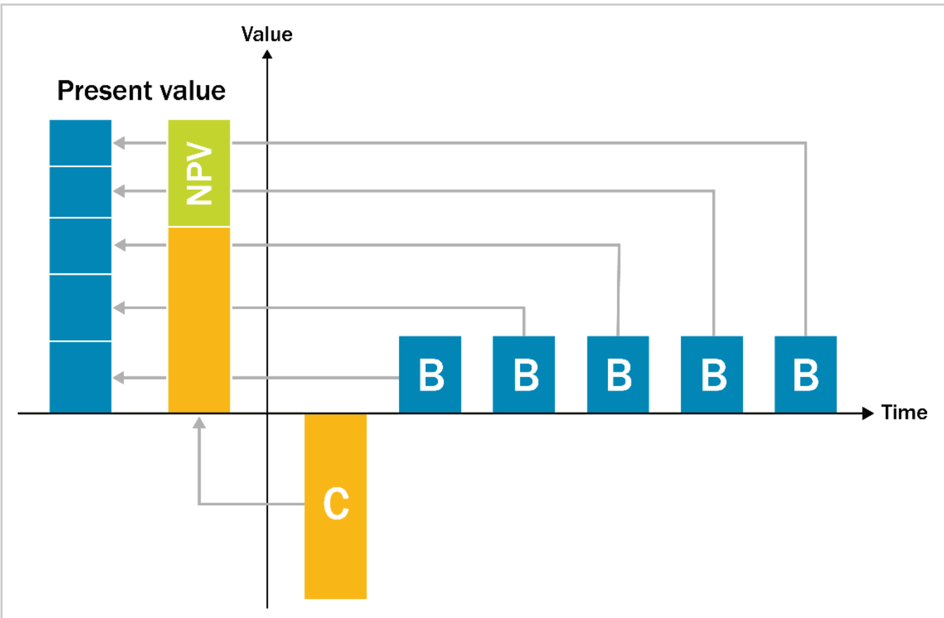
Discount rate

Before it is possible to make a balanced assessment of the net benefits of a project, costs and benefits must be discounted to one single point in time in order to be completely comparable. In order to be able to do that, a discount rate must be decided. The discount rate expresses the required rate of return on investment for the invested capital. For example, the discount rate is used for investment calculation and corporate valuation in order to make future cash-flow across different points in time comparable. The social discount rate expresses society's time preferences and, in other words, reflects society's required compensation for postponing the consumption. The social discount rate often differs from the discount rate used by private investors because the social discount rate takes the welfare of future generations into account in a way that private investors generally do not.

The discount rate is a key parameter in a cost-benefit analysis since it represents the required rate of return that the project must generate in order for it to be considered welfare-improving for society. The higher the interest rate, the lower the value put on the effects arising far ahead in the future, which reduces the profitability of the project if the benefits arise later in the time period. It may also affect the ranking of two or more projects when costs and benefits arise at different points in time.

Since the cost of the investment (*C*) is often incurred at the beginning of the time period while the benefits (*B*) arise later, the annual net effect will be negative at the beginning and then become positive. Figure 7 illustrates how the costs outweigh the benefits in the first time period while the benefits outweigh the costs in later time periods. The net present value (*NPV*) consists of the difference between the present value of the benefits and the costs. Since the present value of the benefits is greater than the present value of the costs, the net present value of the investment in Figure 7 will be positive.

Figure 7. Schematic illustration of how the net present value of future benefits and costs is calculated.



Source: Own processing.

Discount rate level
Extensive literature is available on which discount rate should be used in projects (Johansson & Kriström, 2011). However, there is no consensus on the interest rate level that should be used in socio-economic calculations. Different countries apply different levels; Germany uses 3 per cent, UK uses 3.5 per cent, and France uses 4 per cent (Johansson & Kriström, 2016). Norway uses 4 per cent for the first 40 years (Norwegian Government Agency for Financial Management, 2014).

When it comes to socio-economic methodology in Sweden, extensive work has been carried out, primarily by the Swedish Transport Administration[18], which also chairs the working group for socio-economic calculation and analysis methods in the work of the transport area (ASEK).[19] This is a multi-agency consultation group that is responsible for developing the principles for cost-benefit analysis and the calculation values to be applied to measures within the transport sector. These are published in the report "Analysis method and socio-economic calculation values for the transport sector" (Swedish Transport Administration, 2016). The report is updated annually and in the latest version from 2016, the Swedish Transport Administration recommends that the real social discount rate should be set at 3.5 per cent. The Swedish Energy Agency and the Swedish Environmental Protection Agency, amongst others, use ASEK's recommendations for their own cost-benefit analyses.

The Swedish Transport Administration bases the social discount rate on a method known as the Social Rate of Time Preference (SRTP) and which is based on the so-called Ramsey equation $r = z + ng$ where r is the social discount rate, z is an impatience factor, g is the growth rate in the economy and n expresses the marginal benefit of an increase in consumption. If we do not have any growth in the economy, g is zero. Then the discount rate is equal to the impatience rate, or the pure time preference, z. If we have positive growth in the economy, i.e. g is greater than zero, this means that we consume more in the future than today. If the marginal benefit of the consumption decreases[20] at the same time, n is greater than zero, which means that we get a higher discount rate. A relatively higher discount rate means that the value of future consumption is weighted down in relation to consumption today.

The Swedish Transport Administration determines the parameters based on empirical studies and adjusts its recommendation as necessary. For a detailed discussion about the parameters in SRTP, see EIB (2013), for example.

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[18] Information has been obtained from www.trafikverket.se and a report published by the Swedish Transport Administration (Swedish Transport Administration, 2016). More detailed information about the calculation values, etc. is available in a supporting document issued by the Swedish Transport Administration (Swedish Transport Administration, 2016).
[19] The cross-government consultation group consists of representatives of the Swedish Transport Administration, Swedish Transport Agency, Swedish Maritime Administration, Swedish Environmental Protection Agency, Swedish Energy Agency, Stockholm County Council/Stockholm Public Transport and Transport Analysis (co-opted). The ASEK work is supported by a scientific council consisting of scientific expertise in the fields of economics, environmental economics, regional economics and transport analysis.
[20] One reason may be that we already have sufficiently high consumption so that future consumption increases will not be as valuable.

The method for determining SRTP is also used by others in order to determine the social discount rate. For example, the European Investment Bank (EIB) advocates the method of "Economic Appraisal of Investment Projects in the EIB" (EIB, 2013). The EIB also recommends that a country should use the same discount rate within a country regardless of the sector being analysed. The reason is that society's evaluation of the Ramsey equation's parameters should not differ between different projects and sectors. Instead, the parameters are country-specific. The EIB also mentions that different countries may have different social discount rates as a result of different conditions. For example, having different expectations of how the consumption per capita will develop justifies the discount rate being different between countries.

The EU's guidelines, "Guide to Cost-Benefit Analysis of Investment Projects"[21], which describe how cost-benefit analyses of investment projects should be implemented, discuss the social discount rate for investment projects in Europe (European Commission, 2014). The recommendations in the report are that countries that can receive money from the Cohesion Countries development fund should use a 5 per cent discount rate, while other countries should use 3 per cent.

The EU guidelines on how cost-benefit analyses of investments in smart electricity meters should be performed indicate that the social discount rate should be set to reflect society's valuation of socially beneficial projects (European Commission, 2012). The report also states that different levels can be selected by different countries, based on country-specific macroeconomic conditions.

In different contexts, ENTSO-E has discussed cost-benefit analyses and how the social discount rate should be determined. The most relevant report in this context concerns guidelines for cost-benefit analysis in network development projects (ENTSO-E, 2015). These guidelines directly affect Svenska kraftnät in its European cooperation with other transmission network operators. The guidelines state that a common discount rate should be used for all countries when projects of common interest shall be evaluated and ranked. In fact, the guidelines state that the actual discount rate probably differs between countries in Europe. The reason for using the same discount rate is primarily to facilitate comparability between different countries and projects. The recommended interest rate is 4 per cent. The recommended discount rate originates from the consultation response from ACER (ACER, 2014) on ENTSO-E's guidelines. In the consultation response, ACER states that a common discount rate is needed in order for the results to be comparable between different regions and countries. Their proposal for an interest rate of 4 per cent is mentioned in the consultation response as a preliminary solution and is based on a report from Frontier Economics.

[21] The Guidelines are based on Regulation (EU) No. 1303/2013 of the European Parliament and of the Council of 17 December 2013 laying down common provisions for the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund, laying down general provisions for the European Regional Development Fund, the European Social Fund, the Cohesion Fund and the European Maritime and Fisheries Fund and repealing Council Regulation (EC) No. 1083/2006.

To summarise, it can be concluded that there is no consensus on which discount rate is the best or most appropriate to use in cost-benefit analyses. A high discount rate means the benefits of the project must be realised in the near future since costs and benefits in the long run are measured at a relatively lower value. The reverse applies for a low discount rate. For investments that are expected to generate long-term effects for society, a relatively low discount rate is often used. The primary reason is that the benefit or well-being of future generations should not be ignored in investments with a long lifespan.

The problem of having a constant interest rate over the lifespan of the investment is that major effects in the distant future have little impact on the present value of the project. In such cases the discussion is on whether a hyperbolic discount rate should be used (Dasgupta & Maskin, 2005). This means that the interest rate will fall over time. However, a constant interest rate level is normally used. The Swedish Transport Administration's report "Methodology and parameter values for economic analysis of the transport sector" discusses the possibility of reducing the social discount rate in order to increase the impact of future effects, instead of having different discount rates over time (Swedish Transport Administration, 2016).

Ei's proposal: The discount rate for infrastructure investments within the Swedish electricity sector should be constant during the discounting period. In order to avoid distortion of investments between different sectors in Sweden, the level of the discount rate should be based on Swedish conditions and follow ASEK's recommendation, which currently means that the real social discount rate should set at 3.5 per cent. If the cost-benefit analysis is based on nominal values instead of real values, a higher discount rate should be used in order to take account of inflation.

Limitations

The cost-benefit analysis should include benefits and costs for the geographical areas where significant effects can be expected. Significant effects means they are of such a magnitude that they affect the result of the cost-benefit analysis. This applies regardless of whether benefits/costs occur within or outside Sweden's borders.

The cost-benefit analysis should encompass effects on the environment, as well as market participants and stakeholders that are located in the relevant geographical area. Relevant means the geographical area that will be affected by the investment. If the project is dependent on other projects for the benefit to be realised, the cost-benefit analysis should include the entire cluster of relevant projects.

Ei's proposal: The cost-benefit analysis should not be limited to Sweden if it cannot be shown that all significant effects are within Sweden's borders. All projects or sub-projects directly related to each other should be included in the assessment.

Assessment of the result

A cost-benefit analysis will result in a monetary and qualitative evaluation. Ei proposes that, as a rule, the project should only be implemented if the net present value is positive (provided all benefits and costs are complete and correctly monetised) and there are no significant qualitative objections against (or in support of) the project. The environmental impact assessments and environmental considerations are only fully or partially considered in the analysis through the cost of the project, such as in the form of precautionary measures and restoration costs. Any residual non-priced environmental effects may constitute qualitative considerations in the cases where it is not possible to quantify and monetise them.

In a broader context, it should also be possible to rank all projects under consideration. For instance, there may be a limited budget with several welfare improving projects to choose from. The projects can then be ranked by using e.g. the ratio between the net present value and the investment cost. The project that provide the most benefit per invested Swedish crown should be prioritised (Swedish Transport Administration, 2016). The projects can also be ranked according to their respective internal interest rate, which is derived from the rate of return on investment.

When it comes to infrastructure projects, these often contain complex relationships for which a so-called "multi-criteria analysis" is sometimes recommended, see e.g. (Kiker, 2005). In a well-conducted cost-benefit analysis (according to the guidelines described in this report), decision-makers should have access to the results of different types of model simulations, risk assessments, cost- and benefit evaluations, as well as a comprehensive picture of stakeholder preferences. However, there are no clear rules for how the different results should be weighted, monetised or ranked. Information and data also have different formats. Model simulations often provide clear quantitative values to several decimal places, while risk assessment and the cost-benefit analysis can have major qualitative elements. In addition, information about stakeholder preferences is often brief and incomplete, arbitrarily and subjectively summarised, which may give the impression of a decision-making process that lacks legitimacy and a fair assessment of stakeholder interests. It is also the case that an excessively structured and harmonised decision-making process is likely to be so rigid that it cannot handle specific local conditions, or specific conditions that apply to the particular project in question. An example of this is the need to respect the rights of different minorities.

In a multi-criteria analysis, the choice is to specifically assess the project based on criteria added given the knowledge available about the potential impact of the project. For example, such criteria may be the inclusion of minority rights, ecological impact or social impact not captured by the rest of the analysis. These criteria are quantified by in-depth investigations, surveys and expert opinions. Multi-criteria analysis is a method with similarities to a cost-benefit analysis. The decisive factor in terms of distinguishing between the methods is that the weights for when the effects are summed up are determined on different grounds than citizen willingness to pay. The difficulty is to agree on what are sensible and reasonable grounds for the weights.

Separate distribution analysis

The effects of an investment in terms of distribution are actually irrelevant in a cost-benefit analysis. It is only the effects on the net benefit in society that are in focus. However, it may be useful to conduct a separate distribution analysis (including regional policy analyses) of how the benefits and costs of a project are divided between different parties in society. Since the electricity market is Nordic in many respects, it may be useful to conduct such distribution analyses with regard to how benefits and costs are distributed between the Nordic countries. In accordance with Article 12 (1) of Regulation (EU) No. 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans-European energy infrastructures and repealing Decision No. 1364/2006/EC and amending Regulations (EC) No 713/2009, (EC) No. 714/2009 and (EC) No. 715/2009, the costs of an infrastructure investment that benefits another country shall also be partially financed by that country.

Ei's proposal: Multi-criteria analysis should not be used when summing up the effects. A separate distribution analysis showing how costs and benefits are distributed between market participants and regions should be included.

5 Effects linked to an investment in the transmission network

This chapter aims at identifying, quantifying and monetising welfare effects that may arise in the event of investments in the transmission network and how these effects relate to each other. We begin by reviewing the theory on how the effects should be addressed in the analysis. Then we present Ei's proposal for the effects that have been identified in connection with an investment in the transmission network.

5.1 Effects of an investment option

This section covers how the effects of an investment option in relation to the reference option should be identified, quantified and finally monetised.

Identification of effects

The effects of a measure are either positive or negative consequences that arise as a result of a measure being implemented. Positive effects are also normally termed benefits, while negative effects are termed costs. In a cost-benefit analysis, all the consequences associated with a measure that increases or decreases the socio-economic surplus should be identified, as far as it is economically justifiable.

Market failures may entail challenges when identifying (and monetising) the effects in the cost-benefit analysis. A market failure is a situation where the market outcome does not lead to an optimal allocation of resources. Public goods and non-priced external effects (externalities) are examples of market failures. By nature, externalities are not monetised in a transaction between two parties, while the transaction itself may have an effect on a third party. Sometimes the effect can be identified and monetised directly, for example, if emissions kill fish stocks in a river, thus reducing catches for commercial fishing activities. However, the effects are usually more difficult to identify and monetise. One way to increase information about the consequences of a particular transaction is to broaden transparency and thereby increase the opportunity to allow third parties to comment on possible outcomes of a given action early on in the project phase. For example enabling the public and experts from academia and NGOs to comment on the project.

Another form of market failure may arise when the projects are linked to each other. For example, it may be the case that the benefits of one project depend on another project being performed at the same time. Here it is important that the entire cluster of projects is included in the cost-benefit analysis so that the benefits and costs are correctly defined.

Transfers, such as taxes and subsidies, mean that value is transferred from one party in society to another, without the use of any resources. Transfers should therefore not be included in the analysis since the net value of these effects will be zero in the cost-benefit analysis. However, how the allocation of resources changes between different groups in society as a result of an investment can be analysed separately.

Quantification and monetisation of effects

The identified effects should be quantified and monetised as far as economically justifiable. The monetisation of effects should be based on market prices, as far as possible, provided that the underlying market is well-functioning, and the prices do not include fiscal taxes. However, cost-benefit analyses include effects that cannot or should not be quantified. Possible reasons for this may be that the effects are so uncertain that it is difficult to establish an expected value. There may also be ethical reasons for why it is difficult to estimate the value of effects, e.g. the valuation of human life.

If there are no market prices, the monetisation can be made using indirect methods or studies of willingness to pay. Common to indirect methods is that they are based on the market prices of related goods and services. Common to studies of willingness to pay is that different survey-based methods are used to ask parties affected by the investment to reveal their willingness to pay to avoid a certain effect. These methods are described in more detail in the next section.

Quantification and monetisation of environmental impacts and encroachment effects

Environmental impacts can amount to both costs and benefits relatative to the reference option. As a rule, the impact on the environment and ecosystem services[22] does not have a market price. However, extensive research is being made to be able to monetise the environment and ecosystem services.[23] The purpose of pricing environmental impacts is to have a common unit of measurement to weigh these effects into the decision-making process.

There are mainly two reasons why the full value of the environmental impact is not reflected in the price of a product: the emergence of public goods and external effects. A genuine public good is a product or service that individuals cannot be effectively excluded from use and where the consumption by one individual does not reduce the amount available to be consumed by another individual. National defence is an example of a genuine public good. Clean air is an example of a semi-public good since emissions from one individual negatively affects the access to clean air by other individuals.

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[22] Ecosystem services consist of all products and services that nature's ecosystem provides to human beings and which contribute to our welfare and quality of life. Pollination, natural water regulation and environmental amenities are some examples.

[23] See, for example, the Swedish Board of Agriculture (2017).

A negative external effect means that an economic transaction between two parties has a negative impact on a third party, without the latter being compensated for it. External effects primarily arise when there are no property rights or when there are high transaction costs involved in achieving a market solution. Land encroachment, for example, is not an external effect if there are clearly defined property rights and there is a regulatory framework to ensure that the landowner is compensated for the land encroachment. If the landowner has to undertake costly and risky legal processes to receive compensation, an external effect may arise due to the transaction costs involved.

An example of a negative external effect of electricity grid infrastructure is that the view is disturbed for a third party when an overhead power line is routed between producer and customer. There are also positive external effects that mean increased benefit for a third party. A positive external effect that is often mentioned in connection with investments in the electricity grid is that power lanes create habitats for certain species.

In order to internalise the negative and positive environmental effects in the behaviour of the parties involved, environmental taxes and subsidies can be introduced. Ideally, the environmental taxes should reflect the additional socio-economic cost of the environmental impact arising from the production or consumption of a product or service. An example of an attempt to internalise the external effects associated with greenhouse gas emissions is the EU trade in emission allowances.

There are different methods for estimating the environment and ecosystem services in monetary terms. The suitability of the methods varies depending on the type of environmental effect and area affected. A selection of these methods is described in brief below. For more information on their application see, for example, Brännlund & Kriström (2012).

Indirect methods

Property value method is an indirect method where the effect is monetised by comparing how the market price of properties changes in the event of an environmental or land encroachment effect. The comparison is made between equivalent properties that differ with regard to some environmental quality factor, such as lake view or proximity to a road. A statistical analysis is conducted to make the properties comparable, so that the remaining difference in market price can be derived from the difference in environmental quality. The price difference can then be assumed to reflect the willingness to pay for environmental quality. The method is suitable for use in a well-functioning property market, and where there is a clear difference in the environmental quality that buyers and sellers are informed about.

Travel cost method can be used to tax the recreational value of a natural site. The method is based on information about the cost that visitors have paid to travel to the site, which can be assumed to reflect the value of visiting the site. The presence of, or proximity to, other similar sites affects the recreational value so that these should be taken into account in the analysis.

Mitigation costs are expenses that arise from dealing with the environmental effect that occurs, such as the cost of installing water purification filters, or to install windows that reduce indoor noise. An example that is specific to transmission power lines is setting up bird deflectors on overhead power lines to avoid bird fatalities. Another example is mitigation by purchasing properties located close to the transmission power line. One difficulty with the method is that it can be hard to trace the cost to only the environmental impact (Brännlund & Kriström, 2012).

Restoration cost method is based on the estimated costs of restoring natural resources, often land or watercourses, to an acceptable level. This level may be the original condition, or in accordance with specific threshold values for the presence of certain substances. The restoration cost can be seen as the lower limit for gaining access to the resource. The method is useful for many types of environmental effects, but not when the impact on the resource causes irreversible damage, which is the case for the hole in the ozone layer, amongst other things. Methods based on cost data have a limitation in that they do not include indirect effects, but only those linked to actual costs. It may therefore be necessary to monetise any remaining environmental impacts or encroachment effects.

Studies of willingness to pay

The methods mentioned above are indirect methods that use market prices of related goods or services to estimate the value of a non-priced resource. However, some environmental or natural resources are difficult to associate with a priced product or service. In such a case, a study of willingness to pay can be a useful method for producing an estimate of society's valuation of the resource. Willingness to pay methods can be carried out either by different means asking the parties affected how they monetise an environmental quality or a natural resource, or attempting to deduce the parties' valuation by studying how they actually choose in different situations where options are available.

In a study of willingness to pay, data is collected on what people suggest they are prepared to pay for an improvement in environmental quality/natural resource, or what compensation they would demand for losing access to the resource. It can be noted here that it is important to take into account initial property rights. There is usually a great deviation between what a person claims to be willing to pay for a resource and what compensation he/she would require for losing access to the resource.

In analyses of willingness to pay, it is important to control for the person's income and other factors that affect his/her willingness to pay. Studies of willingness to pay have an important limitation in that they do not provide information about how important an environmental or natural resource is for the functioning of the ecosystem, but only about what people are willing to pay for it. Studies also show that there are distortions so that a "cuteness factor" plays a role in terms of, for example, the conservation of endangered species. The giant panda, for example, can be valued higher than a spider (Small, 2011). Studies of willingness to pay should therefore be seen as a complement to indirect methods and environmental assessment.

Values from previous studies
One way to find values for environmental impact is to use standardised values developed either by applying several of the methods mentioned above or in some other way generalising the results of previous monetisation studies (primary studies). Such generalisations are only valid if the environmental change being monetised in the primary study is similar to the one being monetised in the new context. In addition, factors that are of significance to the monetisation (e.g. number of people affected, income, geographical and cultural differences, etc.) must be similar or at least possible to adjust for. A complete adjustment is not possible to achieve because a certain level of uncertainty will always remain. In a generalisation, it is important to report the uncertainties that remain and to interpret the result with appropriate caution (Brouwer, 2000; Swedish Environmental Protection Agency, 2008).

A socio-economic price database has recently been developed by the Anthesis/Enveco consultancy agency, on behalf of the Swedish Board of Agriculture. The database contains standardised prices for environmental impact and is intended for use by public and private sector administrators, amongst others, who seek to include environmental impact in their cost-benefit analyses (Swedish Board of Agriculture, 2017). The price database contains effects that are of interest for investments in the transmission network, as discussed in section 5.8.

It is disputed as to whether a monetary evaluation of the environment can and should be done. Opponents of a quantification of environmental impacts emphasise the value of the environment in its own right, and an extreme interpretation of this would mean that measures with adverse effects on the biological environment must not be implemented. Accordingly, the environment is given an infinite value. There is also a risk that only environmental impacts attributed a monetary value by man will be taken into account in the analysis.

However, if we accept that monetisation of the environment may be one way of weighing environmental values into a common unit of measurement, certain practical difficulties still remain in determining the value. Methods for environmental monetisation are useful for giving an indication of the value of an environmental resource. However, caution should be taken on application. Firstly, the effect of the environmental impact may be uncertain. Threshold effects can, for example, be a source of uncertainty. Sometimes the environment can only assimilate a certain amount of emissions, but after a certain level, the negative effects grow rapidly. Another example is that fish stocks may have a good capacity to recover up to a certain level of fishing catches, but above this the stock collapses (Myers, Hutchings, & Barrowman, 1997). Another source of uncertainty stems from the variations in how local-specific factors in land and the environment affect how great the impact is from an emission. Methodological problems associated with estimating the environmental impacts are a third source of uncertainty. However, political decisions always require a balance between different interests, of which environmental protection is one. However, the risk is that only the environmental aspects included in the calculation are taken into account in the basis for decision-making.

5.2 Welfare effects arising in the day-ahead market

Historically, the primary function of the transmission network has been to interconnect electricity generation installations with consumption. In addition, increased transmission capacity between bidding zones can lead to increased welfare in society by means of a more efficient allocation of resources. Part of this change occurs in the day-ahead market and can be analysed by studying how welfare effects in the day-ahead market change with an investment in the transmission network. In this section we try to explain in more detail how welfare in the day-ahead market is affected by increased transmission capacity between bidding zones. In this section we also present proposals for how it should be monetised.

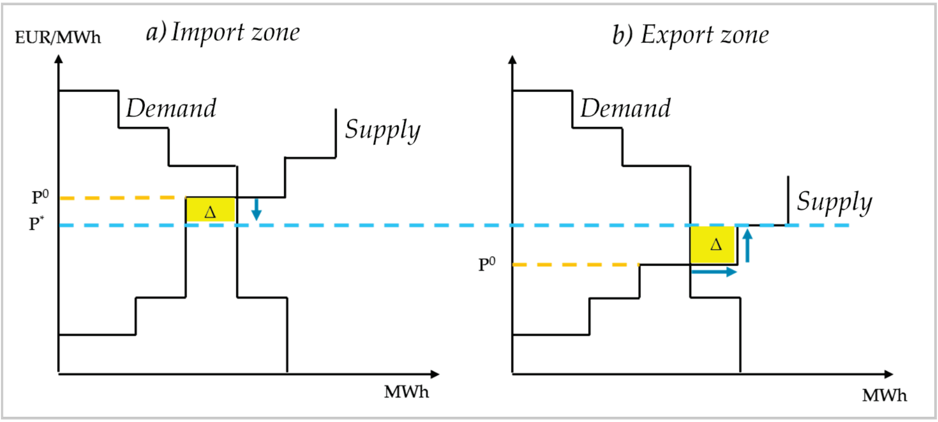
Description of welfare effects in the day-ahead market

An investment in the transmission network that increases transmission capacity between bidding zones allows electricity from a low-price zone with relatively cost-effective production resources to be exported to a high-price zone, thereby replacing less cost-effective production sources.[24] This means increased welfare in the day-ahead market, since existing production sources can be used more efficiently and customers with higher willingness to pay can be reached. The total welfare effect in the day-ahead market is thus equal to the net value of changes in producer and consumer surpluses and congestion charges. Congestion charges correspond to the price differentials between bidding zones arising from scarce transmission capacity. (Turvey, 2006; Hogan, 2018)

Figure 8 illustrates the equilibrium price of the day-ahead market (where supply is equal to demand) before and after increased transmission capacity between bidding zones. The initial equilibrium price, p^0, is higher in bidding zone *a)* compared to bidding zone *b)*. The increased transmission capacity in this case is sufficient for the new price, p^*, to be the same in both bidding zones. The yellow-marked area in Figure 8 illustrates how the net value of the producer and consumer surpluses changes (Δ) with increased transmission capacity. The net value is positive in both bidding zones, which means that total welfare, or welfare in the day-ahead market, is increasing.

[24] Here, a complication arises when the Nordic system operators change the capacity allocation method in accordance with EU legislation in this area. In this model, flows can be forced in the "wrong direction", from low-price zone to high-price zone.

Figure 8. Changes in producer and consumer surpluses in the day-ahead market in the event of increased transmission capacity between a bidding zone a) with high prices and a bidding zone b) with low prices.

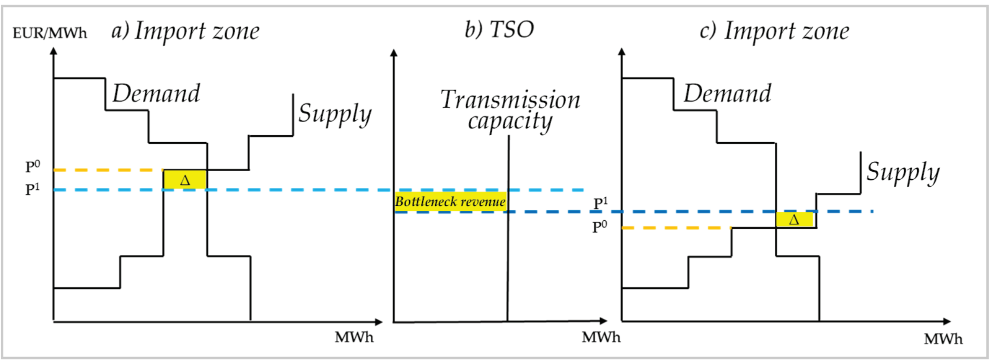


Source: Own processing.

In *a) Import zone* to the left in Figure 8, the benefit arises because less resources are required to achieve the same consumption as before. This means that the customers must pay a lower price for the same electricity usage.[25] In *b) Export zone* to the right in Figure 8, the benefit arises because producers can increase their production since the price of electricity increases. This is an example of how an increased transmission capacity can allow a relatively more cost-effective production to replace a less cost-effective production.

Figure 8 illustrated a situation where the new transmission capacity is sufficient to fully equalise the price difference between the bidding zones. Without price differences the congestion charges that the owners of the transmission network receive will be zero. Figure 9 shows a situation where the transmission capacity is insufficient to completely equalise the price differences between bidding zones. Even if the price differences between bidding zones decreases ($p_{imp}^0 - p_{exp}^0 > p_{imp}^1 - p_{exp}^1$), the remaining price difference will generate congestion revenue for the owners of the connection.

Figure 9. Changes in producer and consumer surpluses and congestion charges in the day-ahead market in the event of increased transmission capacity. The axes with MWh are not to scale.



Source: Own processing.

[25] Electricity usage does not change because in this simplified example we are moving along a vertical (and price insensitive) segment of the demand curve.

How other market participants handle welfare effects in the day-ahead market in their analyses
There is a broad consensus on including welfare effects in the day-ahead market in the cost-benefit analysis (ENTSO-E, CAISO et al do so). The difficulty is to develop realistic scenarios of consumption development, installed production capacity and network development plans in other transmission networks. In order to facilitate cost-benefit analyses covering the entire energy system, ENTSO-E shall produce and publish a Community-wide network development plan every two years. The European Community-wide network development plan shall include model descriptions of the integrated network, a development scenario, and a European supply forecast as well as an assessment of the system's resilience. All methods used by ENTSO-E will be published in order to also facilitate a harmonised cost-benefit analysis at Union level covering the entire energy system and referring to projects of common interest (ENTSO-E, 2015).

Monetisation of welfare effects arising in the day-ahead market
Welfare effects in the day-ahead market due to, for example, an investment in the transmission network can be studied in economic terms using electricity market models. Most commercially available electricity market models assume perfect competition in the electricity market, which means that market participants have access to the same information and that there are no barriers to entry or exit. The welfare effects resulting from increased transmission capacity therefore depend solely on falling production costs by means of a more efficient allocation of production resources and cross-border capacity.[26]

Quantitatively, it is recommended that more than one model be used. For example, in the case of increased capacity between Sweden and Finland, both the "Better Investment Decision Model" (BID) and "EFI's Multi-Area Power Market Simulator Model" (EMPS) were used (Fingrid & Svenska kraftnät, 2016). BID is better suited for a large proportion of solid fuels (nuclear power, coal, natural gas, biofuels) in the generation mix as in the Finnish electricity system, while EMPS better corresponds to what is happening in the hydropower-based north of Sweden. The choice of using two models gives more robust results and can also help to highlight the socio-economic consequences from more perspectives.

All models have limitations and it is therefore important to assess the probabilities in different ways in order to realise the benefits and costs that are being modelled. This can take place qualitatively by comparing, for example, existing market values of financial instruments, and through dialogue with the market's participants. Quantitatively, this can take place through, for example, Monte Carlo simulations in order to ensure the robustness of the results.

Electricity market models are usually predetermined, or deterministic, in the sense that it gives the analyst an exact answer, given the data entered into the model. The answer will not vary, regardless of how many times the calculation is repeated. The Monte Carlo simulation is a method of introducing uncertainty into the deterministic model in order for it to better reflect the risks that are faced in reality.

[26] This reasoning is valid for price insensitive demand (the demand curve is vertical). The analysis becomes more complicated if demand is price sensitive (ENTSO-E, 2015).

The method is to repeat the calculations while a computer randomly changes the digit-sequence of the variables that the analyst considers to be associated with uncertainty. It is also possible to attribute a probability to different outcomes in the sample space, which makes it possible to draw statistical conclusions about how an investment option will affect welfare in the day-ahead market, for example.

Ei proposes that welfare effects in the day-ahead market should be included in the cost-benefit analysis

Welfare effects in the day-ahead market should be included in the cost-benefit analysis and be monetised using available electricity market models. If the size of the project justifies this, more than one model should be used and form the basis for the assessed welfare effects in the day-ahead market. The models that form the basis of the calculations should be available to other stakeholders in addition to Svenska kraftnät so that the results can be repeated and analysed.

Ei further proposes that the plausibility of the results is assessed through an active stakeholder dialogue and with quantitative methods such as Monte Carlo simulations, for example. Welfare effects in the day-ahead market consist of net changes in producer and consumer surpluses as well as congestion charges. The robustness of the result should be analysed by varying input data and assumptions about future scenarios and in this way include various extreme situations in the sample space.

5.3 Impact on the market power of the market participants

Market power means, amongst other things, that market participants can cause the price of electricity to deviate from the prices that had existed in perfect competition. For example, if electricity producers have market power and there are barriers for new electricity producers to enter the market, it tends to lead to higher prices. Prices that deviate from perfect competition lead in general to reduced welfare in society.

Description of market power

Most of the electricity market models commercially available assume that there is perfect competition in the market, both before and after grid expansion. Accordingly, no account is taken of the effects on market power or other imperfections, i.e. how the strategic behaviour of the market participants changes in the event of increased transmission capacity. It is relatively complicated to analyse how the behaviour of the market participants changes during the lifespan of the investment in the event of stronger market integration. The results of the analysis are sensitive to assumptions on how companies will act in the future, assumptions that are difficult to verify (ENTSO-E, 2015).

Regulation (EU) No. 347/2013 on guidelines for trans-European energy infrastructures from the European cooperation body, ENTSO-E, of the owners of the transmission networks, recommends that a concession application should contain a qualitative analysis of how the potential market power of the market participants in the Member States is affected in the event of increased transmission capacity. (ENTSO-E, 2015)

In its guidelines, ENTSO-E (2015) proposes that the analysis should be based on one or more indexes for market concentration. The index may be, for example, the Residual Supply Index or the Herfindahl-Hirschman Index. Market concentration should be calculated with and without network investment. The change in market concentration should then be included in the economic cost and benefit analysis. Since it is not possible to evaluate this change in monetary terms based on these indexes, the result must be handled qualitatively.

When assessing market concentration, it is important to carefully analyse what constitutes the relevant market, before and after the investment in the network. For example, this applies to geographical scope, as well as to which submarket or product referred to.

Previous studies have shown that increased transmission capacity leads to a lower concentration of producers, which may result in significant welfare effects on the market. Simulations of the Italian electricity market have indicated that welfare in the electricity market can be increased by EUR 33 million in the event of stronger market integration, given an assumption of perfect competition. If stronger market integration also leads to improved competition, welfare increases by EUR 396 million per year. This is nevertheless lower than the welfare gain of EUR 674 million that can be achieved by a transition to perfect competition. (Pellini, 2012; Newbery, Strbac, & Viehoff, 2016)

The Nordic electricity market has been developed and integrated since the re-regulations of the 1990s. There are several studies that point out that the market is well functioning (see, for example, Fridolfsson & Tangerås, 2009; Amundsen & Bergman, 2006). Ei has also analysed the issue (Swedish Energy Markets Inspectorate, 2006). It may therefore be difficult to demonstrate direct gains in today's market due to increased competition in the day-ahead market. However, a stronger interconnection between the Nordic bidding zones can create opportunities to trade in financial hedging instruments in other ways than before. The opportunities for an even more liquid financial market could also create a better situation for industrial customers or small market participants, for example (Swedish Energy Markets Inspectorate, 2017).

Ei proposes that market power should be included in the cost-benefit analysis.

The cost-benefit analysis should contain a qualitative analysis of how the potential market power of the market participants may be affected by an investment in the transmission network. In accordance with the guidelines in ENTSO-E (2015), the analysis should address how the market concentration is affected by the investment based on the *Residual Supply index,* and *Herfindahl-Hirschman Index* indicators. This should be performed for both the day-ahead market and the real-time market. When assessing market concentration, it is important to carefully consider what constitutes the relevant market, before and after the investment in the network. For example, this applies to geographical scope, as well as to which submarket or product referred to. The market concentration for a bidding zone, for example, before and after a network investment can be expressed as an average of all the hours in the year.

For large projects, the qualitative analysis should also be preceded by consultation with market monitoring authorities as well as different marketplaces in order to assess the potential market development. The transition of the electricity market will also transfer parts of the activities in time; for example, the increasing dependence on weather, finer time resolution and the resulting uncertainties should increase the need of the market participants to trade themselves into balance closer to real-time. This can change the dynamics of the markets and the opportunities for the participants to compete. In future cost-benefit analyses of investments in the transmission network it may therefore be useful to analyse at least quantitatively the effects on the potential market power of the participants, not only from a geographical perspective, but also from a temporal perspective.

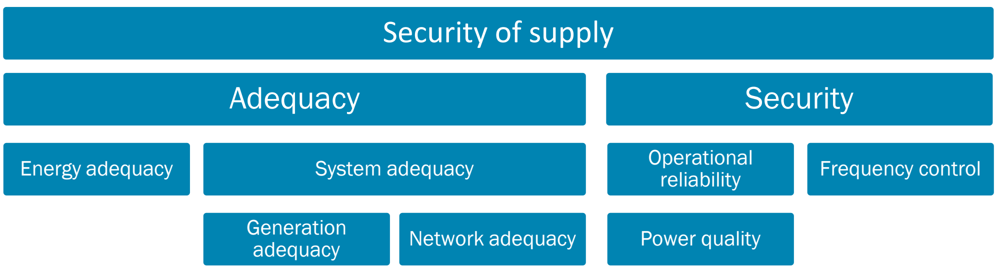
5.4 Effects on security of supply

In the role of system operator, maintaining the system's security of supply is one of Svenska kraftnät's most important assignments. Improved or maintained security of supply is an important driver for investments in the transmission network, and security of supply should therefore be included in the cost-benefit analysis. However, security of supply depends on several factors and caution should be exercised so that the same effect is not included several times in the analysis. Ei proposes that the concept of security of supply is systematised in accordance with Figure 10 in the following section.

Description of security of supply

Security of supply is a multifaceted concept. The figure below illustrates a way of systematising the various factors that jointly determine the security of supply of the electricity system. Conceptually, it is an input-output-model where different input factors with different marginal costs to increase. The cost of increasing an input (for example, a measure that leads to increased system adequacy or some other investment option) should, in a cost-benefit analysis, be weighed against the benefit of a changed security of supply. If the net benefit is positive, the investment option that is assessed as most welfare-improving for society per investment expenditure should be implemented. If the objective is instead to achieve a given security of supply, such as the existing security of supply, different investment options should be weighed against each other and the most cost-effective option should be implemented. Svenska kraftnät does not have direct control over all the input factors.

Figure 10. Schematic picture of the input factors that determine the security of supply of the electricity system.



Source: Own processing.

The difference between the factors *adequacy* and *security* is largely the time perspective. The term *adequacy* means the long-term planning of the electricity system, from start-up and decommissioning of generation capacity in the slightly longer time perspective to how the existing generation and network capacity is made available and dispatched in the day-ahead market.

Energy adequacy means that there is adequate energy (i.e. number of Watt hours [Wh]) in the electricity system within a bidding zone to meet power demand over time (= energy demand) using available production capacity and transmission capacity.

The Swedish Energy Agency's instruction, § 2 (SFS 2014:520) states, amongst other things, that the authority is responsible for planning, coordinating and (to the extent the Government prescribes) implementing rationing, but also other regulation relating to the use of energy. In October 2014, the Swedish Energy Agency submitted a proposal to the Government on new and changed administrative provisions in order to facilitate rationing of electricity. Rationing can only be implemented if the Government, following the proposal of the Swedish Energy Agency, has decided to allow the Rationing Act (1978:268) to enter into force. Long-term energy shortage may lead to the power balance not being achieved for one or several hours making the power unavailable. In order to avoid double counting, the effects on energy adequacy of increased transmission capacity in the report will be handled by studying the generation adequacy for the relevant unit of time in which electricity is traded.

System adequacy is determined by both *generation adequacy* and *network adequacy*. Generation adequacy means that there is adequate power (i.e. number of Watts [W]) within a specific geographical area to meet electricity user power demand using available production capacity and transmission capacity in the relevant market unit of time (currently one hour). Network adequacy means that the installed production capacity can be transferred to where it is needed and with acceptable quality.

The real time operation of the electricity grid is sorted under *Security*. *Operational reliability* (can also be referred to as system stability) refers to the capacity of the network to cope with unforeseen deficiencies in normal operation and *Frequency control* refers to reserve power that is procured in the balancing market in order to ensure that the frequency in the transmission network is maintained within an acceptable range. *Power quality* is difficult to place in a hierarchy, and Ei has chosen to sort this under Operational reliability.

In order to clarify the concept of security of supply, we shall go through *generation adequacy*, *network adequacy*, *operational reliability* and *frequency control* in more detail. Before the detailed description we shall describe how other parties handle security of supply in their analyses.

How other parties handle security of supply in their analyses

Norwegian guidelines

The Norwegian Government has highlighted security of supply as an important effect when evaluating electricity grid projects (Ministry of Petroleum and Energy, 2012). The electricity grid is a critical infrastructure for society, and outages in the power supply have major consequences for network users. The increased security of supply that a network investment contributes to can be partially priced using the so-called "KILE evaluation" (which is a method of estimating outage costs, i.e. costs for non-delivered energy). However, this evaluation does not provide the full value of the increased security of supply. The benefit of increased security of supply can therefore be included in the evaluation with greater weight than just the outage costs for the individual customers. Outages in the power supply in the transmission network have major consequences and this necessitates an adequate safety margin in the network (N-1 criterion).

ENTSO-E

The security of supply effect is defined as the improvement of security of supply (generation adequacy or network adequacy) provided by an investment in the transmission network. It is quantified as the difference before and after the investment expressed in terms of either *Expected Energy Not Served* (EENS) or *Loss of Load Expectation* (LOLE).

Depending on what shall be quantified, either market or network models are used for the calculations. When generation adequacy is analysed, market models are used to determine how the investment contributes to the power balance. Network models, on the other hand, should be used to assess network adequacy, i.e. to evaluate how the investment contributes to the robustness of the network.

In theory, the improved security of supply can be evaluated with the *Value of Lost Load* (VOLL). Due to the difficulties in calculating value of VOLL and the large variation in the end-customers willingness to pay between countries, ENTSO-E proposes only handling this effect qualitatively in the cost-benefit analysis.

CAISO

The system operator for California's transmission network, CAISO, estimates that a certain level of security of supply, or risk of outage, is socio-economically optimal. This level is stated as the largest consumption that can be disconnected in the event of error, for example, or how the reserve capacity should be dimensioned in relation to the maximum consumption during the year. For investments that result in a further improved security of supply, the principle is that the net benefit for end-customers should be positive, which should be assessed via a cost-benefit analysis. Amongst other things, the analysis should include the largest consumption at risk of disconnection, how long outages are expected to last, total power demand and when it can be expected to occur, number of affected customers and their willingness to pay to avoid the outage.

Description of system adequacy

System adequacy is determined as previously stated, both by generation adequacy and network adequacy, the partial effects are reported separately here.

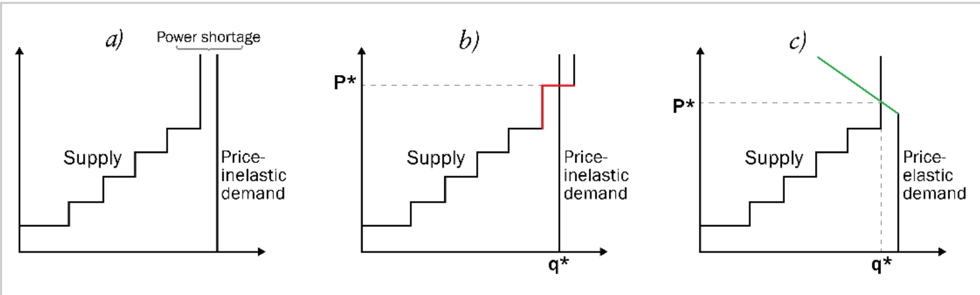
Generation adequacy

In the slightly longer time perspective, we mean planning existing and new demand facilities, production resources and transmission capacity up to and including the day-ahead market. The planning includes everything from future new and re-investments in production resources, demand facilities and transmission capacity, to how they are dispatched in the day-ahead market so that balance is achieved between consumption and production. The delimitation is made in the cross section between the liberalised market and Svenska kraftnät's area of responsibility (i.e. network and frequency control in real time).[27]

Equilibrium in the day-ahead market

In order to reach equilibrium between supply-demand in the day-ahead market, the supply of electricity for each given hour must be equivalent to the demand. The supply can take place by means of electricity generation in installations within the bidding zone or by import via cables from neighbouring bidding zones with positive power balance. In order to reach equilibrium without curtailment of demand[28] in the day-ahead market, flexible production resources are required that can follow variations in demand and weather-dependent electricity generation, or that price-elastic demand is adjusted to supply. Figure 11 illustrates a situation with (a) power shortages and how equilibrium can be reached using (b) new flexible production resources or (c) demand-side flexibility.

Figure 11. Illustration of power shortages as well as examples of equilibrium can be reached using flexible production and consumption.



Source: Own processing.

The situation with power shortages can also be solved by increasing transmission capacity to bidding zones with positive power balance. A power shortage situation means that production, including import opportunities, is insufficient to balance consumption, as illustrated by Figure 11 a). In practice, a power shortage only occurs in real time in which case consumption may need to be curtailed, or disconnected, to avoid major interference in the electricity system.

[27] We simplify the description of the electricity market by ignoring the intraday market where the BSP's of electricity traders and producers make necessary adjustments after the day-ahead market closes, up to and including one hour before the period of delivery. The market participants should then submit their plans to Svenska kraftnät, at the latest 45 minutes before the period of delivery. The need of the market participants to plan for balance depends on a combination of the generation mix and the reliability of the weather forecasts at the time of the day-ahead market.

[28] Curtailment means that production is rationed using forced disconnection of consumers.

Increased transmission capacity may increase availability in renewable electricity generation

Wind power availability has been estimated to be up to 40 per cent of the installed capacity if wind power generation is strongly correlated with the variation in consumption over the whole day, and down to 5 per cent with a high market share from wind power, or if wind power generation is negatively correlated with the variation in consumption over the whole day. The aggregation[29] of wind power generation resulting from increased transmission capacity has the potential to increase the availability of renewable sources of production. This can increase the generation adequacy in a future with potentially increased electricity consumption and decommissioned nuclear power. (Holttinen, et al., 2011)

Quantification and monetisation of generation adequacy

The system's security of supply is lower during peak hours. An investment in the electricity grid can improve the security of supply for the end customer. This effect can be quantified by analysing how the Loss of Load Probability (LOLP) is expected to change in the future in the event of an investment in the network. This can be translated into an expected amount of energy not served (EENS). An evaluation of what the improved security of supply means for the customers in monetary terms can be made by estimating their willingness to pay in order to avoid a power outage, i.e. the value of lost load (VOLL).

Generation adequacy in the day-ahead market can be calculated using an electricity market model. An electricity market model simulates the generation, transmission and consumption of electricity under an assumption of perfect competition, and that the market participants have complete information about hydrological conditions, wind and consumption profiles and other circumstances in the market. The simulations result in prices, quantity produced per generation source and trade between bidding zones. The results produced by the simulation show the number of hours with a strained power situation at different assumptions about future consumption levels. Since historical wind data is used as input in the electricity market model, account is taken of the aggregation effects in the event of increased transmission capacity between the bidding zones (see, for example, Holttinen, et al 2011 for a more detailed method description). A potential disadvantage of using electricity market models for this purpose is that they tend to over-optimise the production resources in the system. With the assumption that the market participants have complete information on precipitation, wind and temperature, the water magazine and other types of energy that can be planned will be distributed during the year's hours in a way that risks being inconsistent with the market participants actual behaviour in practice. How much of a problem this is in practice is an empirical question and there are methods for making the analysis more realistic by introducing uncertainties into the model.

[29] Aggregation of wind power generation, for example, increases with the geographical area as weather systems become increasingly less correlated. A larger geographical area therefore has potential to reduce variability in the generation and thus increase availability in the installed capacity. In other words, the greater the geographical spread, the lower the likelihood of calm wind conditions in the electricity system.

Network adequacy
Investments must be made continuously so that the networks can be adapted to the changes in population development, technical development and the transition that takes place towards renewable energy sources, that may be increasingly intermittent and occur in geographically dispersed facilities. That is, "small" production units that are distributed in the electricity grid at different voltage levels, as opposed to how it has been historically where there were a few large generation sources at high voltage levels.

In addition to adequate transmission capacity, which is handled under the heading Generation adequacy, the power line network needs to be flexible. The solutions chosen to expand the transmission network must be robust in order to handle the system adequacy in different development scenarios, such as with varying production mix, installed production capacity, energy storage, demand-side flexibility and consumption profiles.

Quantification and monetisation of network adequacy
The flexibility of the network, i.e. robustness to handle different future scenarios, can be quantified using sensitivity analysis by means of varying the input data in one or more electricity market models in order to see how LOLP changes in different future scenarios. This uncertainty can then be monetised. This method is suitable if there is a need to evaluate different alternatives to a conventional network investment.

Ei proposes that system adequacy should be included in the cost-benefit analysis

Ei proposes that the effect on the expected energy not served (EENS) in the event of an investment in the transmission network should be quantified using simulations, where varying availability levels of production and transmission capacity, as well as for the magnitude of consumption, profiles constitute the input parameters. This effect can then be monetised using the value of lost load (VOLL).

An investment that leads to improved security of supply can also result in a reduced need for power reserves or other precautionary measures in order to ensure the generation adequacy in the future. Ei therefore proposes that cost savings to reduce or completely remove different types of reserves should also be included in the analysis.

Different types of network solutions may affect the system adequacy in future scenarios differently. This uncertainty can be quantified in a sensitivity analysis by means of varying the input data in simulations to see how the expected energy not served (EENS) changes in different future scenarios. This uncertainty is then monetised using the value of lost load (VOLL). This method is also suitable for evaluating the robustness of different alternatives to a conventional network investment.

Description of power quality

In this report, power quality is defined as the quality of the product that has been delivered (with regard to voltage, frequency, etc.). The power quality is an output, or benefit, and depends on the network's dimensioning, technical solutions and the electrical installations connected to the network.

The voltage may deviate from the nominal level for very short periods (e.g. dips) as well as for prolonged periods, or fluctuate rapidly (so-called flicker). Voltage waveform can also be affected, which is normally called harmonics. Producers and customers can influence each other in that the electrical installations connected to the transmission network cause interference of some of the types mentioned above. The disruptions could cause damage to machines, apparatus and electrical processes that are connected which could lead to disruptions to production. Above all, short outages and voltage dips cause major costs for connected industry (Elforsk, 2006).

The power quality of distributed electricity depends both on the properties of the network and the properties of the electrical installations connected to it. Therefore, Svenska kraftnät requires that connected electrical installations meet requirements for voltage regulation and exchange of reactive power, amongst other things. The requirements are specified in regulations and different agreements.

Ei's regulations (EIFS 2013:1) specify a lowest level of voltage quality that the distributed electricity should have at the point of connection to the end customer. Since, in principle, the transmission network has no end customers, these regulations are of little relevance to Svenska kraftnät. On the other hand, certain types of event in the transmission network can be spread to underlying networks that have end customers. Coordination should therefore take place with the underlying networks in these issues.

Ei proposes that power quality should be included in the cost-benefit analysis

The cost-benefit analysis should contain a qualitative analysis of how an investment is expected to affect the power quality.

In cases where the investment has a significant impact on voltage quality in underlying networks, there is justification to quantify and evaluate this change in monetary terms. The evaluation can be performed by estimating how the costs for damage to demand facilities and disruptions to production will be affected by the changed power quality.

Description of operational reliability

Operational reliability (also system stability) is defined as the network's ability to maintain normal operating conditions or return to normal operating conditions as soon as possible after an unforeseen fault has occurred (EU Regulation 2017/1485). In other words, operational reliability is a combination of the risk of a fault occurring and the network's ability to recover from extreme system conditions or provide stand-by power supply after a failure. Operational reliability in real time in the transmission network is ensured in practice by having safety margins in the transmission network between the bidding zones and counter trade on both sides of the congestion. Both measures consume resources and therefore have a negative impact on welfare. Long-term measures to maintain or increase operational reliability are network investments or to change bidding zone configurations. The costs of these long-term alternatives should be weighed against the cost of maintaining safety margins in the transmission network between bidding zones as well as counter trade.

Operational reliability denotes the system's ability to accommodate an unexpected fault in the grid, without exceeding the network's security limits. Changes in operational reliability affects the system's security of supply. The Electricity Act and Ei's regulations set minimum requirements on the security of supply that the end-users in the electricity grid can expect. These requirements apply at the point of delivery at the end-users, which means that all deficiencies in the overlying electricity system are taken into account when compliance with the requirements are measured. Deficiencies in electricity supply usually occur in the local and regional grids. The outages that nevertheless arise as a result of shortcomings in the operational reliability of the transmission network spread all the way to the end-users. However, the safety margins that Svenska kraftnät applies in the transmission network mean that these regulations are normally met at transmission network level, apart from in exceptional cases.

Safety margin according to the N-1 contingency criterion

The safety margin in the transmission network should be adapted so that the electricity grid components that remain in operation after an unforeseen event can cope with the new operating conditions without exceeding operational reliability limits (Commission Regulation (EU) 2017/1485 establishing a guideline on electricity transmission system operation). The safety margin used in the Nordic region is such that the transmission network should cope with the failure of a component (e.g. an individual power line, generation installation or cross-border connection) that may affect the electricity supply in the electricity system and is therefore in Sweden called the "dimensioning fault", or the N-1 contingency criterion.

One way for Svenska kraftnät to achieve this safety margin is to reduce the transmission capacity available at different marketplaces, such as the day-ahead market, in order to allow stand-by power supply from other bidding zones with available flexible production or consumption. Svenska kraftnät can also reduce the load on internal congestions within a bidding zone by reducing the transmission capacity to neighbouring bidding zones that is made available in different marketplaces.[30] Reduced transmission capacity consumes resources by means of reduced welfare in the day-ahead market and the cost effectiveness of this measure depends on how the reduced transmission capacity can help remedy the internal congestion. The contribution is likely to depend on where the reduced cross-border capacity is situated in relation to the internal congestion and how the electrical flows goes within the bidding zone.

Counter trade measures due to internal congestion

Zonal pricing is the market design that prevails in the European electricity market. Zonal pricing, as opposed to for example nodal pricing, means that electricity users and producers receive the same price within a bidding zone, regardless of where

[30] Regulation (EC) No. 714/2009 of the European Parliament and of the Council on conditions for access to the network for cross-border exchanges of electricity restricts Svenska kraftnät's ability to implement this measure on international connections.

they are in the bidding zone (as mentioned earlier, Sweden has four bidding zones). One disadvantage of zonal pricing is that internal congestions within the bidding zone are not visible in the pricing in the day-ahead market. Any internal congestion therefore constitutes an unpriced effect (externality) at the time for the day-ahead market, and electricity producers and electricity users cannot therefore internalise, or respond to, the network cost in order to facilitate transmission of electricity to the specific location they are in. As a result, the equilibrium price and the quantity that is the result in the day-ahead market, may cause parts of the transmission network to become congested, which reduces operational reliability. Counter trade is one way for Svenska kraftnät to relieve congestions in the transmission of electricity while ensuring operational reliability in real time. Counter trade is conducted by dispatching up and down-regulation of flexible resources in the manual reserves market on either side of the congestion so that it is removed.

In practice, counter trade means that deviation is made from the merit-order decided in the day-ahead market. The deviation means that cost-effective electricity producers who have had their sales bids accepted in the market are asked, in return for compensation, to regulate their electricity generation down. For example, this could mean that electricity producers may let through or spill wind or water. Less cost-effective electricity producers who have not had their sales bids accepted in the market are in turn asked, in return for compensation, to regulate their electricity generation up. The net volume of correctly completed counter trade can in simple terms be said to be zero. However, the deviation from the merit-order in the day-ahead market means increased resource utilisation and increased costs for society to meet the equilibrium quantity in the bidding zone that was the result of the day-ahead market.

Quantification and monetisation of costs for maintaining operational reliability in the transmission network

An investment in the electricity grid can affect operational reliability and thereby security of supply for the end customer. In principle, this effect can be quantified by analysing how the likelihood of unavailability in the operating phase changes in the event of a network investment. However, making probability assessments for the unavailability of all individual network components in the transmission network and how the probabilities change in different operating situations is a complex and extensive task.

A simplified method of monetising how operational reliability is affected by an investment in the transmission network is to estimate how the costs of ensuring operational reliability are affected as a consequence of the investment. This could be the costs of measures that Svenska kraftnät would otherwise have had to implement in order to maintain the operational reliability of the transmission network unless the investment in the transmission network is implemented. Presented below is a method for estimating the costs of two measures that Svenska kraftnät can take in order to maintain operational reliability.

Costs for maintaining safety margins/network reserves in the transmission network

Increased safety margins through reduced trade between bidding zones lead to a less efficient allocation of production and consumption resources, which reduces welfare in the day-ahead market and thus the overall welfare in society. The socio-economic cost of reducing the transmission capacity made available in different marketplaces can be estimated by using an electricity market model. The power in MW of reduced transmission capacity to remove a congestion depends on the internal flows in the bidding zone. These can be analysed using a network model. In addition, an investment in the transmission network can also affect the contingency criterion (N-1) and thus the cost of maintaining safety margins in the transmission network.

Benefits of increasing capacity in an internal congestion
Electricity market models are generally based on there being no internal congestions within the bidding zone and are therefore not suitable for identifying and quantifying the need for transmission capacity within a bidding zone. Identification and quantification of expected capacity problems in the transmission network in different future operating situations are instead performed in a network model. In order to identify potential congestions in real time, the system operator runs multiple flow simulations of the electricity system in a network model to check that physical limitations and voltage stability margins are not exceeded. The same flow simulation is repeated with N-1 or even larger faults until a power line or component becomes overloaded and is disconnected. This critical limit for network security is then compared with the actual flow. If there is a risk of the critical limit being reached in real time operation, the system operator corrects the flows through, for example, counter trade on both sides of the congestion, disconnection of consumption or reduced transmission capacity allocated to different market places.

Svenska kraftnät publishes information about which historical counter trade volumes have been traded in the balancing market. The information is divided by bidding zone and hour. However, Svenska kraftnät does not publish information on historical prices. Imperfect information on price developments in counter trade makes it difficult to estimate the amount of resources consumed due to counter trade needs. The local market that occurs at counter trade also represents increased opportunities for market power for flexible consumers and producers, which may result in prices including a profit margin. Profit margins do not represent a socio-economic cost but are a transfer between consumers and producers. This transfer must be eliminated from the analysis. Svenska kraftnät should therefore not start out from its accounting costs in its analysis because it risks overestimating the true socio-economic cost of counter trade for handling an internal congestion.

In the light of the above, Svenska kraftnät therefore proposes that counter trade needs are monetised using manual reserve prices in the balancing market (Svenska kraftnät, 2017). The manual reserves market constitutes a larger geographic market and is therefore assumed to be more competitive. The difference between the manual reserves price and the price in the day-ahead market would thus provide an approximation of society's additional cost of down-regulation bids or up-regulation bids. See Svenska kraftnät's Background Report for more methodological considerations (Svenska kraftnät, 2017). A difficult-to-solve challenge with historical counter trade volumes is to calculate how a given investment in the transmission network affects future counter trade needs.

There are also other methods for quantifying the future capacity requirement. The simulation models are getting increasingly better and there are models available that can detail the physical limitations of the network at the node level. According to the legislation on capacity allocation in the network currently implemented within the EU (Article 17 of Commission Regulation (EU) 2015/1222 establishing a guideline on capacity allocation and congestion management), all system operators within a capacity allocation area will share a common network model. In this network model, it will be possible to model internal congestions. This means that in future, it will be possible to demonstrate the welfare effects of increasing the transmission capacity within a bidding zone by 1 MW. These so-called shadow values can be used in the cost-benefit analysis of the projects under consideration.

Ei proposes that operational reliability should be included in the cost-benefit analysis

The impact of an investment in the transmission network on operational reliability can be monetised by estimating how the costs of ensuring operational reliability are affected by the investment.

Costs for maintaining safety margins in the transmission network
The size of the safety margins for ensuring operational reliability in various investment options can be quantified using a network model. Svenska kraftnät should monetise how the costs for maintaining safety margins (N-1) in the transmission network are affected by an investment in the transmission network. The costs should be expressed in terms of changed welfare in the day-ahead market in relation to the reference scenario (and the security margins that then apply) and monetised using an electricity market model. Caution should be exercised so that welfare in the day-ahead market from, for example, increased transmission capacity or changed safety margins is not counted twice. It is also important to take into account safety margins in the transmission network when calculating the investment's contribution to system adequacy.

Increased capacity within a bidding zone
Svenska kraftnät should monetise how a given investment in the transmission network affects the future counter trade needs based on historical counter trade volumes. The change in future counter trade needs is monetised using manual reserves prices in the balancing market in accordance with Svenska kraftnät's *System Development Plan 2018-2027* (Svenska kraftnät, 2017).

The simulation models can be developed to better represent the network's limitations within bidding zones. Ei therefore recommends that Svenska kraftnät should continuously develop its simulation models as well as evaluate whether the common network model, according to Article 17 of Commission Regulation (EU) 2015/1222 establishing a guideline on capacity allocation and congestion management, can be used to determine the value of capacity increases in bidding zones.

Description of frequency control

Svenska kraftnät is the system operator for electricity in Sweden. This means that they, together with other TSOs within the Nordic synchronous area, have an overall responsibility of balancing production and consumption of electricity in real time. This is achieved by procuring balancing reserves in the balancing market. Balancing reserves, primarily consist of hydropower, but in principle, they can also consist of flexible electricity users, wind power or other controllable flexible resources. According to the Electricity Act, as system operator, Svenska kraftnät has an overall responsibility that the electricity system subsystems, i.e. all network and generation installations, collaborate safely, but is not responsible for the operation of regional and local networks.

Benefits of increased transmission capacity or other measures in the transmission network may arise in the day-ahead market, intraday market or balancing market. If the system operator reserves transmission capacity for the balancing market, for example, the benefits of the day-ahead market and intraday market will decrease and vice versa. Newbery, Strbac, & Viehoff (2016) find that, using effective forecasting tools in combination with well-functioning intraday trading that continues until the period of delivery, the benefits from increased transmission capacity will have largely already occurred before the balancing market.

Balancing market

In order to correct frequency deviations, that is, restore the momentary balance in the electricity system, reserves in the form of up-regulation and down-regulation need to be activated. Svenska kraftnät solves this by, together with other transmission system operators, organising a balancing market consisting of marketplaces for different balancing products for balancing reserves. The balancing products differ in terms of pricing, requirements for minimum bid size, activation time, time resolution and other characteristics.

The automatic reserves correct smaller frequency deviations while the manual reserves are used for larger frequency deviations. The manual reserves (mFRR) are traded on the manual reserves market, which at the time of the report is a common Nordic market.

The costs that Svenska kraftnät bears on the balancing market for frequency control is financed by electricity users and by producers through their BRPs paying a fee to Svenska kraftnät. The fee consists of a fixed and a variable part linked to the network customer's observed electricity taken out or supplied to the network. The costs for frequency control are allocated between BRPs based on their deviations from the observed and planned consumption or production per hour. Deviations are priced at the manual reserves price in the dominating direction for the particular hour.

The geographical scope of the balancing market at a given period of delivery depends on the amount of transmission capacity between bidding zones that is available after the day-ahead market and the intraday market have closed. Increased transmission capacity between bidding zones increases the likelihood of capacity between bidding zones being available on the balancing market. The aggregation of electricity generation in a larger geographical area can also reduce the aggregated forecast errors[31] in e.g. wind power, which affects the need for balancing reserves. A conclusion in the literature is that the cost of frequency containment decreases if transmission capacity can be used for balancing purposes. [32] (Holttinen, et al., 2011).

Frequency quality

Svenska kraftnät continuously monitors how well the balancing in the electricity system is working by measuring frequency quality, amongst other things. The analyses conducted show that the frequency quality in the Nordic electricity system has deteriorated in recent years. According to Svenska kraftnät, this is due to reduced access to inertia in the system, problems due to changes in import and export capacity via high voltage direct current (HVDC) between hours, and increased production from variable renewable energy sources. (Svenska kraftnät, 2017; Svenska kraftnät, 2015)

Commission Regulation (EU) 2017/1485 establishing a guideline on electricity transmission system operation sets minimum requirements and principles for frequency control and reserves in order to achieve satisfactory frequency quality.

Ancillary services

Ancillary services denote functions provided to support and stabilise the electricity system. These services may consist of active regulation functions that utilise the ability of synchronously connected generators or regulation functions in certain network components such as shunt capacitors and shunt reactors. Inertia from rotating machines reducing frequency variations can also be counted here, especially if they are connected solely to provide inertia. Depending on the choice of technology in the network and the type of production connected, the need for and access to ancillary services will vary. A development with decommissioned nuclear power means fewer synchronous generators, which in the current situation could have a negative impact on access to ancillary services (Uniper, 2016). Voltage regulation is another ancillary service. The voltage is regulated by the supply or withdrawal of reactive power. This ancillary service can be delivered both by connected production units and voltage controlling equipment in the network.

In a future of decommissioned nuclear power, the availability of ancillary services in the electricity system such as inertia and reactive power may decrease. This could significantly reduce the transmission capabilities of the electricity system (Svenska kraftnät, 2017).

At present there are no requirements or incentives from Svenska kraftnät that encourage a given amount of inertia to be present in the electricity system (Svenska kraftnät, 2017). As there is currently no marketplace for pricing ancillary services such as inertia, it can be problematic to monetise these public goods. On the other hand, the electricity system seems to have an increasing scarcity of ancillary services such as inertia. The impact on ancillary services from an investment in the

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[31] The forecast error per wind turbine remains but in aggregation across a larger geographical area the errors tend to occur in different directions.

[32] This conclusion is not an argument for reserving transmission capacity for the balancing market since the reduced balancing costs should be compared with negative welfare effects in the day-ahead market and intraday market.

transmission network should therefore be included in a cost-benefit analysis. Some of the alternative measures discussed in Chapter 6 are aimed at improving access to ancillary services and thereby allow reduced, or postponed, investments in transmission capacity.

The availability of relevant ancillary services ultimately affects the cost of maintaining the network's operational reliability and frequency control.

Quantification and monetisation of balancing costs

An investment in the transmission network can affect the costs of keeping the system in balance. Electricity market models are usually predetermined, or deterministic, and are based on the assumption that the market participants have complete information *(perfect foresight*) about wind, precipitation, and consumption for all the hours of the year. Forecasting errors therefore do not exist in the model. The electricity market model thus provides no insight into how the dynamics between the day-ahead market, the intraday market and the balancing market can be affected by an investment in the transmission network and how welfare in the day-ahead market is allocated between these markets. Researchers point to the difficulty of allocating the benefit of increased transmission capacity between markets with different time windows (Newbery, Strbac, & Viehoff, 2016). This applies in particular when the forecasts improve over time. To avoid double counting, aggregating benefits from different markets should be avoided. It is also difficult to make a realistic simulation of how future imbalances will develop using an optimisation model, since they are designed to ignore many of the uncertainties and imperfections that exist in reality. The dynamics between marketplaces can possibly be studied by observing historical connections between, for example, how an increased transmission capacity affects the costs of electricity balancing for Svenska kraftnät and other system operators.

Ei proposes that frequency control should be included in the cost-benefit analysis

A qualitative analysis of the value of the capacity-expansion *in addition to the* welfare effects in the day-ahead market should be included in the cost-benefit analysis. This can be done by analysing the duration of capacity utilisation in the day-ahead markets, for example, and then evaluating whether additional values for other markets closer to real time can be added through the proposed project.

Ei further proposes that the benefits in the form of different ancillary services, such as inertia, which the project may either provide or in other ways facilitate to the electricity system should be monetised in the cost-benefit analysis.

5.5 Cost-efficient achievement of political objectives

Society is in a state of constant change, and part of the role of infrastructure is to facilitate the achievement of policy objectives, such as a sustainable society, better air, increased communication opportunities, etc. There are therefore reasons to monetise in particular how infrastructure investment can contribute to achieving politically determined objectives at a lower cost to society. Here, we comment on the objectives that exist today but want to emphasise that the proposals should be seen as general recommendations, since the future will certainly bring new policy objectives, and thus new means for meeting objectives.

Description of meeting political objectives

In the continued description, we address three objectives that are currently relevant to the Nordic electricity market. Integration of renewable energy, reduced proportion of greenhouse gases in Nordic electricity generation and integration of electricity markets for a common European electricity market.

Integration of renewable energy sources

Increased integration of renewable energy sources is an objective of Swedish and European energy policy. Investments in the transmission network can contribute to objective fulfilment in several ways. Ei has identified the following effects, based on ENTSO-E's guidelines (2015; 2016):

- that renewable energy sources are connected
- that curtailment of renewable energy sources is avoided.

Connection of renewable energy sources

Connection of renewable generation installations is a natural way for the transmission network to enable the transition of the Nordic electricity system. Svenska kraftnät has an obligation to connect new electricity generation, unless there are operational reasons for denying connection (Chapter 3, § 6, first paragraph of the Electricity Act).

The variability of renewable energy sources creates challenges, since periods of little sun and wind result in low generation and reduced security of supply, as discussed in section 5.4.

Curtailment of renewable energy sources

The electricity certificate system that shall apply up to 2030 is a market-based subsidy program, where the price of electricity certificates should, in theory, cover the difference between the wholesale price of electricity and the cost of building new renewable electricity generation. Subsidies for renewable energy sources complicate the market's pricing to some extent, and the price signals that market participants receive. With an objective effective subsidy program (such as the electricity certificate system), meeting political objectives will be guaranteed regardless of the market value of renewable electricity generation. This increases the risk that power generation must be disconnected under certain conditions. Curtailment of electricity generation (or customers) typically reduces welfare and is therefore not desirable in the long term. Investments that provide better conditions through reduced number of expected hours of curtailment are therefore positive.

Reduced local carbon dioxide emissions

There is also a general ambition in the Nordic market for electricity generation to reduce carbon emissions from electricity generation. This means, for example, investments in more renewable generation but in Finland also investments in nuclear power. Infrastructure that allows a more cost-effective switching from greenhouse gas-generating electricity generation to clean electricity generation should therefore be assigned a value for this contribution to meeting political objectives.

Integration of electricity markets
With a number of electricity market directives and electricity market regulations, the EU has clearly announced the political intention to create a single European electricity market. An important part of this is to also improve the interconnection of national electricity systems. Since the benefits are already monetised in terms of welfare in the day-ahead market and generation adequacy, no further monetisation should be made.

Quantification and monetisation of cost-effective political objective fulfilment
This section is based on how Norway and ENTSO-E handle quantification and monetisation of cost-efficient objective fulfilment.

Norwegian guidelines focus on the value of new production and consumption
Expected new consumption or new production is a common reason for building power lines. The common Norwegian-Swedish electricity certificate market and the transposition of the Renewable Energy Directive in Norwegian energy policy involve major demands on network expansion in Norway. The cost-benefit analysis should include the value of connecting new electricity generation or new consumption. The value of new electricity generation and new consumption is associated with great uncertainty, such as electricity prices and other market conditions. The regulatory framework of the authorities should be used as the basis for the overall monetisation of the network project. The network company should then take into account the transmission needs created by, for example, the need to follow the electricity certificate market. Other examples may be rules that make a generation technology unrealistic, or rules that lead to increased consumption.

ENTSO-E focuses on connection and curtailment of renewable energy sources
ENTSO-E focuses on connecting renewable energy sources and avoiding curtailment of renewable energy sources. Connection of renewable energy sources is expressed in megawatts while the reduced curtailment due to reduced occurrence of internal congestions is expressed in megawatt hours.

Ei proposes that cost-efficient political objective fulfilment should be included in the cost-benefit analysis

Given that the political ambitions contain concrete objectives, such as the development of certain technologies, the infrastructure's contribution to meeting objectives could also be quantified. However, in itself, objective fulfilment is not the relevant justification for including the effect in the analysis - it is the effect and whether it is valued by the citizens that is decisive for whether it should be included in a cost-benefit analysis. The cost-benefit analysis may contain an analysis showing different costs *given* that a certain objective should be met. Such objectives may for example be that a certain amount of offshore wind should be present in the Swedish electricity system by 2030 or that a certain area should have carbon-neutral electricity generation by 2050.

Svenska kraftnät's assignment includes promoting the integration of renewable electricity generation. For Svenska kraftnät, integration partly concerns improved possibilities for connecting renewable generation, and partly concerns counteracting curtailment of renewable generation.

The first purpose is fulfilled in Sweden through the connection obligation. The connection obligation may be in direct conflict with the requirement that investments in the transmission network should be welfare-improving. If we take the example of offshore wind power, the added value of renewable electricity generation (i.e. the difference between wholesale price and production cost, including environmental and encroachment effects) may not justify the investment cost of connecting the wind farm to the transmission network. Connection obligation could thus constitute a special reason for granting a concession, despite the investment not being welfare-improving for society.

The second purpose is at least partially monetised in the calculation of welfare in the day-ahead market for the different scenarios applied. The part that remains to quantify is how the costs of counter trade due to internal congestions are affected by an investment in the transmission network.

Problems with more explicitly attempting to quantify how the infrastructure contributes to political objective fulfilment is, for example, the risk of double counting (e.g. the climate effects are already internalised in welfare in the day-ahead market by the price for carbon dioxide involved in the EU trade in emission allowances). Measures to develop the infrastructure can also lead to the development of technology for renewable electricity generation, for example, following a lower cost trajectory. This will benefit society through lower costs for e.g. subsidies, and higher profits for the companies.

Regardless of whether it is possible to quantify these effects, Ei proposes that, in the cost-benefit analysis, Svenska kraftnät should include a qualitative analysis of how the investment is expected to affect the cost of achieving different policy objectives.

5.6 Network losses

Network losses can be considered as the resource utilisation required to transfer electricity from producer to consumer. An investment in the transmission network can affect network losses in both positive and negative ways.

Description of network losses

Network losses refer to the losses that arise in the transmission of electricity and are defined as the difference between the amount of electricity supplied and the amount taken out of the network. Normally, a distinction is made between current-dependent losses (transmission losses) and non-current-dependent losses, i.e. load losses (transformer losses). Whether the losses decrease or increase depends on the type of investment made in the electricity grid. For example, an investment that creates more routes for the power flows can result in decreased transmission losses. Similarly, an increase of the voltage level in an existing network decreases the currents (flows) and thereby the network losses. In addition, if production is held constant, the network capacity increases in both cases, which should result in an increase in robustness/flexibility. However, if the investment is linked to new production or measures to immediately increase interconnector capacity, the increased flows result in increased network losses.

Quantification and monetisation of network losses
The network losses are quantified by comparing the network losses that arise with the investment relative to the reference scenario. The losses can be quantified using a network model and monetised using one or more electricity market models that can assess future electricity prices.

How ENTSO-E handles network losses
The benefit of changed network losses (also referred to as energy efficiency) of a project is quantified using the reduction of thermal losses (heat losses) in the system. At a given level of transmission, network development generally results in reduced losses, i.e. increased energy efficiency. Some projects may also result in decreased transmission losses when the distance between production and consumption decreases. Voltage increases and the use of more efficient cables also reduces the losses. However, it should be noted that the main driver of transmission network projects is currently an increased need to transfer electricity over long distances, which increases losses.

The change in net losses for different investment options can be calculated using a combination of market models and network models. Network models are used to quantify how network losses in the system are affected by different investment options. The differences in network losses for different options in relation to the reference scenario can be monetised using an electricity market model. (ENTSO-E, 2015; ENTSO-E, 2016).

Ei proposes that network losses should be included in the cost-benefit analysis
Svenska kraftnät should use a network model (for example, the model they use today - Samlast) in order to quantify how the network losses are affected by an investment in the transmission network. After that, Svenska kraftnät should monetise the effect using one of the electricity market models used in analysing welfare in the day-ahead market.

5.7 Construction, maintenance and reinvestment costs
This cost component includes all relevant costs such as investment and reinvestment costs, as well as costs for ongoing operation and maintenance. Decommissioning costs are also included.

Description of construction, maintenance and reinvestment costs
The description of the project costs incurred during the lifespan of the investment is based on ENTSO-E's guidelines.

ENTSO-E
The total expected project costs that ENTSO-E states should be included in a cost-benefit analysis are presented by their guidelines (ENTSO-E, 2015). The guidelines state that for each project, the following costs and uncertainties are estimated and reported.

- Expected cost of materials and construction.
- Expected cost of temporary solutions required to complete a project.

- Expected environment-related costs (costs to completely avoid, mitigate or compensate for environmental impact).
- Expected costs for components that must be replaced within a specified period (economic lifespan of the component).
- Expected decommissioning costs when the lifespan is reached.
- Expected maintenance costs.

Quantification and monetisation of construction, maintenance and reinvestment costs
A general principle of cost-benefit analyses is that only the real resource utilisation for society should be included as costs in the calculation. Payments to suppliers is technically a transfer between market participants but can be used to estimate this resource utilisation, provided that the market is well-functioning. Accounting depreciation should not be included in the calculation since it would lead to double counting of the capital cost that has already been included in the calculation at the time when the investment was made. Interest payable represents the time value of money and should not be included in the calculation since the time cost is represented by the discount rate. Caution should be exercised when interpreting rental costs in the profitability calculation since a large part of the time cost is usually included in the rental.

All expected accounting costs that a measure incurs may be included in the cost assessment, both for construction and for estimated reinvestment needs during the economic lifespan of the investment. The Ei proposal provides a more detailed description of individual cost items.

Ei proposes that construction, maintenance and reinvestment costs should be included in the cost-benefit analysis

Ei's proposal is largely consistent with the guidelines that are developed by ENTSO-E and described above, but we propose a slightly different categorisation in order to conform to Swedish conditions. The items not explicitly stated in the ENTSO-E guidelines are transition costs and costs for field planning, as well as consultation and permit consideration processes.

Direct construction costs
Direct construction costs, i.e. expected costs for materials and construction should be included in the costs. Among these costs, costs for temporary solutions required during the construction period should also be included. Given that the discounting period starts at the decision date for the network concession, no construction costs will be incurred before the start of the discounting period.

Costs for field planning as well as consultation and permit granting processes
This item includes the costs relating to field planning as well as consultation and permit granting processes. Amongst other things, this includes the costs of developing the necessary documentation in order to make the best assessment of how a new power line should be routed or a new station planned. This item also includes expected environment-related costs, i.e. costs of completely avoiding, mitigating or compensating for an environmental impact in accordance with the regulations of the Environmental Act and the Utility Easements Act.

In order to assess costs related to field planning and consultation and permit granting processes, the working hours for this are estimated and priced at an average hourly rate. Additional costs (related, for example, to public consultations) are added to the cost of labour.

Other transition costs

In addition to direct construction costs, any changes in the concession may cause costs in the internal processes of the network companies. The costs are often linked with the transition or change of the concession. Between the options studied, the costs can both increase and decrease.

To estimate transition costs, the estimated working hours for process transition can be estimated together with direct costs for training, equipment and inventory. Depending on the options studied, an assessment can be made of the working hours saved by shorter lead times for applications (both at network company and authority) and working hours for training and/or working hours for organisational transition. Decreasing or increasing working hours are priced at an average hourly cost and are summed up with the direct costs of training, equipment and inventory.

Operating and maintenance costs

The calculation of socio-economic costs includes all operating and maintenance costs that arise throughout the economic lifespan of the installation. An annual summary of expected costs therefore needs to be prepared. It is reasonable to assume that this summary shows higher initial costs (running-in) as well as higher costs towards the end of the economic lifespan of the installations.

Also included here are the necessary reinvestments in parts of the installation with shorter lifespan, i.e. the parts of the installation that must be replaced during the lifespan of the main components. Costs for reinvestments in such parts of the installation should be included in the analysis based on when they can be expected to occur. The cost items referred to include energy costs, consumable inventories and consumable materials, repair and maintenance, costs for means of transport, shipping and transportation costs, travel expenses, office supplies and printed matter, etc.

Decommissioning costs

Decommissioning costs include restoration costs as well as any environmental and clean-up costs incurred in connection with decommissioning an installation. Also included here are recycling costs and any landfill expenses.

5.8 External effects

External effects, or externalities, of an investment in the transmission network that facilitate electricity deliveries between two parties (producer and electricity user) are such effects that affect a third party without the latter being compensated for it. Amongst other things, external effects can occur when the benefit is collective by nature and there are no rights of ownership. Some of the effects associated with land encroachment and environmental impact are fully or partially internalised in the project cost since private rights of ownership are defined as well as design costs, compensations, mitigation costs or restoration costs that are regulated in, amongst other things, the Environmental Act and the Utility Easements Act. The question is whether these compensations can be used to calculate the socio-economic cost of taking a land resource or whether there are still non-priced effects that must be corrected to form the basis for the cost-benefit analysis.

External effects caused by a transmission network installation can be systematised in different ways. Ei has chosen to categorise them as local encroachment effects, local environmental impacts and emissions related to power line infrastructure. These can be analysed qualitatively, quantitatively or monetarily.

How other market participants handle external effects

ENTSO-E

ENTSO-E (2016) takes into account environmental impact in terms of the local impact on nature and biodiversity as estimated in preliminary studies. The "environmental impact" indicator (and also "social impact") is used to show what potential effects are not already internalised in the investment cost. Only the "remaining part" of the environmental cost should be included. ENTSO-E considers that the costs of remedying these negative effects, or compensating for them, cannot be estimated with sufficient certainty in order to be monetised in the cost-benefit analysis. On the other hand, ENTSO-E considers that it is important to make a quantitative analysis of these effects. For example, local environmental impact should be quantified in terms of the number of kilometres of overhead power lines or ground cable routed through environmentally sensitive areas. However, the effects on carbon dioxide emissions as a result of increased integration of renewable energy, for example, are not quantified in the ENTSO-E guidelines.

Swedish Transport Administration

The Swedish Transport Administration makes cost-benefit analyses of investments in infrastructure, operational and maintenance measures and minor investments in, for example, noise control measures. The cost-benefit analysis is reported in a combined impact assessment, in which results from distribution analyses and objective fulfilment analyses are reported. The external effects reported in the analysis include, for example, encroachment into the natural and/or cultural environment, barrier effects, and any indirect effects on markets outside the transport sector. These effects are not valued monetarily but are only described qualitatively in the analysis. The effects that are not valued monetarily are divided into either environment or other effects. Environment includes climate, health and landscape, and other effects include travellers, goods transport and road safety.

The external effects that may occur with regard to the environment, and which are monetised in the cost-benefit analysis, include air pollution, emissions of climate gases and noise. The disturbance cost for noise is treated slightly differently from other evaluations of environmental impacts by means of estimating the individual's willingness to pay indirectly through so-called hedonic property price studies. The disturbance costs are assumed to be direct and thus observable to a property buyer, and what can be observed by a property speculator is assumed to be included in the hedonic evaluation. Longer-term effects, such as cardiovascular disease, are treated in a different way. (Swedish Transport Administration, 2016)

Swedish Environmental Protection Agency

The Swedish Environmental Protection Agency is also a member of ASEK and shall, according to instructions from the Government, consult other authorities and develop, follow up and evaluate the application of cost-benefit analyses within the environmental objectives system. The Swedish Environmental Protection Agency's main activities within ASEK include continuous review and follow-up of the analyses conducted. The purpose is to identify deficiencies, gaps and strengths in the analyses conducted or ordered by authorities. The greatest focus of the review is on whether the cost-benefit analyses contribute to achieving environmental objectives and whether it takes place in a cost-effective way.

The Swedish Environmental Protection Agency also actively works with environmental assessment and the development of methods for monetising the environment. It has been involved in the valuation project, where the Swedish valuation database, ValueBaseSWE, was updated, and produced its own report *Normalised Monetary Values for Environmental Impact* (Gerda Kinell, 2010). Amongst other things, the latter states that it is possible to create intervals of monetary values for recreational fishing and water quality. However, aside from recreational fishing, conservation and recreation are deemed to be too heterogeneous in the change that is monetised in each study for it to be possible to create a meaningful interval for these groups.

The Swedish Environmental Protection Agency has also developed a price database aimed at supporting the work of other authorities to assess environment-related costs and benefits in cost-benefit analyses. The price database contains socio-economic normalised values categorised according to water pollutants, air pollutants, chemicals and heavy metals, noise, health and accidents as well as values associated with landscape. It compiles both existing normalised values, such as the Swedish Transport Administration's ASEK values, and new normalised values. (Swedish Environmental Protection Agency, 2018)

Description of local encroachment effects

The term encroachment effect refers to a range of different types of influence in cultural and natural environments. Encroachment can roughly be categorised as both pure physical encroachment and encroachment that manifests itself as visual or emotional encroachment, and results in a changed experience of a particular environment. The problem with encroachment effects is that they can only be partially identified and monetised. In cases where land is used for an investment, the encroachment may in part be monetised since there are often defined rights of ownership and regulated levels of compensation. However, such valuation constitutes only part of the total value. In a cost-benefit analysis, it must be determined whether the regulated compensation for the damage caused by the encroachment represents a correct monetisation of the socio-economic costs for the long-term use of a land resource.

Quantification and monetisation of local encroachment effects

A company with a network concession has the right to excavate, cut down forests and perform other measures required to prepare a site for a power line. However, a network concession does not give the right to claim another party's land for this purpose. In order to gain access to land to construct power lines requires rights of way according to the Utility Easements Act (1973:1144), alternatively, special rights or concession agreements with the owners of the properties affected according to the Swedish Land Act.

Rights of way means that the cadastral authority gives the holder of the rights of way the right to construct, maintain and retain power lines on the charged property. In accordance with § 13 of the Utility Easements Act, the tenure of rights of way shall be determined on the basis of the rules in Chapter 4, Expropriation Act (1972:719). The property owner is entitled to compensation under the Expropriation Act for the encroachment and for any other damage. In order for rights of way to be granted, the purpose must not be achievable otherwise and the benefits should outweigh the inconvenience created by the encroachment.

The effects that are compensated are divided into effects caused by *tenure* i.e. that land or other space is used for the power line, and effects caused by the *undertaking* i.e. the power line itself. Effects arising from *tenure* are compensated in accordance with Chapter 4, § 1 of the Expropriation Act and effects caused by the *undertaking* under the influence rule in Chapter 4, § 2 of the Expropriation Act.

According to the Expropriation Act, encroachment compensation shall be paid at an amount corresponding to the decrease in the market value of the property arising from the expropriation. In the event of other damage to the owner due to the expropriation, such damage shall also be compensated. In addition, additional solvency and encroachment compensation shall be paid at 25 per cent of the market value or the market value reduction (except for economic damage). Compensation according to § 13 of the Utility Easements Act shall be determined in monetary terms and paid as a lump sum.

Lantmäteriet (Real Property Register) valuation method for land encroachment
When evaluating the impact of a land encroachment, the effect is the "physical" damage to the property or other perceived consequence caused by the power line. The starting point for the basic principle of compensation follows from the Utility Easements Act and the Expropriation Act mentioned above. In the practical application, standards or standard methods are often used, based on standardised assumptions about anticipated encroachment effects in the event of an tenure.

Amongst other things, the Lantmäteriet's valuation manual contains principles for evaluating the encroachment of overhead power lines in forest or agricultural land. For example, compensation for encroachment of pylons in arable land is calculated using the 1974 arable land standard, and encroachment in forest land using the 2018 forest standard. Other compensation shall be paid for other compensable damage. The evaluation manual mentions, for example, encroachment into forest land where it may be necessary to compensate the property owner for costlier logging if the property owner performs the logging for the power lane.

Experienced consequences, or effects as a consequence of the undertaking, are view obstructions by electricity pylons and so-called mental immissions (for example, fear of magnetic fields) caused by transmission power lines.

In addition to the general evaluation methods resulting from the Expropriation Act, a special model for the evaluation of encroachment on property yields is used. One problem with encroachment on property yields, primarily agricultural and forest land, is drawing the boundary between the two types of compensation (reduced market value and other compensation for other compensable damage). An encroachment on agricultural land, such as an electricity pylons in arable land is usually of the nature that it affects both the market value of the property and the operating result of the agricultural holding (reduced revenues and/or increased costs). The evaluation model used in these cases is designed to determine the decrease in market value separately and the item for other compensation as an accounting residual item, namely the difference between the compensable total damage and the decrease in market value.

In the case of the encroachment of power lines on rural land, a calculation is usually based on how the future income and/or expenses are affected for the owner of the property. The calculation method used is the so-called IAN model. IAN is an abbreviation of encroachment in land use and has been accepted by the Supreme Court as a method of determining a reduced net present value. The factors to be determined in an IAN calculation are the impact of the encroachment on future revenues and expenses, probable decrease in market value on future tenure, the discounting period and discount rate. (Lantmäteriet, 2016)

In rights of way proceedings, it is only possible to consider such matters for properties of injured parties in the proceedings. Owners of properties that are not directly affected by the rights of way tenure are not injured parties in the rights of way proceedings, and compensation for economic damage and/or environmental damage to such properties can therefore never be considered within the framework of land registration proceedings. Owners of such properties are referred to requesting compensation for environmental damage according to the rules of the Environmental Act. This will apply, for example, to such properties not directly affected by the rights of way but whose market value is nevertheless affected by the power line (spoiled views and concerns about the health effects of electromagnetic fields). Restrictions resulting from the encroachment also mean that residential buildings or buildings where people permanently reside cannot be constructed within a certain distance from the power line. However, if a building permit is granted, compensation may be paid if these cannot be utilised. Calculating compensation for view obstructions and electromagnetic fields is difficult. Normally, an overall assessment of both effects is made. The compensation is normally determined as a percentage of the property's value before the power line was built.

In practice, there should be no major difference between compensation, regardless of whether it is determined in accordance with the Utility Easements Act or the Environmental Act. In both cases, the right to compensation is limited by the provision that the damage must be of a certain size (tolerance threshold) and that it must not be typical or general for the district in question. What differs above all are the rules for the costs of the legal proceedings. The Utility Easements Act refers to the Expropriation Act, which means that property owners do not normally risk having to pay either their own or the counterparty's legal costs in the Land and Environment Court, and only their own legal costs if they lose in the Land and

Environment Court of Appeal or the Supreme Court. If the Environmental Act is applied, normal legal costs are also applied. Those who lose then have to pay both their own and the counterparty's legal costs. In view of the risk of having to pay large amounts in legal costs, it is likely that more property owners refrain from requesting compensation in accordance with the Environmental Act.[33]

Electromagnetic fields

In addition to the effect on the property's market value due to mental immissions, there are limit values (Swedish Radiation Safety Authority, 2008) aimed at protecting against acute effects of very high power frequency magnetic fields (100s microtesla, μT). However, there are no limit values for magnetic fields at the levels that occur adjacent to power lines (approximately 100 times lower). Svenska kraftnät has developed a policy[34] for magnetic field levels around its power lines. The choice of precautionary level in their policy is based on the overall research findings available. When planning new AC power lines, the magnetic field should not normally exceed 0.4 microtesla where people live or reside permanently. When network concessions are renewed for existing AC power lines, measures are often taken to reduce the magnetic field, or Svenska kraftnät offers to purchase buildings that are so close to the power line that the magnetic field exceeds 4 microtesla. Svenska kraftnät's policy means that the current value of electromagnetic fields is implicitly included in the investment cost by means of the compensation paid for properties purchased in order to avoid exposure (i.e. a form of mitigation costs), but Svenska kraftnät does not make any additional cost-benefit analysis.

Ei proposes that local encroachment effects should be included in the cost-benefit analysis

The Lantmäteriet's valuation manual is unclear when it comes to, amongst other things, a method for calculating how the market value of the property is affected in the event of a land encroachment. It is also unclear how the net present value is calculated and how it relates to the added value of the reduced production. Ei proposes that the Lantmäteriet's valuation manual provides a starting point for the monetisation of local encroachment effects but that the discounting period and value of any production loss should be adjusted to clearly reflect the socio-economic value of the land. Ei proposes that the discounting period should be 40 years.

The standard values for calculating market values for e.g. forest land and arable land developed by Lantmäteriet are used unless otherwise agreed between the injured parties and may therefore be seen as a lower cost estimate for the statutory compensation for land encroachment. The standard values primarily take account of the encroachment made in the right of ownership and therefore only relate to the current owner's losses. These standard values therefore do not necessarily correctly reflect the true socio-economic alternative costs associated with claiming a land resource. In the cost-benefit analysis it is important to include all socio-economic costs and ensure that the statutory compensation does not underestimate

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33 Email conversation with Margareta Holmquist Kindlund, LRF konsult.

34 Svenska kraftnät's magnetic field policy: http://www.Svenska kraftnät.se/aktorsportalen/samhallsplanering/var-magnetfaltspolicy/

or overestimate the alternative cost of the production loss. The production loss should be monetised according to its added value. This means that the costs for machines, fuels and labour, for example, should be deducted from the market value of production. In regions with high unemployment it is not certain that the labour force can find new jobs, and in these cases it may be justified to reduce the cost of labour by 25 to 75 percent in the calculation.[35] This increases the value added by the production loss. The discounting period should be 40 years and the discount rate 3.5 per cent in accordance with other proposals.

Costs due to visual impact and mental immissions are already included in the project costs for the power line and should therefore not be reported as a single item. However, this only applies to the properties directly affected, i.e. the properties the power line passes over, or the properties bought out for other reasons. Properties in the vicinity can also be affected indirectly, for example visually, but these costs should be reported in a separate cost item. Ei notes that the standard values used to monetise local encroachment effects do not have a strong empirical basis. The monetisation of encroachment effects in the event of investments in the electricity grid in a Swedish or Nordic context is thus a research area that needs to be developed.

Description of local environmental effects

The majority of the local environmental effects arising from an investment in the electricity grid are described in the environmental impact assessment. Examples of local environmental effects, amongst others, that may be appropriate for inclusion in the analysis if these interests are affected include the following:[36]

- effects on reindeer husbandry, such as barrier effects that arise from the power line,
- effects on groundwater levels due to, for example, tunnel work for underground power lines
- effects on land use for carbon sinks
- effects on the possibility for recreation
- effects on cultural values (for example archaeological sites)
- effects on biodiversity (power lanes contribute to a species-rich environment)
- fragmentation of habitats (power lanes constitute obstacles in nature)
- birds that are injured or die in contact with overhead power lines.

The Environmental Act sets requirements, for example, which mean that parts of the identified environmental effects are fully or partially internalised in the cost of the project. Any remaining effects should be dealt with, and this can be done by either quantitatively or qualitatively. As mentioned earlier, some parties use price databases to monetise an effect. However, in some cases, this is not appropriate or

[35] Telephone interview with Gunnel Bångman, Swedish Transport Administration (180212).
[36] Several of these effects have also been identified by Svenska kraftnät in the memorandum 2014/1705 which served as the basis for the Board meeting on 24 September 2014.

even possible due to the specific nature of the effect. In such cases, it is more appropriate to describe the effect qualitatively.

Ei proposes that local environmental impacts should be included in the cost-benefit analysis

Ei notes that there are major uncertainties associated with monetising environmental impacts. The Environmental Act aims to limit the environmental impacts that an installation has on the environment and influences project costs through design costs, compensation payments, mitigation costs or restoration costs. External effects consist of the environmental impact that is not internalised in the cost of the project. As far as possible, these potential effects should be quantified and monetised in the cost-benefit analysis. The effects that cannot be quantified and monetised should be described qualitatively, preferably based on the environmental impact assessment.

The price databases currently available, such as the Swedish Environmental Protection Agency's price database can be used as a starting point for quantifying and monetising local environmental impacts for investments in the transmission network. However, without further processing, it is difficult to use the price databases since environmental impacts are often site-specific. In principle, each lake, forest or field has its own unique value linked to the local site, so it is difficult to apply a general value from a database. Therefore, each time a value is used from the price database, an analysis should be made of why the price is used, and whether it is also relevant in the situation in question.

Description of emissions linked to power line infrastructure

The construction, operation and decommissioning of an electricity grid involves the use of natural resources and gives rise to emissions. The emissions to air that may arise include carbon dioxide (CO2), nitrogen oxides (NOx), sulphur dioxide (SO2), hydrocarbons, volatile organic compounds and particulate matter (PM). These emissions originate mainly from work machines. Emissions with environmental impact may be internalised to a certain extent by taxes and charges - carbon tax, sulphur tax, NOx tax. Svenska kraftnät states that the actual cost associated with emissions is likely to be higher than that collected by taxes and charges. Svenska kraftnät has a proprietary tool for life cycle analysis and financial assessment of environmental impact from investments in the transmission network, called the environmental assessment tool. In its guidelines for cost-benefit analyses, Svenska kraftnät recommends that life cycle analysis should be performed to roughly assess material utilisation and emissions caused by a transmission network installation during its service life. (Svenska kraftnät, 2014)

Ei proposes that emissions related to power line infrastructure should be included in the cost-benefit analysis

Emissions to air and water, as well as noise, should be quantified and monetised separately. The damage caused by local emissions of NOx, SO2, hydrocarbons and particles from work machines can be calculated, for example, using Svenska kraftnät's environmental assessment tool or using ASEK's calculation values.

The price database for environmental impact (Swedish Environmental Protection Agency, 2017) also includes air pollution and carbon dioxide emissions. The description of the database states that carbon dioxide can be monetised according to the damage cost method or the mitigation cost method. There are different values for the emissions included in EU trade in emission allowances and those that are not. An assessment must therefore be made of whether or not the measures could mean a net reduction of the emissions.

Ei proposes that these effects should be quantified as far as possible, and that the price databases available should be used if there are no particular reasons for departing from these (which should then be described).

5.9 Summary of effects proposed for inclusion in the analysis

Below we have compiled the effects that we propose should be included in the cost-benefit analysis.

Table 1. Table of effects to be taken into account when investing in the transmission network.

Effect	Quantification	Valuation
Welfare effects arising in the day-ahead market	Using electricity market models (at least two available and established models)	Monetary
Market power	Residual Supply index (RSI) and Herfindahl-Hirschman Index (HHI)	According to measurements as well as a qualitative analysis
System adequacy	Change in Expected Energy Not Served (EENS)	Monetary (Value of Lost Load (VOLL))
	The robustness of the network for different development scenarios - Variation in the likelihood of energy not supplied (Expected Energy Not Served (EENS))	Monetary (Value of Lost Load (VOLL))
Operational reliability	Changed welfare in the day-ahead market for maintaining safety margins in the transmission network	Monetary
	Benefit of capacity expansions within the bidding zone	Monetary
	Power quality	Qualitative
Frequency control	Welfare from the expansion in addition to welfare effects arising in the day-ahead market: - Balancing costs - Ancillary services	Monetary

Effect	Quantification	Valuation
Cost-efficient achievement of political objectives	Benefits in the form of reduced resource utilisation for society to achieve a given political objective	Monetary/qualitative
Network losses	Network model to analyse the change in losses	Monetary Electricity market models
Construction, maintenance and reinvestment costs	All expected accounting costs that a measure incurs should be included in the cost assessment, both for construction and for estimated reinvestment needs during the economic lifespan of the investment	Monetary
Local encroachment effects	Use of land that is not internalised in the project cost Local environmental impacts that are not internalised in the project cost Mental immissions (e.g. electromagnetic fields) and visual impact on indirectly affected properties that are not internalised in the project cost	Monetary/qualitative The Lantmäteriet's valuation manual may be a good starting point for the evaluation of the encroachment effect, but this value must be supplemented and adjusted to better reflect the socio-economic value of the land during the project's economic lifespan
Emissions	Noise and emissions to air and water	Monetary/qualitative The price databases available should be used if there are no particular reasons for departing from these (which should then be described).

Source: Own processing.

6 Alternatives to investments in increased transmission capacity

When performing a cost-benefit analysis, it is important to also compare increased transmission capacity with alternatives that have the potential to be a more cost-effective way of achieving the same objective.

Network development projects, especially at the transmission network level, have become more and more administratively demanding, with long lead times and complicated permit granting processes. The costs are also high - one kilometre of 420 kV overhead power line can cost up to SEK 7 million. Requirements for underground cable and far-reaching environmental considerations have also made network development projects costlier.

There may therefore be cost-effective to replace some new construction of transmission capacity with options that do not require this expansion. This section highlights a number of options, discusses the feasibility of alternatives, and provides Ei's assessments and recommendations with regard to whether these alternative measures should be included in Svenska kraftnät's cost-benefit analyses.

6.1 Alternatives to investments in increased transmission capacity

A need for Svenska kraftnät to invest in transmission capacity can arise for several reasons, see a detailed description in section 2.2. Depending on the type of investment - connection of a new electrical facility, reinvestment, system expansion or market integration that is planned, various alternative measures may be relevant. Ei's review of alternatives is based mainly on two background reports from Sweco and DNV GL (DNV GL, 2018; Sweco Energuide, 2018). Alternatives to traditional network investments can, in principle, be divided into two main categories:

1. adapting the need to transfer electricity to existing network capacity by reducing the demand for electricity or generating electricity close to the end customer or
2. utilising the existing electricity infrastructure in a different (more efficient) way.

This statement is not an exhaustive review of the options available and there may be other possible measures. In pace with development in network technology, more options can be added and the cost-effectiveness of new as well as existing alternatives can be improved. More detailed descriptions of the respective options can be found in the background reports.

Adaptation of the need to transfer electricity

Demand-side flexibility - This means that electricity users change their use of electricity based on some type of signal. For example, customers may reduce their electricity usage during peak hours (electricity prices, network tariffs or other price signals are relatively high) and increase their electricity usage during off-peak hours (low prices).

The Swedish Energy Markets Inspectorate's report on the potential for demand-side flexibility in Sweden showed that it is the largest among household customers and industrial companies (Swedish Energy Markets Inspectorate, 2016). A Norwegian study shows that there may also be significant potential in larger buildings (Vista Analysis AS, 2018). This potential is primarily associated with electricity usage for ventilation.

The party that can provide demand-side flexibility is the end user (households, industry, etc.). Possibly, it may also be a third party (aggregator) with an agreement on the use of the end customer's flexibility.

Energy efficiency is closely related to demand-side flexibility and means that the electricity user uses less electrical energy to achieve the same utility or derive more utility from the existing energy usage. For example, this could involve installing more energy efficient lighting, refrigerators or heat pumps in the home, resulting in the consumption profile decreasing by an amount equivalent to the energy efficiency. Energy efficiency measures, such as equipment with longer operating hours (e.g. ventilation units), result in a lower consumption during periods of high consumption. Much of the equipment installed for energy efficiency can also be used to shift load, i.e. temporarily increase or decrease the consumption and thus achieve demand-side flexibility. For example, it could be a question of using control equipment to switch off an electric boiler or water heater or different types of communication solutions to control heating.

Energy Storage - The term energy storage comprises a wide portfolio of technologies for storing electricity, such as flywheels, lead batteries, electrochemical batteries, flow batteries, super capacitors, compressed air, thermal storage (heat storage) and pumped-storage hydroplants. All of them can store energy that can be re-produced later as required. However, the different technologies have different properties, such as efficiency and storage time.

Using energy storage in the electricity system could reduce the need for transmission capacity in several ways. One alternative is to install energy storage in individual buildings such that their consumption profile can be smoothed, thus reducing the need for transmission capacity during periods of high consumption.

On behalf of the Svenska kraftnät, Sweco has previously studied the extent to which energy storage could deliver system benefit at transmission network level in the form of balancing services. The calculations showed positive investment scenarios for several energy storage technologies.

Energy storage can be owned by an end user (industry, household) or by commercial parties whose business model may consist of arbitrage trading on the day-ahead market, for example, or by providing network companies (including Svenska kraftnät) with ancillary services. In theory, even a network company can own energy storage, but there is currently a discussion in the EU about how it should work in practice since there is a desire to avoid disturbing the functioning of the market.

Counter trade - This is not a physical measure but a way of handling a transfer limitation using financial incentives. The system operator uses market mechanisms to remedy transmission congestions by using flexible producers and consumers. Counter trade is used by system operators in Europe to handle mainly temporary congestions within a bidding zone. Svenska kraftnät is the authority that decides on this measure in Sweden. However, the supplier of the flexibility is responsible for delivering the service.

New electricity generation and relocation of electricity generation - New local generation can replace, in whole or in part, a transmission network expansion in a bidding zone in order to handle an internal congestion. If new local generation can be stimulated, there is great potential for replacing network expansion. One variant of stimulating new electricity generation in a specific location is to influence the location of production installations that have already been planned. For example, new electricity generation can be increased combined heat and power production, re-investment or new investment in peak power[37] (oil condensing power plant, gas turbines or diesel engines) and increased installed capacity of solar power or wind power.

Solar power has great potential to increase installed capacity and the production is usually located close to the consumers. However, the seasonal variation in solar radiation involves the risk that solar power is unavailable for long periods during the winter months when it is needed most. Wind power generation has limited potential in a metropolitan area but may be a possible alternative for reducing congestion elsewhere in the transmission network. However, this also involves the risk that the installed wind power capacity is unavailable during the hours when it is needed most.

More efficient utilisation of existing networks

Risk-based transmission limits - The actual amount of transmission capacity in the system depends on the requirements for reserves and safety margins, amongst other things, in the real time operation of the network. Today, the system is largely dimensioned using the principle that it should be possible for a component to be disconnected and remain disconnected without any network customer losing its electricity exchange with the network, the so-called N-1 contingency criterion.

For certain periods, a more situation-based and/or probability-based use of the network could result in higher transmission limits, i.e. during favourable periods, transmission capacity would increase. However, the cost of this is reduced

[37] The maximum output that the total consumption requires. In Sweden, this output is typically required during the coldest hours of the year (DNV GL, 2018). During the rest of the year, significantly less output is required.

operational reliability (and thus impaired security of supply) and a higher risk of consumption disruption.

Transmission limits with countermeasures - Countermeasures refers to different types of measures in the network to counteract events in the network that create operational cases that ultimately lead to the system or parts of the system being disconnected. Automatic countermeasures to ensure the system's security of supply after unusually large production losses, in the form of frequency-controlled load shedding i.e. automatic disconnection of customers, have been used and widely accepted since at least the 1960s. Equivalent automatic countermeasures to ensure the system's security of supply after an unusually large loss of network capacity do not have the same level of development or acceptance.

Dynamic power line rating - For shorter overhead power lines and underground cables in the transmission network, the transmission capacity can be dimensioned based on thermal criteria. For example, by measuring the ambient temperature in the air/ground and possibly wind conditions, the transmission limit can be set closer to the thermal limit of the conductor.

For ground cables and overhead power lines at transmission network level, Svenska kraftnät can introduce different types of temperature measurement, either through direct measurement or indirectly via other indicators. Svenska kraftnät decides on this option.

6.2 Supporting information for Ei's assessment

In order to evaluate the extent to which there are alternative measures for increased transmission capacity, Ei engaged two consultants to analyse which alternatives are technically possible and whether they are cost-effective alternatives to fully or partially replacing increased transmission capacity. Ei has also drawn inspiration from a Norwegian consultancy study on alternatives to increased transmission capacity in Oslo and Akershus, ordered by Statnett (Vista Analyse AS, 2018). As mentioned above, Svenska kraftnät's cost-benefit analyses should include alternatives to transmission capacity. Since it is not possible to develop universal solutions, there is also no possibility in this report to specify which alternatives should be included. However, on the basis of the consultancy reports, Ei's assessment is that Svenska kraftnät should consider and evaluate alternatives to increased transmission capacity.

To facilitate the description of the alternatives, consultants were engaged to apply them to a range of cases, which are presented in more detail in the respective report. Sweco (Sweco Energuide, 2018) has looked in more detail into the following specific cases: additional capacity for the Stockholm region, increase of average capacity through the southwestern link, increase of transmission capacity to Finland, and increased operational reliability and facilitating the connection of additional production in the area around Långbjörn and Storfinnforsen. The DNV (DNV GL, 2018) has more generally focused on different cases linked to the utilisation of existing networks, i.e. risk-based transmission limits in the Swedish transmission system and transmission limits based on countermeasures in the Swedish transmission system.

Sweco's conclusion

Based on the cases that Sweco has studied, they conclude that the implementation of alternatives to investments in the transmission network appears to be feasible at a cost that, in some cases, is on a par with increased transmission capacity in the transmission network. However, several options such as demand-side flexibility and strategic reserve are only available in limited volumes and therefore cannot completely replace an investment in a new power line.

Sweco's study shows that when the development of power demand has reached a certain point where investments in the transmission network are necessary, it is rational to plan and implement investments that provide a significant increase in transmission capacity. Sweco therefore considers that the central question is whether it is possible to free up capacity in other ways and thereby postpone the investment.

Sweco specifically highlights the option of working with the underlying consumption profiles from individual customers at local grid level and upward, thus postponing the need for increased capacity at transmission network level. Examples of measures that could make a difference are energy efficiency and efficient price signals (network tariffs, electricity prices and taxes) that work towards a flatter consumption profile.

DNV GL's analysis

DNV GL states that demand-side flexibility and transmission limits with countermeasures are the most cost-effective and feasible measures in the short term. In the slightly longer term, energy storage and more refined probability-based methods can also be relevant in calculating transmission limits.

Norwegian study regarding alternatives to increased transmission capacity in Oslo and Akershus

A Norwegian study has evaluated alternatives to increased transmission capacity in Oslo and Akershus (Vista Analysis AS, 2018). The results of the study are specific to the area examined and therefore cannot necessarily be generalised to Swedish conditions. The results are presented in brief below. The overall assessment according to the study is that Oslo and Akershus have good conditions for implementing alternative measures that correspond to the need for increased transmission capacity in the transmission network.

Alternatives to networks can mitigate peak power

The study has examined the alternatives to network investments that may be relevant to Oslo and Akershus. Common to the measures is that they reduce the electricity demand when it is coldest. Examples of demand reductions given include avoiding charging electric cars during the coldest hours of the morning. With planning and sufficient incentives, a car can be charged during the night before. Another measure is to ensure that indoor temperatures are not lowered at night, but rather raised. This shift in electricity usage in time would significantly reduce network congestion the following morning. If water heaters use electricity when the network has spare capacity, it will also reduce network congestion during peak hours.

Alternatives that have been evaluated
The study has focused on measures based on a so-called feasibility study. However, the results presented in the report is only a first step in a longer process. Further studies are required that can validate the effectiveness of the measures and policy instruments.

- Ventilation in buildings - reducing the amount of air circulating in the buildings during the coldest days and hours.
- Controlled heating of water heaters - in many types of buildings there are water heaters where it is possible to shift load from day to night.
- Demand-side flexibility in households - primarily refers to changed charging patterns for electric cars so that fewer electric cars are charged at the same time in the morning or afternoon.
- Shifting the consumption in buildings over time - heating buildings at night to heat during office hours.
- Use of fuel-fired boilers - being able to keep boilers in Oslo and Akershus when the ban on the use of oil for heating comes into force. However, these need to be converted to burn pellets or biofuels.
- Use of backup generators - many institutions and businesses in Oslo and Akershus have backup generators to cope with power outages.

A strategy for alternatives to network investment uses all measures
In the Norwegian pilot study, the network capacity to Oslo and Akershus was assumed to be approximately 5 000 MW. The latest consumption forecast from Statnett states that peak demand in the region will be just below 5 000 MW by 2030, and 5 500 MW by 2050. The study examines whether society should use different alternatives to network investment by 2050. Since the costs associated with the measures are both fixed and variable, it is not considered obvious whether to focus only on a few measures or several measures. The study shows that in practice it is rational to use all measures.

In order to calculate the best combination of measures, an optimisation model for alternatives to networks has been used. This model is under development at Statnett. The model takes into account the potential output of each measure, the investment costs and the operating costs in order to calculate the composition of measures that minimises the cost of implementation. The optimisation model also takes into account of how the different measures costs as well as physical and technical limitations will develop in the future.

The study has identified a number of measures required to facilitate the implementation of alternatives to network expansion and, amongst other things, concludes that NVE should

- adopt a new regulation on the design of tariffs in order to clarify the network tariffs and develop new agreements between costumers and network companies for disconnection of consumption, and

- clarify who can become an aggregator (for example, whether network companies can) and what requirements will be set on those who take on the role.

The study also discusses that Statnett should act as follows:

- Start initial dialogue with Hafslund Nett (and possibly other regional network companies) on their role in implementing alternative measures.
- Clarify Statnett's role and responsibility, including the responsibility for using the necessary funds to implement measures as alternatives to networks. For example, is there a need for authorisation to influence the regional network companies?
- Evaluate the measures more closely with regard to cost-effectiveness, potential for implementation, etc.

How other market participants handle alternatives to increased transmission capacity

ENTSO-E

Investments in increased transmission capacity are, according to ENTSO-E, one of several possible measures in the energy system of the future (ENTSO-E, 2015). The report states that possible alternative measures may include energy storage, and flexibility in production and demand. The report also presents a principle for evaluating energy storage projects based on the guidelines from ENTSO-E.

Norwegian guidelines on alternatives to increased transmission capacity

The Norwegian Government's guidelines for the expansion of the electricity grid stipulate that a cost-benefit analysis for an investment aimed at improving security of supply must include alternatives to new transmission power lines in order to be complete. Other measures such as voltage or temperature upgrading of existing networks, measures in transformer substations or underlying networks, agreements with producers or consumers, should also be evaluated in the analysis. (Ministry of Petroleum and Energy, 2012)

The Norwegian guidelines state that the responsibility of the network owner should be clearly stated in an investigation of alternatives. The guidelines also state that the need for increased transmission capacity is affected by several factors, most of which are beyond the control of the network owner. The network owner should indicate how likely it is that alternative measures will be implemented, even if implementation of the measures is not within the company's area of responsibility. However, the network owner can contribute by coordinating the market participants so that different alternative solutions can be introduced. Where measures are implemented by other market participants, the need for increased transmission capacity will decrease, as should be highlighted in an updated needs analysis. (Ministry of Petroleum and Energy, 2012.)

6.3 Ei's assessment of alternatives to network expansion

Ei's assessment is that in some cases it is possible to use alternative measures to postpone the expansion of networks. However, the possibility of using alternative measures cannot be described in general, i.e. there are no universal alternatives for all the cases we have identified. Alternative measures need to be analysed on a case-by-case basis since the design of the electricity grid varies with local conditions. In addition, one measure cannot replace the entire need for increased transmission capacity - although it may be the case that several measures together can complement or postpone an expansion of transmission capacity.

The transmission network in Sweden has traditionally been dimensioned to handle the relatively few hours of the day and year where electricity consumption is greatest, as well as cope with power outages and disruptions. The peak power and the instances of faults for which the network is dimensioned mean that the full transmission capacity is rarely used. In practice, the network is therefore over-dimensioned for an absolute majority of hours of the year. If the power peaks can be cut during these critical hours, a network expansion, if not replaced, can in any case be postponed. How much it can be postponed depends on the availability of possible alternatives in the particular area in question.

The cases that Sweco has analysed and described in its report show that it is possible to replace parts of the transmission capacity with other alternatives, but the cost of the alternatives is estimated to be at parity with the cost of a network (Sweco Energuide, 2018). Preliminary results in the larger Norwegian study (Vista Analysis AS, 2018) show that the alternative measures proposed should together have the capacity to replace network expansion in the region studied up to 2050. However, the cost for this has not been compared with the corresponding cost of network expansion.

Alternatives require long-term work

Network investments are costly and have long depreciation periods, and once the network is built it is costly to make major adjustments. Since the marginal cost of increasing capacity is relatively low, it is common to have a margin of safety when building new power lines in order to meet potentially increased transmission capacity needs in the future. The alternative to this is to reduce the need for transmission capacity before the situation becomes urgent, and instead work actively with energy efficiency and demand-side flexibility at lower network levels. A flatter consumption profile (load factor) at lower network levels can increase the utilisation rate at all network levels, including the transmission network. However, these alternatives require long-term work on several fronts. These include transmission network tariffs, regional grid tariffs and local grid tariffs being cost-reflective and differentiated over time.

Several measures should be investigated and optimised

The study made by Vista Analysis shows that it is likely that several alternative measures will be required to replace the demand for increased transmission capacity. It is reasonable to assume that for most projects at transmission network level, the demand for increased capacity is so large that several alternative measures must be taken. To assist in the calculation of a rational set of measures, an optimisation model for alternatives to networks has been used, which is under development at Statnett. The model takes into account the potential of the measures, the investment costs and the operating costs in order to calculate the composition of measures, including the phasing-in of measures that minimise the costs. It also takes into account the physical and technical limitations as well as the development of the technical potential and costs of the measures. Such an optimisation model must probably be developed to be able to evaluate the real potential of alternatives to network expansion.

Coordination with other parties

If Svenska kraftnät's analysis showed that another measure, such as new production or relocation of production, was a more cost-effective solution compared with increased transmission capacity, Svenska kraftnät would have limited scope for action due to unbundling rules (rules for separation between network monopolies and competitive activities).

Therefore, in order to implement certain alternatives to network expansion, Svenska kraftnät needs to coordinate with other market participants, such as regional network owners, local network owners, producers or consumers so that different alternative solutions can be introduced.

Risk-based transmission limits and transmission limits with countermeasures

In the consultancy report for this investigation, DNV GL has briefly described the possibility of utilising existing networks more efficiently by not using the N-1 type of static safety margins, but instead dynamically utilising the capacity closer to the physical limitation of the network. According to the consultant, this may mean a substantial increase in capacity in a relatively short time that does not require any further expansion of transmission capacity. Since this option is within Svenska kraftnät's role as system operator and probably requires an agreement with the other Nordic system operators, Ei has chosen to simply state that this option exists.

Ei proposes that alternatives to increased transmission capacity should be included in the cost-benefit analysis

Currently, there are alternative measures available to meet the increased need for transmission capacity in the transmission network. For example, demand-side flexibility, flexible production, energy storage, relocation of consumers and production units can help to remedy temporary congestions in the transmission network. Market and technology development means that alternative measures are becoming more cost-effective over time compared to conventional investments in increasing transmission capacity. Ei proposes that alternatives to increased transmission capacity should always be included and evaluated in cost-benefit analyses of investments in the transmission network.

7 Impact assessment of Ei's proposals

On 29 June 2017, Ei was commissioned by the Government to establish guidelines for cost-benefit analyses in the construction of transmission capacity for electricity. The overall purpose of the assignment is to improve the basis for decision-making on investments in the transmission network so that the projects implemented are welfare-improving for society. The assignment includes analysing the need for an independent third party to carry out "shadow analyses" in addition to Svenska kraftnät's cost-benefit analyses as well as to analyse whether alternative investments such as energy storage, production capacity or demand-side measures can be a cost-efficient way to achieve the same objective. The assignment also includes evaluating to what extent it is appropriate to use regulation as a measure for implementing the guidelines, the purpose of which is to improve the decision-making processes for investments in the transmission network. The proposals presented by Ei provide conditions for transparent decision-making processes and informed investment decisions, which in the long term can lead to new business opportunities for technology and service providers, reduced land use and lower costs for Swedish electricity grid customers.

7.1 General information about the electricity grid in Sweden

The electricity grid in Sweden consists of 559 000 km of power lines, of which approximately 367 000 km consists of underground cables and 192 000 km overhead power lines. The electricity grid can be divided into three levels: transmission network, regional grid and local grid. The transmission network transports electricity long distances at high voltage levels. The regional grids transport electricity from the transmission network to local grids and, in some cases, directly to major electricity users. The local grids connect to the regional grids and transport electricity to households and other end customers. Local and regional network companies are responsible for ensuring that the level of maintenance of their own grid is sufficient to ensure that security of supply is maintained. The Swedish electricity system is closely interconnected with neighbouring countries, in particular Norway, Denmark and Finland, but also with Germany, Poland and Lithuania.

The transmission network in Sweden is managed by Svenska kraftnät and the regional grids are mainly owned by Ellevio, Eon and Vattenfall. The local grids are approximately 60 percent owned by Ellevio, Eon and Vattenfall, and the remaining part by various private and municipal entities.

In total there are 174 electricity network companies in Sweden. Of these, 157 operate local grid activities, 20 regional grid activities and two transmission network activities or only international connections[38]. Five companies have both local grids and regional grids[39].

A permit is required, a so-called **network concession**, to build and use electrical power lines. The conditions for issuing permits are set out in the Electricity Act (1997:857) and the Electricity Code (2013:208) and the Environmental Act.

There are two types of network concession. **Network concession for power line** refers to a power line for a largely predetermined routing. **Network concession for area** is a permit for building and using power lines up to a certain predetermined voltage within a certain geographical area.

A party with a network concession for an area has the exclusive right to build and use power lines within that area up to and including the maximum permissible voltage for the area. For power lines above the maximum permissible voltage level, a network concession is required for the power line. One area network concession must not coincide with another network concession for the same area.

In order to prevent cross-subsidisation between companies engaged in different types of electricity activities, network activities must not be carried out by the same legal entity engaged in the production or trading of electricity. Within the same legal entity, the network activities must be reported economically separate from all other activities. This means that electricity grid activities must be separate in both legal and accounting terms from companies engaged in the production or trading of electricity. However, electricity production may take place in an electricity grid company if it is intended to cover network losses or to replace electricity lost in the event of power outages. In addition, there is a requirement that some network companies should be functionally separate[40] from companies engaged in the production or trading of electricity. The functional unbundling applies to companies that operate network activities and belong to a group whose total electricity grid has at least 100 000 electricity users.

Ei regulates the revenues of the electricity network companies in advance over a four-year period. Revenues shall cover reasonable costs for operating network activities and provide a reasonable return on invested capital. The purpose of the supervisory model is on the one hand that the customers of the companies should have predictable network charges, and on the other that the companies should have the opportunity to invest and maintain the networks. In order for network charges not to vary too much between the supervisory periods, there is the opportunity to level out increases in network charges over several periods.

7.2 Ei's proposal

Ei presents a proposed amendment in the current Electricity Act (1997:857) and a consequential amendment to the Electricity Code (2013:208). The proposed amendment in the Electricity Act implies that a network concession for a

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[38] Svenska kraftnät and Baltic Cable.

[39] E.ON Elnät Sverige, Ellevio, Skellefteå Kraft Elnät, Vattenfall Eldistribution, Öresundskraft.

[40] In accordance with Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC.

transmission power line can only be issued if the installation is welfare-improving, provided there are no special reasons to waive this requirement. In order for the permit-issuing authority, in practice Ei, to be able to verify that the installation is welfare-improving, Svenska kraftnät must include a cost-benefit analysis with an application for a network concession for transmission power lines. The cost-benefit analysis shall also be drawn up following consultation, be published, and audited by a third party independent from the applicant.

The proposed amendment in the Electricity Act also contains an authorisation to the Government, or authority appointed by the Government, to issue regulations on how to design the cost-benefit analysis, what effects should be included in the analysis, how the consultation shall be conducted and how the cost-benefit analysis shall be published. This impact assessment will focus on the overall effects of the proposed amendment presented in Chapter 3. If the Government approves the proposed amendment and grants Ei the right to issue regulations on the details of the cost-benefit analysis, Ei will conduct impact assessments for the regulation or regulations that are then drawn up based on the proposals in Chapter 4 - 6.

The impact assessment of the proposed amendment that Ei presents in this report is based on the reference option that no action is taken, i.e. it will continue to be difficult for Svenska kraftnät, permit-issuing authority and Government to evaluate whether or not an investment in the transmission network is welfare-improving for society. The effects of Ei's proposed amendment are expressed as a change compared with the reference option. In cost-benefit analyses of major complex investments, it is often difficult to put a monetary value on all the benefits and costs that arise, but any uncertainties that may arise will be remedied using clear guidelines. Taking into account the large investment volumes and amounts at stake, Ei can, however, state that any additional costs associated with the proposed amendment can be quickly balanced by increased benefits if projects that are not welfare-improving for society can be postponed or avoided completely. This will streamline the use of resources in the economy, the use of Government funding and, in the long run, also lead to lower network charges for electricity grid customers.

7.3 Market participants affected

The proposed amendment will primarily affect the work of Svenska kraftnät and the permit-issuing authority. Other market participants that may also be affected by the proposed amendment are owners of underlying electricity grids and other infrastructure, technology and service providers, consultants, stakeholders affected, consumers and electricity producers.

Svenska kraftnät

It is important that investments in transmission capacity for electricity are socio-economically justifiable and that it is clear from the instructions from Svenska kraftnät that the transmission network for electricity shall be expanded based on cost-benefit analyses. Ei's proposal that an investment in the transmission network should be welfare-improving for society is therefore in line with the overall regulatory framework and existing instructions.

Svenska kraftnät has already initiated a project to develop formal guidelines for how its cost-benefit analyses should be designed. Svenska kraftnät states that it is awaiting the results of Ei's report before defining the final guidelines.[41] At the end of 2017, Svenska kraftnät's Board also approved a new decision-making procedure in the investment process.[42] The decision-making procedure states that the Board should have an earlier and increased transparency in the decision-making process for investments in the transmission network. The decision-making procedure also clarifies that cost-benefit analyses should be included as supporting information when the Board makes the decisions.

Ei considers that the proposed amendment and proposals for detailed guidelines presented in this report will facilitate the work of Svenska kraftnät to draw up formal guidelines for the cost-benefit analysis. A clear net benefit criterion in combination with clear and standardised guidelines with regard to how the cost-benefit analysis should be designed and what it should contain is expected to lead to increased quality and standardisation in Svenska kraftnät's basis for decision-making. This also allows comparisons and ranking between projects in the cases where Svenska kraftnät must prioritise its resources.

The new decision-making procedure means that Svenska kraftnät's costs associated with the proposed amendment presented in this report will be reduced to the costs for two new elements that the proposal includes. These elements are that the cost-benefit analysis shall, on the one hand, be drawn up following consultation, and on the other, be audited by a third party independent from the applicant.

Svenska kraftnät already has consultations with, for example, the owners of underlying networks, electricity producers and customers about their needs and how they are affected by an investment. In order to be able to conduct a cost-benefit analysis, it is natural that Svenska kraftnät coordinates with the market participants and stakeholders affected such as landowners, municipalities and county administrative boards so that they can assess the benefits and costs associated with a project, as well as to evaluate alternatives to conventional investments in overhead power lines and underground cables. Significant synergy effects may also arise for society if Svenska kraftnät coordinates with the Swedish Transport Administration, for example, on the coordination of infrastructure. In this case, the synergy effects would consist of reduced land encroachment and reduced environmental impacts to achieve the same objective.

Svenska kraftnät's consultancy costs are affected by the proposed requirement for a mandatory audit of the cost-benefit analysis, but what the overall impact will be on the total consultancy costs is difficult to determine. The consultancy cost per audit should at most be in the range of SEK 150 000 to 400 000. Naturally, it is not only costs associated with an independent audit that arise, but also benefits due to the increase in transparency, thereby also reducing potential conflict areas, for example. The more decision makers who have access to this cost-benefit analysis, the greater the benefit of the analysis.

[41] E-mail conversation with Mira Rosengren Keijser and Hilda Dahlsten, Svenska kraftnät.
[42] Svenska kraftnät, Case no. 2017/3204.

Ei

At present, there is no requirement in the Electricity Act (ellagen) that a transmission power line should be welfare-improving or that a cost-benefit analysis should be included in the application for a network concession, even though the network process of granting network concessions aim at preventing inefficient investments in the transmission network (prop. 1996/97:136). In accordance with its instructions and decision-making procedure, Svenska kraftnät shall also draw up a cost-benefit analysis of investments in the transmission network. It is therefore a natural development that an investment in the transmission network should be welfare-improving and that a cost-benefit analysis should be included in the application for a network concession in accordance with the proposed amendment that Ei presents in the report.

A consideration of the cost-benefit analysis involves a new element for the permit-issuing authority, in practice Ei. Concession applications for transmission network power lines are often extensive and the processing is therefore labour intensive. Since 2008, Ei has received on average approximately 17 concession applications for transmission network power lines per year. These can be divided into new applications (6) and extension cases (11). The number of extension cases will decrease in the future since the concessions have begun to be issued on an until further notice basis, with the option for reassessment after 40 years. The reduced number of extension cases is offset by the continued high investment needs that Svenska kraftnät has announced in its network development plan. Ei's additional work to consider the cost-benefit analysis is estimated to amount to a maximum of one employee per year, i.e. approx. SEK 1.1 million. Ei estimates that a more detailed basis for decision-making and clearer net benefit criterion will lead to increased quality and predictability of the regulatory process of granting network concessions. These benefits are expected to offset any additional costs that arise from handling the cost-benefit analysis.

Regional network owners

Ei's proposal for consultation at an early stage in the decision-making process aims to systematically include several market participants as well as increase transparency in Svenska kraftnät's decision-making process. Increased coordination allows the investment to be cost-effective and efficient in order to achieve a given objective or meet a need. Sweden has three major regional network owners (E.ON Elnät Sverige, Vattenfall Eldistribution and Ellevio) but also a number of smaller regional grids to connect wind farms and merchant cables on the Swedish border. In total, there are approximately 20 regional network owners in Sweden. In principle, these can incur additional costs to participate in consultations. Svenska kraftnät states that it is already conducting consultations with regional network owners for an investment in the transmission network, which should limit the additional costs. However, Ei considers that a more formalised requirement for consultation with regional network owners is necessary in order to realise many of the positive effects that result from Svenska kraftnät gaining increased understanding of the needs of regional and local network owners and how security of supply are affected by a planned investment in the transmission network.

Technology and service providers

A cost-benefit analysis means that the investment option that is most welfare-improving for society should be implemented. It also means that conventional investments in ground cable and overhead power lines should be compared with other alternatives such as energy storage, production capacity or demand-side measures. This may increase the demand for new technology and thereby create incentives for research and development of new technical solutions as well as increase the range of energy services and ancillary services. The increased business opportunities for these companies can take place at the expense of reduced business opportunities for suppliers of conventional underground cables and overhead power lines.

Consultants

The requirement for a mandatory audit of the cost-benefit analysis by a third party independent from the applicant is likely to lead to increased business opportunities for consulting firms. In Norway, which has a regulatory framework similar to Ei's proposal in this respect, consultants are responsible for the independent audit of Statnett's cost-benefit analyses. A meaningful audit of Svenska kraftnät's cost-benefit analysis sets high and specific requirements of the consultant's competence in electricity systems. This is quite a niched field, but in principle, both small and large consulting firms can offer these types of services.

Consumers and electricity producers

Increased transparency in Svenska kraftnät's decision-making process means that electricity grid customers in the form of consumers and electricity producers can make more well-informed investments decisions on where to establish and how to design their consumption facilities or generation units. Well-informed investment decisions allow cost-effective electricity supplies. In addition, the formalised requirement for consultation means an increased opportunity for electricity grid customers to influence the development of the transmission network to suit their needs. Ei considers that the increased coordination can result in positive effects and more efficient network expansion. In the long term, this will benefit connected consumers and electricity producers through lower network charges. In the short term, the direct effect of lower network charges is an increased welfare in society. In the longer term, the lower network charges can also have indirect effects in that electricity-intensive industry becomes more competitive in the global market, thereby facilitating increased production.

Stakeholders affected

The stakeholders directly or indirectly affected by an investment option will, if the proposed amendment goes through, also be able to benefit from the results of the cost-benefit analysis prior to the consultation that is conducted in accordance with the rules of the Environmental Act. The cost-benefit analysis shows which net benefits for society that an investment option is expected to bring, thus putting the land and environmental impacts of an establishment in a broader perspective. The increased transparency can reduce the number of conflict areas and thereby facilitate the consultation process with the stakeholders affected.

The requirement of a cost-benefit analysis in an application for a network concession for a transmission power line also provides the opportunity to include, amongst other things, the costs of land encroachment and environmental impacts of different technology choices and power line routes in a systematic and transparent way.

Special focus on small companies

Since the proposed amendment will primarily affect the work of the state enterprise, Svenska kraftnät, and the permit-issuing authority, Ei considers that it will not be administratively burdensome for small companies. On the other hand, the proposed amendment may make it easier for small and innovation-driven companies to spread their technical solutions or services, provided that they are cost-effective in relation to conventional investments in increased transmission capacity in order to solve a given need.

7.4 The proposed amendment complies with EU legislation

The proposal complies with and is in line with current EU legislation. The requirement that an investment should be welfare-improving for society and that a cost-benefit analysis should be included as supporting information in an application for a network concession for a transmission power line is in line with the requirements set for investments in the transmission network that are deemed to be of common interest within the EU in accordance with Regulation (EU) No. 347/2013. There are therefore clear synergies and efficiency gains in harmonising and coordinating the regulatory frameworks.

7.5 Overall assessment

The proposed amendment clarifies the net benefit criterion that the permit-issuing authority, in practice Ei, uses to consider a concession application. A clearer net benefit criterion in the Electricity Act (1997:857) means a harmonisation with Svenska kraftnät's instruction that investments in the transmission network for electricity should be based on cost-benefit analyses. This is also in line with the international development. A clearer evaluation criterion is also expected to facilitate the legal review for the permit-issuing authority and also for the applicant party. The proposed amendment is expected to have little effect on the labour costs of Svenska kraftnät and Ei, while the benefits of greater clarity and transparency regarding cost-benefit analyses are expected to have significant positive effects. The benefit of cost-benefit analyses for investments in the transmission network consists of more informed investment decisions, which reduces the risk that projects that are not welfare-improving for society are implemented. In the long term, this will lead to lower network charges for consumers and electricity producers.

In addition to leading to increased quality in Svenska kraftnät's basis for decision-making, the proposed amendment will also provide the prerequisites for a more transparent and inclusive decision-making process at Svenska kraftnät, which is beneficial to the market's participants and the stakeholders affected. A cost-benefit analysis of the effects that an investment has in the electricity system may, for example, require some coordination with the owners of underlying networks and other infrastructures, as well as new and existing electricity producers and consumers or energy service companies. Similarly, the requirement for an independent third party to audit Svenska kraftnät's cost-benefit analysis will create a demand for consultancy services with relevant competence. An evaluation of the cost-effectiveness and feasibility of alternatives to a conventional investment in increased transmission capacity may also create increased demand for new and existing consultancy services, different types of energy and ancillary services, as well as technical solutions. This can stimulate a continued development of Swedish innovations within the energy field, which is beneficial to small, medium-sized and large companies.

If the proposed amendment presented in this report is not implemented, Ei considers that it will continue to be difficult for Svenska kraftnät, permit-issuing authority, market participants, stakeholders affected and Government to evaluate whether or not an investment in the transmission network is welfare-improving for society.

Appendix 1

Electricity Act regulations

As mentioned earlier, a power line may not be built or used without a network concession. The construction of a power line also includes excavation, cutting down forests or similar measures to prepare space for the power line. These measures may therefore not be started before the network concession has been issued for the power line (Chapter 2, §§ 1 and 3).

If there are special reasons, Ei may allow a power line to be built even before the network concession has been issued. However, such prior authorisation only applies for a limited period, pending the final consideration of the application for a network concession. If the case concerns an international connection, the Government considers questions about prior authorisation (Chapter 2, § 5).

Prerequisites for issuing a network concession

A network concession may only be issued if the installation is suitable from a general point of view. One purpose of the consideration is to prevent inefficient investments in the transmission network, i.e. to prevent new installations being built where sufficient transmission capacity is already available (prop. 1996/97:136). A network concession for a power line must not conflict with the detailed development plan or area regulations, but minor deviations may be made if the purpose of the plan or regulations is not counteracted (Chapter 2, §§ 6 and 8).

A network concession may only be issued to parties that, from a general point of view, are suitable to perform network activities. A network concession for an international connection may be granted and held only by a transmission network company or legal entity in which such a company has a controlling influence, e.g. a company co-owned by Svenska kraftnät and an international operator. However, a network concession may be granted to others if the power line is of less significance to the overall cross-border capacity on the Swedish border (Chapter 2, § 10).

The provisions of Chapter 2-4 and Chapter 5, §§ 3 and 15 of the Environmental Act shall apply when considering an application for a network concession for a power line. The question whether the construction or use can be assumed to result in a significant environmental impact shall be determined in a special decision in accordance with Chapter 6, §§ 26 and 27 of the Environmental Act after an investigation in accordance with Chapter 6, §§ 23-26 has been conducted, unless otherwise stated in Chapter 6, § 23, second paragraph. If a significant environmental impact can be assumed, a specific environmental assessment must be performed, information submitted and coordination take place in accordance with Chapter 6, §§ 28-46 of the Environmental Act. If a significant environmental impact cannot be assumed, a small environmental impact assessment must be drawn up in accordance with Chapter 6, § 47 of the Environmental Act (Chapter 2, § 8a).

However, questions that have been considered in a case or matter relating to a permit in accordance with the Environmental Act need not be reassessed in the case of a network concession. If there is an environmental impact assessment in a case or matter relating to a permit in accordance with the Environmental Act that describes the direct and indirect effects on human health and the environment that the power line may cause, there is no need for a specific environmental impact assessment in the concession case (Chapter 2, § 8a). An example of when this might be relevant is when a wind farm has undergone permit consideration and the power line that shall connect the wind farm to the regional grid has been included in the consideration. In such a case, Ei does not need to perform a new consideration of the power line's environmental impact, but only a consideration in accordance with the provisions of the Electricity Act or of the environmental issues that could not be considered in the case for the wind farm.

Validity period of a granted network concession for a power line
A network concession applies until further notice. However, the validity of a network concession for a power line may be limited for a certain period of time if requested by the applicant or if there are special reasons. In such a case, the validity period may be as long as 15 years. A network concession for a power line that has been issued for a certain period may be extended by up to 15 years at a time. If the applicant so requests, it may be decided that the network concession will instead be valid until further notice (Chapter 2, §§ 13-14).

A network concession for a power line that is valid until further notice may be reconsidered in terms of the route of the power line, permissible voltage and other conditions. A reassessment may only be made 40 years after the network concession was issued. A reassessment shall be initiated upon application by the holder of the network concession or a municipality or county administrative board affected by the network concession. Ei may also decide to initiate a reassessment on its own initiative (Chapter 2, §§ 15 b and 15 c).

A reassessment shall be initiated if it is justified in view of the interests listed in Chapter 2-4 of the Environmental Act or any other relevant public interest. A reassessment shall also be initiated upon application by the holder of the network concession if a reassessment is justified to ensure rational and efficient operation of the network activities. A reassessment shall refer to the requirement that the installation is appropriate from the public point of view, that the power line is designed for a voltage exceeding the maximum permissible voltage for the network concession for the area, and that the network concession does not conflict with the detailed development plan or area regulations. The same provisions of the Environmental Act apply to the reassessment as in the consideration of the application for a new network concession.

The network concession holder shall handle the investigation required for the reassessment and Ei may instruct the concession holder to provide the investigation required. Once a reassessment has been performed, a new reassessment may only be performed 40 years after the decision to reassess (Chapter 2, §§ 15 h and 15 i).

Environmental Act regulations

In order to understand the possible environmental impacts that a power line entails, it is justifiable to describe the particular environmental considerations taken in the Environmental Act. As mentioned earlier, Ei shall apply certain regulations in the Environmental Act when considering the application for a network concession for a power line. The regulatory frameworks apply in parallel, which is why an independent consideration of the respective provisions is made. A power line must thus meet the requirements of both the Electricity Act and the Environmental Act in order to be granted a network concession.

Chapter 2. Environmental Act - General rules of consideration

The general rules of consideration form the basic requirements for all types of activities and measures. These rules also affect the interpretation of the remaining provisions of the Environmental Act. The rules in Chapter Two consist of the following rules and principles:

Burden of proof

Burden of proof means that it is up to the practitioner to show that there is no risk and that all legal requirements are met (Chapter 2, § 1)

Knowledge requirement

The practitioner must possess the knowledge required to counteract and limit the environmental impact of the activity (Chapter 2, § 2).

Best possible technology

The practitioner must use the best possible technology. The technology must be available on the market and proven. The technology must be practical, as well as economically feasible to implement (Chapter 2, § 3).

Precautionary principle

The practitioner must implement the safety precautions, respect the limitations and take other precautions necessary to prevent, minimise or counteract the activity or measure causing harm or inconvenience to human health or the environment (Chapter 2, § 3).

Product choice principle

The practitioner must not use chemical or biotechnology products if there are others available that are less harmful to human health and the environment (Chapter 2, § 4).

Resource management and ecocycle principles

Everyone who runs a business or implements a measure must ensure efficient use of raw materials and energy, as well as take the opportunities to reduce the amount of waste, reduce the amount of harmful substances in materials and products, reduce the negative effects of waste and recycle waste (Chapter 2, § 5).

Appropriate location principle

The appropriate location principle means that when an activity uses land or water, the site chosen must be appropriate for the purpose to be achievable with minimum encroachment and inconvenience for human health and the environment. The intended site must therefore be compared with other potential sites in order to establish that it is appropriate (Chapter 2, § 6).

Remedy damage
Everyone who runs or has run a business or implemented a measure that has caused damage to the environment is responsible for remedial action to remedy the damage (Chapter 2, § 8).

Reasonableness principle and stopping rule
All rules of consideration must be applied after weighing up the costs and the benefits. The requirements set for an activity must be environmentally justifiable without being economically unreasonable. There is a limit for a where the benefit to the environment does not outweigh the costs incurred in the precautions. However, the benefit to the environment takes precedence when balancing environmental benefits and costs. If the costs of taking the measure are too high, but the measure is environmentally justifiable, the so-called stopping rule enters into force. The activity may then only be continued if there are special reasons (Chapter 2, §§ 7 and 9–10).

Chapters 3-4. Environmental Act – Resource management provisions
The resource management provisions in Chapter 3 regulate the use of land and water regardless of where they are in the country. The provisions can be divided into two categories: provisions aimed at protecting *conservation values* and provisions aimed at protecting the *use* of certain areas. It is common for an area to include several interests that warrant protection, which must then be weighed up against each other. Some of the areas may also be of national interest and then receive stronger protection. The special provisions for resource management in Chapter 4 apply to certain geographical areas, which are listed directly in the legal text. The chapter consists mainly of a list of geographical areas that are of national interest for nature conservation, cultural heritage or outdoor recreation, amongst other things, as well as rules on when exemptions may be made from the provisions.

If a power line is routed through an area protected according to Chapters 3-4, it does not mean that the power line is automatically unsuitable or that the application is rejected. What is important is how the power line affects the interest in question. How the power line affects an interest depends on a range of factors, such as which materials are used or during which season and with which methods the construction is carried out. Sometimes the impact can be so small that no damage prevention measures are required, while in other cases, extensive measures may be required for construction of the power line to be possible. Most interests in Chapters 3-4 must, as far as possible, be protected against measures that may significantly impede the preservation or pursuit of the interest.

Chapter 5. Environmental Act – Environmental quality standards
For certain geographical areas or for the whole country, the Government may issue regulations on the quality of land, water, air or the environment in general. These regulations are called environmental quality standards. When Ei considers an application for network concession, Chapter 5, § 3 applies. According to this paragraph, authorities and municipalities are responsible that the environmental quality standards are complied with. Ei must therefore obtain information from the

network company on what emissions the planned power line is estimated to cause, as well as whether the estimated emissions mean that an environmental quality standard is breached. Ei shall also apply Chapter 5, § 15, which states that the authority that handles a case or matter in accordance with the Environmental Act must ensure that such implemented action programmes and management plans that are regulated in Chapter 5, and which are relevant to the consideration, are available in the case or the matter.

Environmental assessment

Amongst other things, a specific environmental assessment means that an environmental impact assessment must be drawn up, that consultation is conducted, that account is taken of the contents of the environmental impact assessment and the findings of the consultation when a decision is made. The specific environmental assessment is a process that is started before an application for a permit is submitted to the examining authority and which continues and is concluded within the framework for the permit granting process. The environmental assessment is thus conducted partly by the applicant company, which is responsible for consultation and drawing up the environmental impact assessment, and partly by Ei, which takes into account and reviews the environmental impact assessment and results of the consultation in the permit consideration of the application for network concession.

To identify, describe and asses the effects on human health and the environment is central to an environmental assessment. The environmental assessment therefore includes to identify *which* areas and interests that the power line will affect, as well as *how* the power line will affect the area or interest. As mentioned earlier, there are several factors included in how a power line affects an area or interest. If the power line entails worse conditions for the survival of certain species, if the power line impedes the use of an area for outdoor recreation, if the power line uses land that would otherwise have been used for agriculture or forestry, etc. The assessment must also include a review of what consequences there are and how extensive their effect is on the area or interest in question. Worse conditions for the survival of species may result in the species completely disappearing from the area and affecting the local conservation status, taking land from agriculture or forestry may result in continued and future activities in the area being impeded or completely prevented. In the assessment of the consequences of the power line, Chapters 3-4 of the Environmental Act are of great importance since it is in these chapters that the protective value of the interests is stated. For example, if an interest *as far as possible* shall be protected from *significant impediment* to use of the interest, it is thus of interest to assess whether the power line involves significant impediment.

An important part of the environmental assessment is what damage prevention measures the applicant company is planning to take. The damage prevention measures must aim to avoid, reduce or remedy the harmful consequences that the power line has on an area or interest. If the harmful consequences are so extensive that damage prevention measures are required and if the costs for taking the measures are high, but the measures are environmentally justifiable, the stopping rule enters into force.

The environmental impact assessment is an important part of the environmental assessment because it aims to describe the possible effects of the project. It is therefore the applicant that has the ultimate responsibility to identify and describe which areas and interests are affected, the effects of the impact and what measures are planned to avoid, reduce or compensate for the impact. If Ei needs more material to complete the environmental assessment within the framework of a permit consideration, Ei may ask the company to complete the application with the material. Ei can also conduct its own investigations if justified, as well as draw on the referral bodies for assistance.

Consultation and environmental impact assessment

An important part of the process of drawing up a correct environmental impact assessment is the consultation. In cases where it is not obvious that the power line can be assumed to have a significant environmental impact, investigative consultation must be conducted to examine if this is the case. If investigative consulting has been conducted, the county administrative board can make a decision on whether a significant environmental impact can be assumed. For activities and measures that cannot be assumed to have significant environmental impact, it is sufficient to conduct a so-called small environmental impact assessment (Chapter 6, § 27). However, for these activities and measures it is still possible to demand the submission of the necessary documentation in order to conduct an assessment of the environmental impact in the individual case. Since most transmission power lines must always be assumed to have significant environmental impact, no investigative consultation is required in these cases (§ 3 (6) of the EIA Regulation).

If a significant environmental impact can be assumed, a specific environmental assessment must be performed, information submitted and coordination take place (Chapter 6, §§ 28–46). The consultation within the framework for a specific environmental assessment is called demarcation consultation. Demarcation consultation must be conducted prior to work on the environmental impact assessment in order to determine its boundaries. The demarcation consultation shall also address the location, extent and design of the activity or measure, and the environmental impact that the activity or measure can be assumed to have itself or as a consequence of external events, as well as the content and design of the environmental impact assessment. The consultation shall also take place with the county administrative board, the supervisory authority[43] affected and the individuals that may be considered to be particularly affected by the activity or measure, as well as the other government authorities, the municipalities and the general public that may be affected by the activity or measure. The consultation shall be initiated and consultation documentation submitted in good time to allow for meaningful consultation before the operator draws up the environmental impact assessment and the final permit application (Chapter 6, §§ 29–31). It is

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[43] Supervision is carried out by, amongst others, the Swedish Environmental Protection Agency, the county administrative board, other government authorities and municipalities in accordance with the regulations issued by the Government (Chapter 26, § 3 first paragraph MB). The Government has divided the responsibility in the Environmental Inspection Regulation (2011:13) as well as in the Environmental Assessment Regulation (2013:251) and the annexes to the regulation (1998:899) on Environmentally Hazardous Activities and Health Protection.

therefore important that the consultation is held while there is still the opportunity to make changes in the project. This applies to both alternative routes and alternative designs for the power line.

The environmental impact assessment must contain information on the location, design, extent and other characteristics of the activity or measure that may be of significance to the environmental assessment. It must contain information on alternative solutions for the activity or measure and information in the prevailing environmental conditions before the activity is started or the measure taken, and how the conditions are expected to develop if the activity is not started or the measure is not taken. It must also contain an identification, description and assessment of the environmental impact that the activity or measure can be assumed to have, either itself or as a consequence of external events. The environmental impact assessment must also contain information on the measures planned to prevent, minimise, counteract or remedy the adverse environmental impacts, as well as information on the measures planned to prevent the activity or measure from contributing to non-compliance with an environmental quality standard according to Chapter 5, if such information is relevant with regard to the nature and extent of the activity. The environmental impact assessment must also contain a non-technical summary of the above and an account of the consultations that have been conducted and what has been discussed in the consultations. The environmental impact assessment will therefore be a means for the company to describe how the rules of consideration in Chapter 2 will be taken into account (Chapter 6, § 35).

The information to be included in the environmental impact assessment must have the extent and degree of detail that are both reasonable, taking into account existing knowledge and assessment methods, and necessary for an overall assessment to be possible of the significant environmental impacts that the activity or measure can be assumed to have (Chapter 6, § 37).

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