# Transparent methods to support infrastructure investments

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***Abstract*—The transmission grids have an important role in the development of the internal electricity market, and as a tool for fulfilment of EU's ambitious energy policy, known as 20-20-20 in 2020[1]. The key issue is how to get the national TSOs to broaden their scope in order to realize the full potential of trades across borders. The TSOs need to get the incentives to take an active part in the foreseen structural change in electricity generation, which will require actions both nationally and across borders. In this paper we focus on the importance of a broadened international scope when planning the future development of the European transmission grids. We exemplify our method by some empirical findings from the Nordic electricity market.**

## I. Introduction

The European Commission has recently published a draft directive for the promotion of renewable energy which together with the drafts for emission trading directive and the third internal market directive set the framework for EU's energy policy approaching year 2020. Strong actions from national governments and the EU are required, none the least because of the urgent need for increasing cross-border cooperation as we shall elaborate upon in this paper.

As pointed out in [2] existing political and regulatory boundaries imply very different conditions for national and international transmission investment. The latter requires an evaluation process with wider perspective than the national.

The transmission grids in Europe were built in different preconditions. Originally we had vertically integrated utilities "aimed" at, in a state-planning setting, exploiting economies of scale. The failure of this approach to fully make use of the productive apparatus, and a somewhat hampered dynamics, as well as political impetus towards market solutions, led to a decision to deregulate the European electricity markets. Thus the goal of an efficient European market, with sustainable production of electricity and decentralized investment decisions demands a partial re-thinking. The planning and development must allow for flexibility, and make it possible to reap European welfare gains given that environmental issues should be solved globally, not by each individual country. Having replaced the earlier vertically integrated entities and planning coordination with competition in generation and retail, we are hoping to reap some of the liberalized market benefits (see for example [3] for an account of this).

### A. *Potential cost savings in cross border trade*

Perhaps the easiest way to quantify economic benefits from a new transmission line, or a strengthened existing one, is to

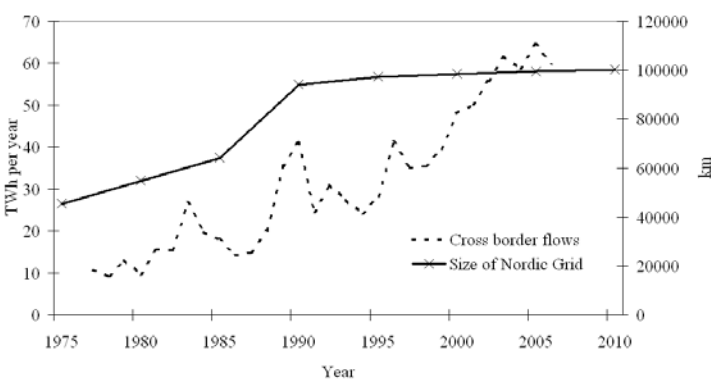
[1] A 20% reduction of green house gas emissions, 20% share of renewable energy and 20% increase in energy efficiency in 2020 [1]

look at it the same way as we usually study international trade. In the short run low cost producing areas producers will gain, and consumers lose, and vice versa. In the long run we would have to add dynamic effects in the low cost countries as a more competitive industry, increased security of supply, etc.

Capacity in transmission and distribution needs to match the changes in demand and supply. The foreseen changes are not limited to size or growth of consumption, but also as mentioned above imply change in structure of consumption and supply which generate new patterns in the flow of electricity throughout the European transmission grid. For example, more wind power in the system may require more transmission capacity in certain areas (see for example [4] and [5] for accounts of the requirements more wind put on the system)

Some constraints of the benefits of network markets are set by the current infrastructure and how this infrastructure develops. Alas, in the Nordic market it is alarming that the transmission grid seems to have halted in development, see figure 1. As figure 1 shows, little if any investments are done. Figure 1 also illustrates that development in use of cross border capacity since the 70th initially was supported by investments in transmission capacity, but during the last 15 years the investments have fallen behind. Given the direction of energy policy and the more and more frequently expressed view that electricity has an increasing role to play in a sustainable energy supply (se for example [6] and [7]) this development is alarming.

Figure 1. Annual Cross border flows between the Nordic and bordering markets (left axis) and size of Nordic transmission grid (right axis)




Source: The World's T&D Systems and Markets for Transmission and Distribution Equipment 2006 – 2011 and Nordel annual statistics.

One criterion to use is when discussing welfare changes is the Pareto-criterion [8]. What this criterion says is that we should allow the welfare change if everyone gets an improvement without anyone getting worse off. Thus, we would make an improvement only when there is a clear win-win situation for all involved stakeholders. The current process for development of the grid seems to mean that any interest group may veto trade improvements if it does not lead to gains for them. Now, trade improvements only rarely involves such a clear short run benefits to all parties. The early infrastructure development in the North European market may be an example as it basically meant coupling an energy-based system with a capacity based system. It is very difficult to find cases when trade is harmful in the long run (for some discussion on the "infant industry argument, see [9]) so anything that makes this kind of transaction possible is bound to have some benefits from trade[2]. Two points has to be made about this. First, there is generally better for a society to concentrate its efforts to produce goods and services that it has comparative advantages in doing. Thus it should clearly be beneficial when areas with good conditions for producing electricity can export to areas with less benign conditions for production. Secondly, applying the Pareto-criterion strictly is likely to lead to a deadlocked situation where changes cannot occur. Someone is likely to lose in the short run. Examples are producers in high cost areas and consumers in low cost areas. Thus protectionist measures will always be in some stakeholder groups' interest. Therefore, we need to apply a different criterion in identifying the future development of transmission expansion, and at least in theory allowing for income transfers from beneficiaries to potential cost bearers of the direct costs of the transmission projects.

### *B. Cost allocation should follow benefit- beneficiary pays*

Costs and Benefits must be transparently identified – to the whole region and to all stakeholders. Infrastructure, the transmission grid, may be considered a public good[3]. Thus an approximation of the benefits of a new transmission capacity needs to cover consequences for different stakeholder groups as well as the expected changes in neighbouring grids. Although this task is challenging it should by no means be perceived as impossible. Some of this work is already done in a competent fashion at the TSO-level.[4] Our claim is that some additional, important benefits are rarely taken into account, as well as the obvious fact that benefits and costs are calculated over too small geographical areas (see for example [12] on the latter point).

The reluctance towards a wider geographical and stakeholder perspective may originate in issues of financing transmission investments. As of today there is a lack of established mechanisms that provide a transparent base for allocation of costs due to transmission investments. This may affect both bilateral investments (where a 50-50 sharing rule often is deemed to be inefficient) and investments that create benefits in third country. One may for example suspect that the five Nordic grid investments [13] are not the top five in

[2] A perverse version of the infant industry argument is sometimes occurring where customers of electricity wish to prevent international trade as this may raise prices locally. Such barriers to international trade, would not only be costly from a global social economic perspective, but could impede the long run dynamics for investments.

[3] In general large in terms of time, resources, geography, and you can hardly exclude people from using it when they are connected, the services are non-excludable, and there can be large positive external effects when they are in use such as better and more environmentally friendly balancing of wind power, less volatilities in prices, a more robust network overall (SoS), and finally less transports of raw materials such as biomass

[4] Some international experience of transmission investment evaluation can be found in California where the independent system operator CAISO has developed a method to calculate the social net value of transmission projects and make it available to regulators, system operators and market actors see [10] and [11]

order of social economic merit, but a compromise as a substitute for an established burden-sharing rule.

The purpose of the Inter TSO Compensation mechanism (ITC) [14] is to accommodate the development of an inner market for electricity in which producers and consumers are given access to the entire market by paying a local/regional/national input or outtake tariff, and serve as a link between the cost of international flows and the local tariffs. In practice, discussions on the ITC mechanism have come to focus on payment for existing infrastructure, which today is (partially) used by cross-border flows. In order for a fully integrated European electricity market to become a reality, a considerably more forward-looking payment system is required that supports investments in new transmission capacity, which in turn contributes towards the regions of Europe becoming more closely knit. Furthermore the road towards an agreement seems to bee long and complicated.

The coming challenges for the EU will require a sound and recognized method for identifying the distribution of benefits of transmission investments as a basis for cost allocation. Furthermore the evaluation must be sufficiently forward looking as transmission investments in general involve lead times of 8-10 years [11].

The rest of this paper is divided into 2 sections. First we attempt to identify the main benefits that should be taken into account, and further elaborate on how to include them in the analysis. The last section focuses on the importance of perspective of the analysis and choice of input assumptions for the final result or investment decision.

## II. Which are the benefits?

The purpose of the Cost-Benefit-analysis is to calculate society's true valuation of a predefined project. The CBA calculation differs from privet calculation since decision makers in companies (or household) often apply a too narrow delimitation of relevant cost and benefits, and existing market prices may not always include the full cost for society, (for example air pollution). The flow of cost and benefits for the lifetime for the specific project is discounted back to a net present value, signalling society's valuation in today's money.

Figure 2 shows the general principle of social benefits from an increase of transmission capacity between two countries.

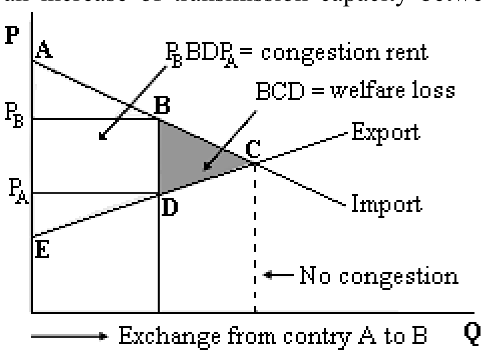



Figure 2 Social benefits of transmission

Country A, is a surplus area (*low price area)*. A is interconnected with country B (*high price area).* The existing interconnection capacity is not sufficient to level prices; hence there remain some price difference ($P_B$-$P_A$) caused by the congested interconnector. The congestion imply a welfare loss equal to the area B-C-D which correspond to the social gains from increased trade. Thus the social economic benefit may be extracted from forecasted market prices.

The cost and benefit analysis have to rest on forecasting and sometimes heroic assumptions. For example we may need to forecast changes in size and structure of demand, how the structure and size of production at different locations will (or should) change. Both changes in demand and supply are not only influenced by market fundamentals, e.g. the expected large expansion of wind power is strongly influenced by policy measures. Market benefits are in general recognized in principle by the TSO:s, but are often underestimated when (if) quantified, due to the national mandate and regulation. Table 1 summarize the benefit areas discussed below.

Table 1 Benefit areas

| Description | Category | Source |
|---|---|---|
| Benefits from trade | Market | [15] & [16] |
| Sharing of reserves | Market | [17] |
| Operational security | Technical | [15] & [16] |
| Efficient operation | Technical | [17] |
| Integration of markets | Political | [17] |
| Security of Supply | Political | [18] |
| Renewable energy | Political | [17] |
| Greenhouse gases | Political | |

*Sharing of reserves* refers to avoided investment in peak power capacity, sharing of operational reserves etc. As an example the energy deficiency in the Nordic countries due to the very dry year 2002-2003 described in [19] was partially solved by trade between countries. The value of shared reserves may for example be estimated through standardized cost of building new peak capacity or the cost or tenders such as the Swedish "peak power reserve

In a simple world, the technical benefits are the main focus of the TSO. Operational security refers the power system's overall ability to supply electricity without interruptions. A stronger grid is better equipped to handle a sudden failure in the grid or in a larger generation plant. Valuation of a blackout is complex and will always rest on more or less heroic assumptions: What categories of consumers are affected, how many are they, how long is the blackout etc. Furthermore, what are the costs of a blackout? Three methods estimating the value of lost load is elaborated upon in [20][5]: The Swedish TSO's report from the large blackout in Sweden 2003 valued the social costs to 50 SEK/kWh [21].

In efficient operations we include cost savings in the operation of the system due to increased transmission capacity, e.g. more efficient regulation or reduced network losses. As briefly touch upon above, a large expansion of wind power will mean that the relative importance of these values is likely to increase. One example is the Swedish TSO's control area where balancing resources is distributed

[5] (1) Investigate which direct costs customers suffer due to a blackout (e.g. food in the freezer, lost production). (2) Revealed preference - actions related to the risk of future blackouts (e.g. invest in reserve generation). (3) Map the customers' willingness to pay to avoid a black out. The important distinction

around 85/15 in the north/south half of the country. As most wind power investments are planned in the south areas balancing power will require a larger share of the transmission capacity, thus increasing the benefit of potential investment in new internal transmission capacity. [4] Writes on this: "Policy-makers appear to have only a weak grasp of this critical fact and its implications. Indeed, the accommodation of the variable output from wind turbines into the transmission system is complex and the technical challenges are barely understood outside professional circles. Fossil-fuelled capacity operating as reserve and backup is required to accompany wind generation and stabilize supplies to the consumer." These kinds of results are also discussed in [22] where it is noted that wind energy, fed to the grid to save resources and reduce emissions, requires control power to balance fluctuations. They conclude that a European-wide balancing of wind power from large-scale offshore generation of the scale that politicians are currently contemplating would definitely call for an expansion of the high voltage system. There are large potentials for cost reductions in the possibility to exchange balancing power between the Nordic and continental Europe.

*A. Political benefits.*

The energy sector has experienced an increasing amount of attention during the last couple of years. Much of this is related to environmental concerns such as sustainable development and climate change. As a consequence (and exemplified by the EU 20-20-20 policy) there is a strong political strive towards a more sustainable and also emission free energy system. Intimately related to these political challenges is the overall goal of an internal EU-wide electricity market, with secure supply of energy, as a backbone for a competitive European economy. Thus we can single out four distinct but related political goals; (1) Reduced emissions of green house gases; (2) Security of supply; (3) Integration of regional electricity; and (4) Sustainable energy supply We argue that at the current state, with the restructuring process ahead and the importance of getting the incentives for transmission investment right, these value need to be included as the benefit of fulfilling the society's will, expressed through the political goals. The evaluation requires a two-step process, incorporating long and short-term dynamics:

The issue of transmission investments in connection with the expansion of wind power is important. Renewable energy sources such as wind power is currently best treated as a public good, wanted not only for its economic or environmental characteristics but also involving a political will to strive for the sustainable society. This implies that the institutional setting accommodating additional wind power must take into account the incentives needed for TSO:s to perform the necessary strengthening of the network when doing the cost/benefit analyses. The expansion of renewable energy is facilitated through transmission investment that enables access to more efficient and lower cost balancing energy. Furthermore it is important to include a forward-looking perspective and include the effect a transmission expansion may have on conditions for investment in renewable generation.[6]

The locations reasonably adapted for wind power only occasionally coincide with high population density or high industrial activity. This means that the electricity generated needs to be transported both within control areas and between countries. To some extent the internal market exist already today, e.g. there is a price related flow of electricity between the Nordic and continental Europe, which depend on peak or off-peak hours. As discussed above and elaborated upon in [22] this connection opens up for reduced emissions of $CO_2$ which we think should be included in the valuation of transmission expansion.[7] .

*B. The cost of transmission investment*

The building of new transmission includes the capital cost of building the line, operating and maintenance costs over the life of the line, environmental impacts from construction of the line, and changes in property values resulting from the location of the line. Although it is commonly assumed that property values decline in the vicinity of a transmission line; they could increase, particularly for industrial properties benefiting from better access to transmission lines. A study prepared for the European Commission [23] published data on the costs of building overhead AC-lines in different locations in Western Europe, see table 2 below.

TABLE 2 COSTS OF BUILDING TRANSMISSION LINES, EURO/KM.

| Countries | € '000/km | Specific cost factors |
|---|---|---|
| Finland, Sweden | 200-300 | Flat land (fewer towers) less populated |
| Greece, Portugal | 200-300 | Low costs (land, labour) |
| Denmark, Norway, Spain | 300-400 | Close to base case |
| Belgium, Netherlands, Italy | 400-500 | Close to base case. Heavily populated |
| France, Germany | 500-600 | Heavily populated. High labour costs |

As we can see the data on Finland and Sweden reflects the fairly easy construction environment whereas the Greece and Portuguese lines are cheap due to cheap labour. We would claim that some of the issues mentioned, for example high environmental standards in the Austrian case is probably already "harmonized", as we see similar objections to overhead AC-lines all over Europe. As very little has been built in the northern hemisphere the costs given in table 2 is at best good approximations.

Worth mentioning is the technology using underground DC cable with lower impact on existing land. This may lead to

between (1)-(2) and (3) is that the latter includes effects normally not being priced in the market e.g. "I cannot read which I do every night".

[6] In our simple example we propose to use the price of green certificates (or feed-in tariff) as an approximate valuation of the benefit of sustainability. E.g an increase in renewable energy of 0,25 TWh per year has an annual social economic value of 0,25 "times" price of green certificate.

[7] In our simple example we propose to use the price of EU-ETS as an approximate valuation of the benefit of reduced CO2 emissions. E.g an increase in wind energy of 0,25 TWh per year has an annual social economic value of 0,25 "times" price of EU-ETS.

lower costs than the conventional techniques used today (e.g South west link Norway-Sweden) [24]. Although this is stating the obvious, in an industry dominated by people working with overhead AC-lines, we may need the regulatory authorities to initiate institutional change when it comes to technology.

## III. Importance of perspective and assumptions

One perspective of a study answers the question: *Who's benefit is maximized?* The difference between calculating domestic versus regional benefits is a key issue, as the interconnected systems have different characteristics. For the credibility of the study and to enable a benefit reflecting allocation of costs it is also important to bring forth the distributional effects between regions and stakeholder groups. Examples of different perspectives are *national*, *tariff payers* or domestic *consumers*.

Input assumptions and forecasting models are potential sources of large differences in results. Given the long life of transmission assets and that accuracy of forecasts decrease with the time it is important to provide a balanced choice of scenarios, see [25], [15]. The scenarios express the net benefits as an interval and indicate specific sensitivity factors. As an example a set of 84 different scenarios was used in the evaluation of examples a "Path 26" in California [11].

Investment plans on a liberalised market are generally not public information, so the full picture of planned investment in the system may be somewhat unclear. Still [11] emphasize the importance of a correct modelling and representation of location and size of future production investments. The rationality for this is that transmission investments in general are associated with longer lead times, than investments in generation. The main uncertainty concerning the short-term dynamics of generation is forecasting fuel prices.. For hydro-based system as the Nordic the uncertainties of water inflow needs to be represented. One implication of the latter is that traditional thermal models may generate a result that underestimates the transmission need.

The physical lifetime of transmission assets is long, and often claimed to be longer than the applied depreciation rate of around 40 years. As benefit flows can be expected for as long as the asset is in use, the analysis should cover at least 50 years. But as forecasts exceeding 10-15 years imply a significant share of uncertainties the net benefit of any transmission investment involve a great deal of uncertainty. On the other hand a shorter perspective underestimates the real benefit of transmission.

The choice of the discount rate can be decisive on whether a project is profitable or not. We need the discount rate to properly account for the time factor (consumption now may bis more "valuable" than consumption in the future). The most common estimation method is the net present value, where a time preference rate (not to be confused with an interest rate or inflation) is used to calculate the value of a future cost or benefit at the present. A positive net present value reflects that the benefits are larger than the costs. The important issue for us is the difference between the social discount rate – social time preference, and the rate of return use by the transmission companies.[8] The latter is often higher since the perspective for the companies are constrained to costs and benefits directly related to its financial results. Table 3 show suggested time reference rate, or discount rates, for projects in different regions, and from different sources.

Table 3 The social and other discount rates

| Source | Discount rate |
|---|---|
| Evans & Sezer (2005) EU[a] | 4,5 % |
| Evans & Sezer (2005) Sweden | 2,8 % |
| Oxera (2002) | 3,5 % |
| Swedish EPA | 4 % |
| SIKA (2002) | 4 % |
| Svenska Kraftnät, Swedish TSO | 5 % |

[a] Average of EU-15, plus Czechia, Hungary, Poland, Slovakia
Source: [27]

For regulated industries it is sometimes proposed to use the regulated cost of capital as discount rate. However as [15] clearly states transmission characteristics, as a public good requires the use of a social discount rate.

To illustrate the method and sensitivities discussed above, and especially emphasize the need for a transparent process we present a rough calculation, based on a case of building to decrease the current systematically occurring bottleneck between the middle and the south of Sweden[9].

Table 4 Illustrative calculation - Cost and benefits

| Description | Million SEK[10] | Details |
|---|---|---|
| ***Benefits*** | | |
| Benefit from trade[a] | 460 (1-10)<br>230 (11-50) | Sweden: 240; Norway: 210;<br>Denmark 70; Finland: 140; Germany: -270. CR:s excluded |
| Operational security | 15 | 500 m SEK divided by 40 |
| Efficient operation | 10 (1-10)<br>20 (11-50) | Assumed value (probably low, corresponding value of NorNed 200mNOK [28] |
| Renewable energy | 50 | Assumed 0,25 TWh wind power year 1-30. Price of green certificates 200 SEK |
| Green house gases | 50 | Assumed 0,25 TWh wind power year 1-50. Price of emission rights 200 SEK/ton |
| ***Costs*** | | |
| Loss of forestry production | 4 | 80 % through forest land 2000 ha . Growth 8,5 $m^3$/year. Pulp wood ca 200 SEK/$m^3$ |
| Deforestation | 80 | |
| Operation and maintenance | 30 | Share of SvK:s total cost. |
| Cost of investment | 3300 | Assumed |
| Loss of forestry production | 4 | 80 % through forest land 2000 ha . Growth 8,5 $m^3$/year. Price on pulp wood ca 200 SEK/$m^3$ |

[a] Based on Vattenfall long time forecast

The results are rough approximations and at this stage only intended for discussion. Table 4 summarizes our assumptions[11]. We use a social discount rate 3,5 % and assume an economic life of 50 years. Figure 3 below shows the development of the accumulated present value for this

[8] [26] argue for a decreasing discount rate and a long term level of 1 %.
[9] We include the Nordic countries and Germany
[10] Eur/SEK = 9.15
[11] For additional information we refer to [18].

project under four different sets of assumptions.

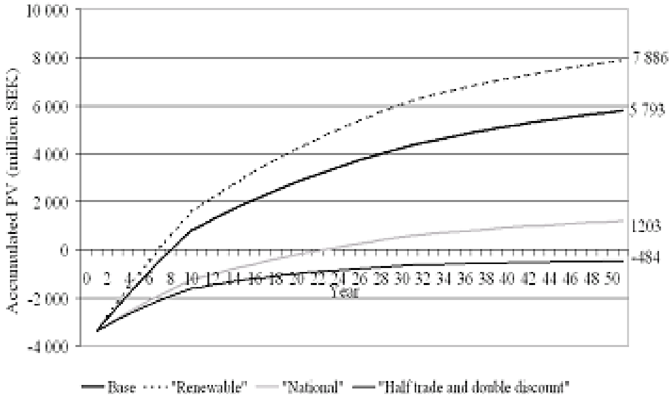



Figure 3 Accumulated present value under four different assumptions

The three scenarios complementing the base case, “Renewable”(double renewable), “Domestic” (only Sweden) and “Half trade double discount” (“the pessimist”) are chosen to represent sensitivities and risk of underestimation due to a too narrow perspective. The difference in final result suggests that total benefit may be as much as 4-5 times lower if a pure domestic perspective is chosen.

## IV. Conclusions

To implement the EU’s 20-20-20 goal, we believe that infrastructure changes are needed, accommodating the path forward. If a regional or at best, a EU-perspective is taken on the harmonization on support schemes, this may initiate a European path towards the sustainable future. To a certain extent, our claim is that the grid development needs to follow the market and the political will of how the market should develop. It will likely become very expensive from a social economics perspective to enter the path towards sustainability without a proper understanding on the infrastructure’s role in this development.

In this paper we argue that infrastructure investments concern more entities, larger geographical areas and support of energy system change in ways that currently seem excluded from decision maker’s information gathering when deciding on transmission investments. We believe that the inclusion of some of these factors in a transparent cost benefit process may enlighten the debate, as well as speed up the investment and permitting processes.

It is, at present, not clear that the current development is handled at all by the regulatory authorities. Little if any cost-benefit analyses of improvement in the regional trade are neither done, nor if done, presented publicly, to support groups of regulators to make supranational decisions. There is no doubt that all cost benefit analyses should be viewed with critical eyes and the results mulled over and changed dependent on views and opinions on the future and the evaluation of non-market goods. Our findings shows that including a regional perspective, as well as environmental and political benefits in the evaluation process will lead to a more accurate valuation.

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## VI. Biographies

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