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CROSS-BORDER ELECTRICITY TRANSMISSION INVESTMENTS

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Abstract

The objective of this paper is to analyse what targets and criteria should be followed for electricity transmission investments which would be beneficial for Europe. The paper indicates that there is serious underinvestment in the European transmission network from the overall welfare point of view. The paper demonstrates that in transmission investments there is an important dimension of welfare distribution between the countries connected but also within the countries due to the change in the market outcome when an interconnector is built.

The paper shows that it is possible to develop objective criteria for interconnector investments. Social welfare benefits from price arbitrage should be one criterion but several other criteria should be used as well including price convergence, security of supply and competition benefits. Flaws in market design, capacity calculation and capacity allocation need to be addressed to provide efficient signals for interconnector investments. This should include designing of optimal price zones for Europe.

Keywords

Electricity transmission network, investments

1. Economic principles*

It is obvious that any TSO should make only beneficial transmission investments. The challenge is to identify which transmission investments are the most beneficial and how to prioritise them.

Inside a control area, transmission investments are needed to connect power plants, distribution systems and industrial consumers to the transmission network. Without a connection, a power plant, distribution system or consumer is not able to operate. Regarding investments in interconnectors, there is an option not to build anything at all as they are usually not absolutely necessary for the functioning of the system. The need for interconnectors is reduced by the common political wish of many sovereign states to have a high degree of autonomy in the electricity supply. For large countries a certain level of autonomy is necessary from the technical point of view, at least with currently used transmission technology. Only small countries could be entirely supplied from the neighbouring countries, Luxembourg being an example. This means that even if it is well possible to optimise European electricity production by transporting electricity from surplus areas to deficit areas, it is not possible in practise with current transmission technology to cover the consumption of the whole Europe by producing only in a small number of countries.

Thus the main role of interconnectors is, in addition to providing system security back-up to national systems, to optimise the overall system by allowing some higher cost generators to be replaced by lower cost generators in the regional dispatch. This means that an approach based on optimising social welfare when deciding on building an interconnector is very appropriate even if the political wish for autonomy might in some cases overrule the social welfare calculations. The assessment of the increase in social welfare due to building new interconnectors is developed in this paper.

2. Social welfare

An interconnector between two price zones with a price difference will allow generators in the low price zone to supply load in the high price zone. This will result in an increase of overall social welfare if the net increase in producer surplus, consumer surplus and congestion rent is higher than the investment costs. However, there can be important distributional effects. In the low price zone, part of the consumer surplus will be transferred to the producer surplus as the price increases. Equally, in the high price zone part of the producer surplus will be transferred to the consumer surplus, as the price decreases. This phenomenon is illustrated in Figure 1.

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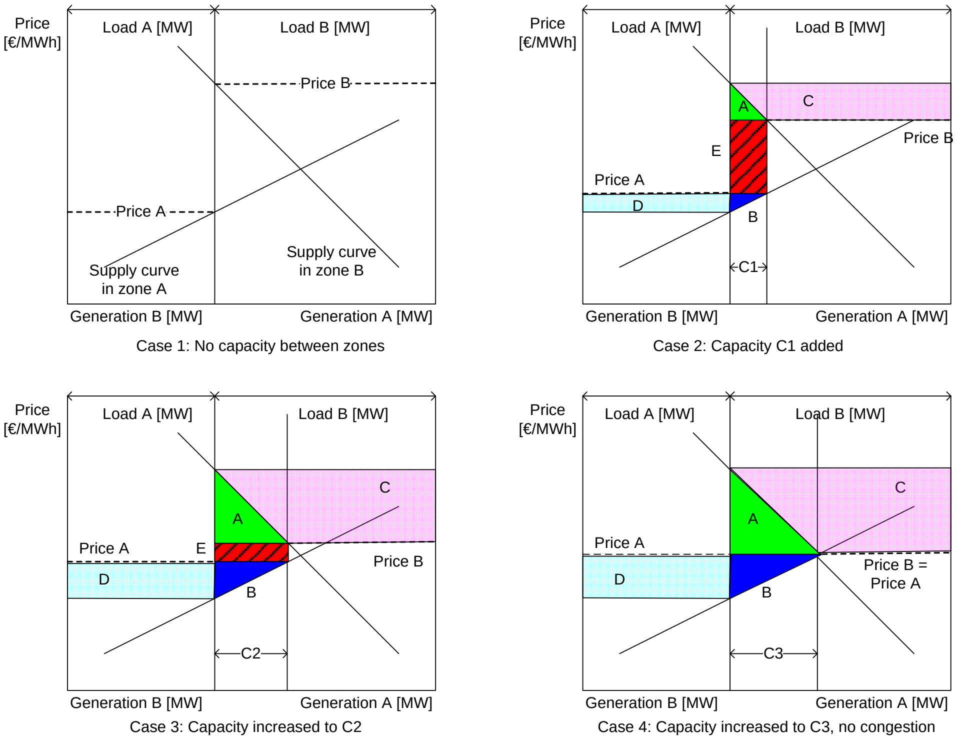
* Matti Supponen is working for the European Commission. However, the views expressed in this study are personal views of Matti Supponen. They have not been adopted or in any way approved by the European Commission and should not be relied upon as a statement of the European Commission's views.

This paper is based on the dissertation of Matti Supponen for Aalto University (Espoo, Finland): "National and Company interests in European Electricity Transmission Investments". The dissertation is available at: http://lib.tkk.fi/Diss/2011/isbn9789526042701/

Drawings: Outi Supponen

Figure 1 Social welfare effects of an interconnector investment.[1]



A: An absolute increase in consumer surplus due to increased transmission capacity
B: An absolute increase in producer surplus due to increased transmission capacity
C: A transfer from producer surplus to consumer surplus
D: A transfer from consumer surplus to producer surplus
E: Congestion rent

As shown in Figure 1, the transfer of surplus from producers to consumers and vice versa is dependent on the slope of the demand and supply curves. If the supply curve is gradual, a capacity increase will cause only a modest transfer of surplus. If it is steep, the transfer of surplus is important. Regarding prices, a steep supply curve will cause prices to change faster when increasing cross-border capacity than in the case of gradual supply curves.

In large price zones supply curves are more gradual than in small price zones as there are more power plants forming the supply curve. Thus building an interconnector between a large and a small price zone will influence the level of prices more in the small zone. However, the transfer of surplus can also be important in the large price zone as the price change applies to bigger volumes.

Also, in peak load conditions supply curves tend to be steeper than in base load conditions. This means that the influence of interconnection capacity to prices during peak load times can be more significant than during base load hours.

Figure 1 is simplified by leaving out the effect of demand elasticity. Demand is usually inelastic in short term. In longer term, demand is elastic in all electricity markets and needs to be taken into account when analysing transmission investments.[2]

Consumers are particularly interested in congestion costs for consumers[3] which are equal to the area of zone D as shown in Figure 1 subtracted from zone C+A. It is interesting to note that increased

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1 UCB, Lesieutre and Eto, 2003; CRE, interconnection 2008, 2009

2 In this case the welfare effects will be even bigger as deadweight loss is reduced.

interconnection capacity does not automatically lead to increased welfare to consumers when summing up the effect on both sides of the border. For example if the supply curve in the exporting country is very steep and in the importing country very gradual, the result of building an interconnector is a substantial price increase in the exporting country but only a slight price decrease in the importing country. In these circumstances, overall social welfare for consumers will be reduced while overall social welfare for producers will be increased. An inversed slope of the supply curves would give the opposite result.[4]

3. Congestion rent

TSOs are particularly interested in congestion rents, zone E in Figure 1. Congestion rent is collected by the TSO in the form of auction revenue from selling interconnection capacity as already discussed above. This can take place explicitly when the TSO sells interconnection capacity and the traders organise themselves how to use this capacity, or implicitly when cross-border electricity flows are decided based on bids in power exchanges.

Welfare effects in function of the increase of cross border capacity are shown in Figure 2. When the capacity of an interconnection is increased from zero, the amount of congestion revenues received from selling transmission capacity first increases rapidly as shown by the parabolic congestion rent curve. With a further increase in capacity, the increasing flow in the interconnector reduces the price difference over the interconnection and the congestion rent will grow slower until it reaches its maximum. From that point onwards a further increase of capacity will reduce the congestion rent until it becomes zero at the full price convergence point.

The increase in producer and consumer welfare is almost opposite to the increase in congestion rent. With small capacities the increase in producer and consumer welfare is small but they increase exponentially with the increase of capacity. Thus the first megawatts are interesting for the TSOs' income and the last megawatts are interesting for the producer and consumer welfare. However, it is important to note that the biggest influence of an interconnector capacity increase is usually through the transfer between the producer and consumer welfare within each country as shown in Figure 2. This transfer increases almost linearly with the capacity increase until the full price convergence point.

In Figure 2 it is assumed that a linear capacity increase is possible. In practise the main capacity increase option is adding new transmission lines corresponding large capacity steps. However, smaller intermediate steps are often possible such as upgrading existing lines to higher capacity ratings.

From Figure 2 interesting observations can be made regarding the optimum outcome for various parties. A merchant investor would aim to maximise the net revenue for the interconnector owner which is reached with the capacity of 1500 MW. The overall social welfare maximum of the investment corresponds to the capacity of 3000 MW or 3500 MW which has almost the same overall social welfare as 3000 MW. In the case of 3500 MW the TSO would make a loss. Country A would choose a capacity of 2000 MW because at higher capacities the social welfare for Country A decreases. Country B would invest up to 4500 MW, which is the capacity needed for full price convergence, because this gives the maximum welfare for Country B.

(Contd.)

3 Congestion cost for consumers is the difference in overall costs for consumers between the congested situation and the situation without congestion.

4 This analysis only takes into account the effect on the electricity market in the respective countries caused by the new interconnector. The long run general equilibrium consequences of any voluntary trade are always beneficial. This is due to the fact that resources in the importing country can be reallocated to be better used in other sectors, and in the exporting country resources will be allocated to the electricity industry from less value creating sectors (comment by Mats Nilsson).

Figure 2 Welfare effects of an interconnector investment in function of capacity. [5]

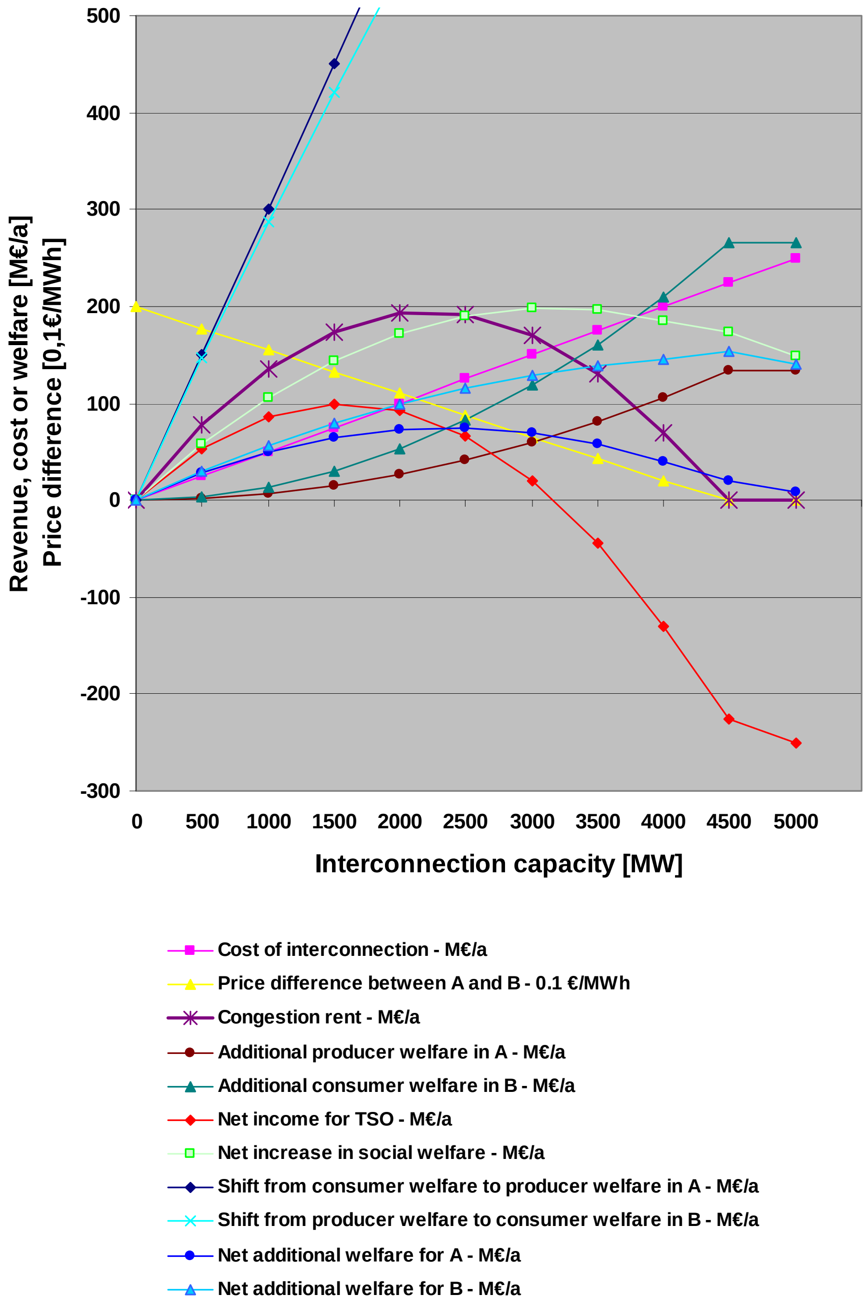
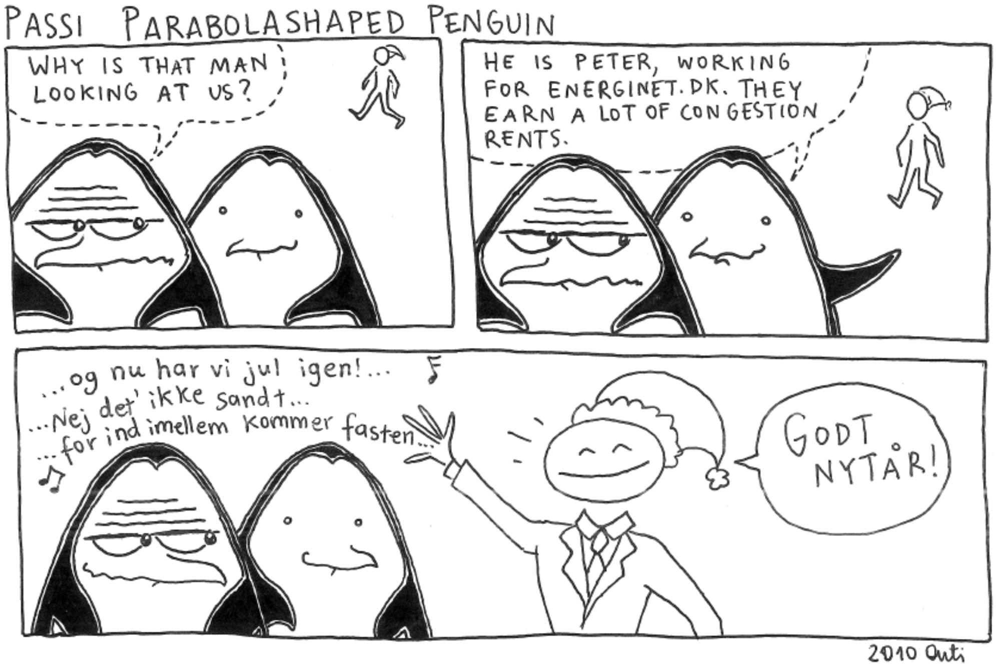


Figure 2 illustrates the importance of the transfer of social welfare between producers and consumers. The negatively affected parties potentially seek for limiting the capacity of the investment far below the overall welfare optimum level.

[5] Discussions with Peter Jørgensen, Energinet.dk in 2002; EPFL, Duthaler and Finger, congestion revenues, 2008; ESRI, Valeri, IE-UK interconnector, 2008

Figure 3 Congestion rent accrual follows a parabolic curve.



Congestion rents have increased constantly after the introduction of implicit and explicit transmission capacity auctions. Year 2009 was an exception. In 2009 congestion rents dropped due to consequences of the economic crises reducing electricity cross-border trading. It is, however, foreseeable that the overall congestion rents in Europe will increase again when the economic crisis is over. There are also some borders on which congestion rent is still not collected but capacity is given for free based on historical long term contracts. This applies in particular to the Swiss borders. In the EU priority allocation of cross-border capacity for historical contracts is forbidden.[6] Table 1 gives the development of congestion rents in Europe in 2006 – 2009.

It is important to understand how congestion rent is accumulated as a function of the price difference and the capacity of interconnection. In most interconnections in Europe the price difference and hence the commercial flow is predominantly in one direction as illustrated in Figure 4.

On average only about 10% of the commercial flows are in reverse direction. Only in the Finnish-Swedish, German-Swiss and Belgian-Dutch interconnections both directions were almost equally used in 2008.

The price difference can change direction in different time patterns. Daily or seasonal price difference patterns are usual between thermal and hydro systems. Thermal systems have typically a high price difference between day and night. Hydro systems have a smaller price difference between day and night because of the storage capability.

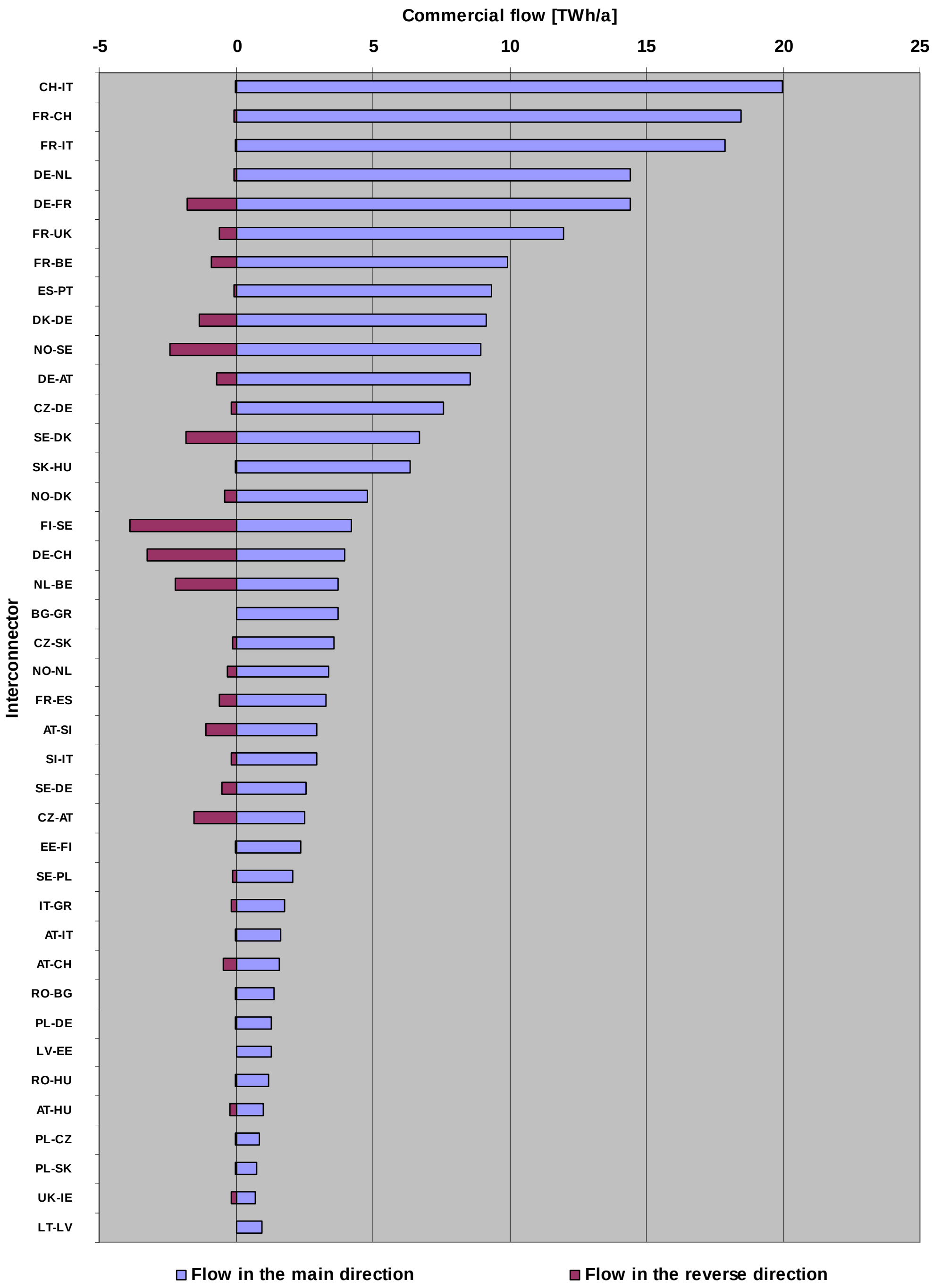
6 EU, court decision C-17/03, 2005

Table 1 Annual congestion rents collected by the TSOs in Europe in 2006 - 2009.[7]

TSO	Country	2006 [M€]	2007 [M€]	2008 [M€]	2009 [M€]
Verbund APG	Austria	26.3	44.5	63.2	49.45
Elia	Belgium	58.1	40.3	29.2	28.6
ESO	Bulgaria	0	2.3	23.6	19.1
Swissgrid	Switzerland	35.3	40.1	78.1	59.4
CEPS	Czech Republic	102.0	59.8	34.6	26.2
EnBW (DE), RWE (DE), EON (DE), Vatenfall (DE), VKWNetz (AT)	Germany	316.3	220.6	222.5	167.9
Energinet.dk	Denmark	79.5	95.2	129.9	58.3
OÜ Pohivork	Estonia	0	0	0	0
REE	Spain	25.8	61.8	78.0	41.6
Fingrid	Finland	11.9	22.6	23.2	4.9
RTE	France	342.0	376.5	380.6	257.0
HTSO	Greece	22.0	5.1	30.9	35.5
Mavir	Hungary	29.4	47.1	76.4	49.0
EirGrid	Ireland	6.2	13.1	0	0
Terna	Italy	89.8	333.8	299.6	187.8
AB Lietuvos energija	Lithuania	0	0	0	0
Cegedel	Luxembourg	0	0	0	0
AS Augstsprieguma tikls	Latvia	0	0	0	0
Tennet	Netherlands	107.6	54.0	105.9	59.0
Statnett	Norway	18.0	31.9	112.9	45.6
PSE Operator	Poland	70.2	40.9	28.1	13.4
REN	Portugal	0	23.2	32.3	5.5
Transelectrica	Romania	10.7	17.7	36.7	22.1
Svenska Kraftnät	Sweden	35.4	67.8	85.3	28.2
ELES	Slovenia	3.1	25.9	32.6	33.0
SEPS	Slovakia	22.48	44.39	36.2	27.9
National Grid	United Kingdom		61.14	106.0	66.1
TOTAL [M€]		**1412**	**1730**	**2046**	**1286**

7 EC, ITC consultation documents, 2008 ; ENTSO-E, congestion rents 2008, 2009; ENTSO-E, congestion rents 2009, 2010; CRE, interconnection 2007, 2009

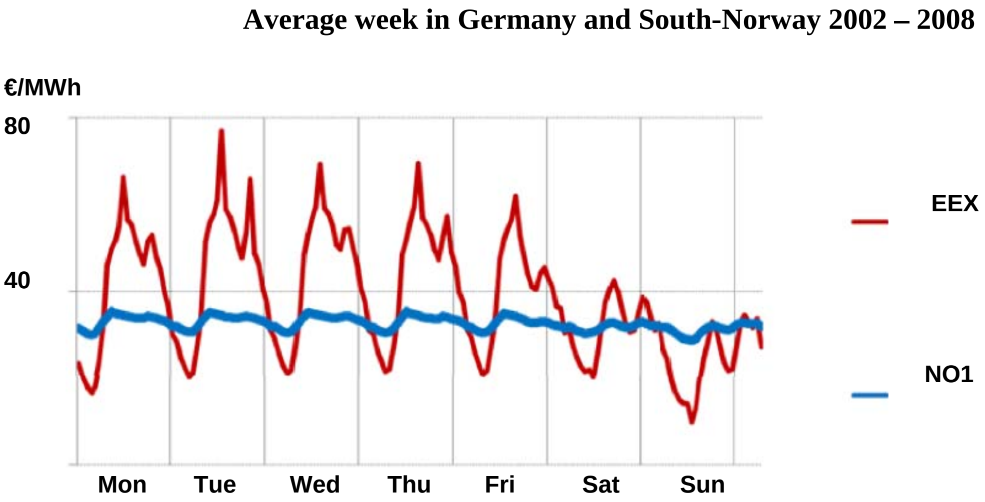
Figure 4 Net hourly commercial flows in each direction at the European interconnections in 2008.[8]



A usual seasonal variation in hydro systems is low prices in spring when snow is melting and high prices in winter when there is less water available. As an example, the price difference pattern between Norway and Germany is shown in Figure 5. This dynamic price difference pattern is one important part of the economic basis for a cable investment between these countries.

8 Source: ENTSO-E. Some values are estimated as there is missing data in the ENTSO-E dataset.

Figure 5 Average weekly pattern of the hourly spot price difference between the Norwegian price area NO1 in the Nord Pool Spot power exchange and the German spot price in the European Energy Exchange (EEX) in the period 2002-2008.[9]



Real congestion rent usually remains below the theoretically possible congestion rent. There are several reasons for this. Capacity is not always available due to outages or due to curtailment of capacity for network security reasons. Another reason is that in most European interconnections congestion rent is not gathered from implicit auctions but from explicit auctions or from a combination of these two types of auctions. Explicit auctions give a congestion rent based on traders' estimate of the price difference, not on the final price difference. Usually implicit auctions give a higher rent for the TSO as in explicit auctions the uncertainties for traders are higher.[10]

A comparison between the real congestion rent accrual with the theoretical accrual, calculated by multiplying the hourly price difference with the maximal flow, is presented in Table 2 for some European interconnections. From the table it can be seen clearly that in some cases the real congestion rent is close to the theoretical congestion rent but in some others both the utilisation ratio and the congestion rent is far below the theoretical maximum. Explanations for this lack of efficiency are further explored in this paper.

As congestion revenues indicate how much market participants value the possibility for cross-border trade, congestion rent could be a good criterion to determine at which interconnection capacity should be increased.[11] Congestion rent can be easily compared with the cost of any potential investment to remove congestion.[12] TSOs are obliged to publish the commercial flows and congestion rent at each interconnection which allows any stakeholder to have a view whether a higher capacity might be justified. The analysis needs to be based on an estimation of future congestion rents for which the current rents are not necessarily a good proxy.

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9 Statnett, Bente Hagem, transmission investments, 2010

10 Frontier Economics and Consentec, congestion management methods, 2004

11 For interconnector projects between countries with no existing interconnectors there are no historical congestion rents, so other methods need to be used for assessing the profitability of a possible interconnector.

12 In many countries congestion rents are collected from several borders. An interconnector investment affects the market price and thus also affects congestion rents at all borders, not only at the border at which the new interconnector is built. Thus it is necessary to take into account the combined effect, not just the increase of congestion rents at one border.

Table 2 Comparison of the realised congestion rent with the theoretical congestion rent at some European interconnections in 2008.[13]

Exporting country	Importing country	Capacity [MW]	Commercial flow in the interconnector [TWh]	Utilisation ratio of the interconnector [%]	Absolute price difference [€/MWh]	Congestion rent in 2008 [M€]	Theoretical congestion rent [M€]	Share of real congestion rent of the theoretical rent [%]
DE	FR	2675	16	69%	10	156	232	67%
NO	NL	700	4	60%	27	113	168	67%
FR	IT	2525	18	81%	21	300	454	66%
FR	ES	1300	4	35%	17	93	192	49%
DE	NL	3925	14	42%	10	65	329	20%

It has been discussed whether the whole transmission infrastructure could be financed through congestion rents. A general conclusion of this discussion has been that even if a considerable share of the investments can be made using congestion rents, it is usually not possible to cover all transmission costs from them.[14] From Tables 1-2 one can observe, however, that for small transit countries situated at a high price gradient, namely Switzerland, Slovenia and Denmark, this might well be possible.[15]

The congestion rent declines when the cross-border capacity is close to the price convergence level, as illustrated in Figure 2. This decrease in congestion revenues could discourage TSOs to invest up to the overall welfare optimum level. It is important that this phenomenon is taken into account by the national regulators when setting incentives for the TSOs and by the ACER when giving an opinion of the ENTSO-E ten year network development plan.[16]

4. Identification which interconnector projects would be profitable

To identify which interconnector projects would be profitable from the overall social welfare point of view in Europe, a method is developed in this paper. This method is illustrated in Figure 6.

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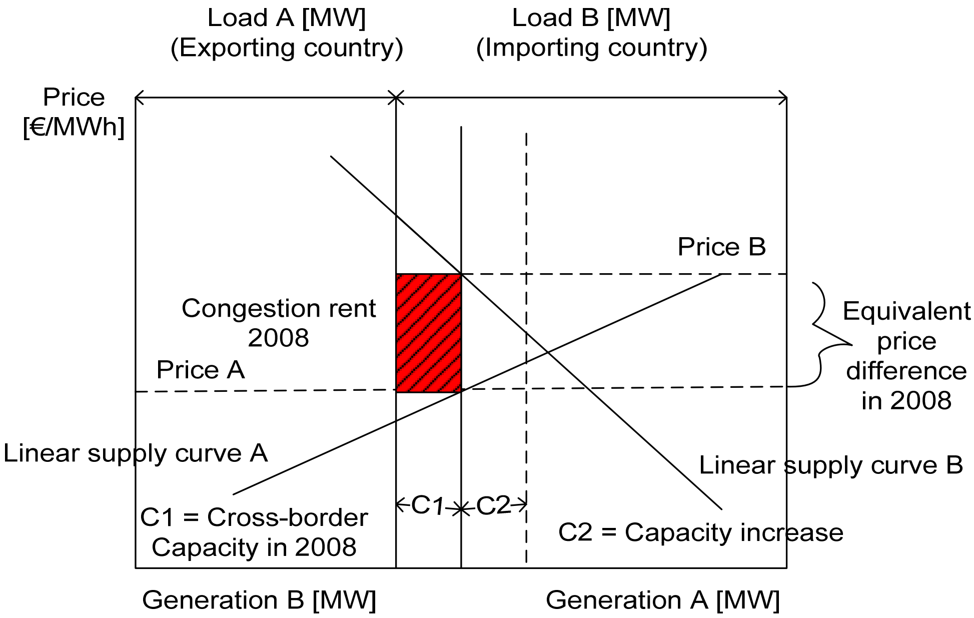
13 ENTSO-E, congestion rents 2008, 2009; ENTSO-E, NTC winter 2007 – 2008, 2007; Price data from Power exchanges' websites. Theoretical congestion rent calculation is based on hourly spot price differences. Yearly average absolute price difference is the average of the absolute values of the hourly spot price difference

14 Rubio-Odériz and Perez-Arriaga, marginal pricing of transmission, 2000; Duthaler and Finger, congestion revenues, 2008

15 See also Table 3 later in this paper.

16 According to Electricity regulation EC/714/2009 one of the tasks of the ACER is to give an opinion on the ten year network development plan of ENTSO-E.

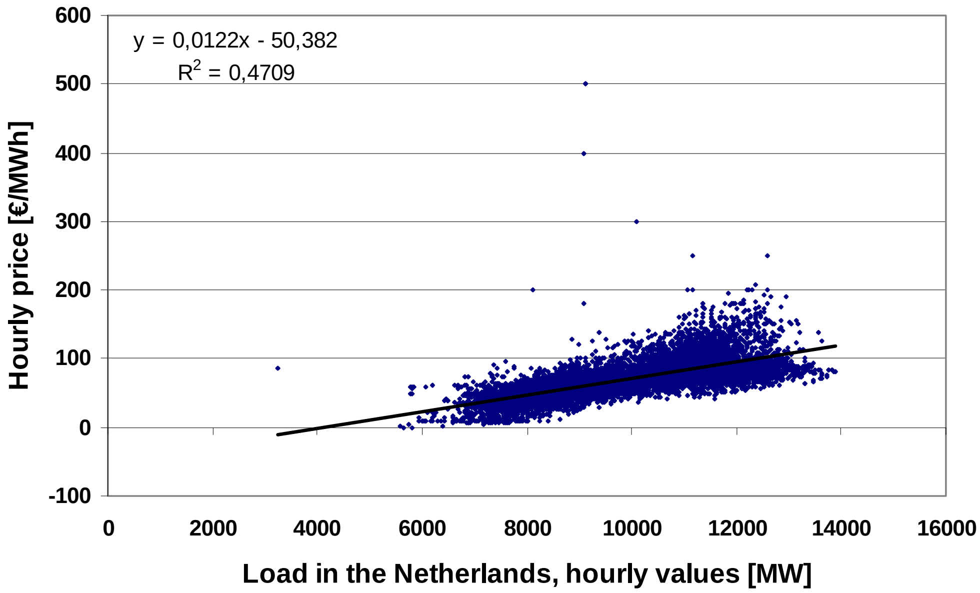
Figure 6 Approximation of the supply curves on both sides of the interconnection by using linear supply curves as a proxy and estimating the relative position of the supply curves through the congestion rent. [17]



The method is based on a model using as input parameters (i) supply curves with the slope equal to the linear regression line of correlation between spot price and load in 2008 (2009) for each price zone as illustrated in Figure 7, (ii) the cross-border capacity and trade between countries in 2008 and (iii) the congestion rent collected from each border. An equivalent price difference between two countries is generated by dividing the congestion rent in 2008 by the corresponding cross-border flow. The linear supply curves are set in the model to a distance corresponding to this equivalent price difference. The changes due to increasing the interconnection capacity are then calculated by assuming that the additional capacity is fully utilised and that the flow at the interconnection reduces the price difference in function of the new supply balance in each zone as illustrated in Figure 6.

[17] It is assumed that both the supply curve and the load in each country are fixed. Trade between the two countries moves the operation point in each country along the supply curves as part of the load in Country B is served by generators in Country A. The linear regression line of correlation of spot market price versus load is used as a proxy for the supply curves in the calculations.

Figure 7 The regression line of correlation between the hourly spot price in APX Power NL power exchange and the hourly load in the Netherlands in 2008, used in this paper as a proxy for the slope of the supply curve in the Netherlands.[18]



The model allows calculating all relevant parameters for an interconnection capacity increase. The calculation includes the optimal increase of capacity and the change in congestion rent and social welfare. Summary results of this calculation are shown in Table 3 below.

The first conclusion of the calculation shown in Table 3 is that there is clearly potential for many profitable interconnector projects in Europe. In particular links between the Nordic countries and the Central Europe, investments at the borders of Italy and the UK are extremely profitable even if they would be DC interconnectors with an annual cost in the range of 50 – 100 k€/MW/a.19

Also many investments inside Central Europe are potentially profitable. Even if price differences in Central Europe are not as important as between Central Europe and the other regions, the possibility to build relatively cheap overhead lines makes them interesting from the social welfare point of view.

The fact that building overhead lines has become very difficult because of public acceptance issues means that this potential is not easily realised. Most of the interconnectors that have been successfully finished in the past years are expensive undersea projects which are less sensitive regarding public acceptance.

The results presented in Table 3 are based on a method using rather heroic assumptions.[20] One needs to be particularly careful when interpreting the results for the highly meshed Central European transmission network. Interconnectors often have influence on several countries, not only on the two

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18 Source: APX Power NL.

19 Costs of DC interconnectors vary depending for example on technology, capacity and length of the interconnector. The range of 50 – 100 k€/MW/a corresponds to such recently finalised or planned investments as BritNed (1300 MW of capacity, about 600 M€ of investment costs), NorNed (700 MW, about 650 M€) and France-Spain interconnector (1400 MW, about 800 M€). Shorter interconnectors such as Estlink (350 MW, 110 M€) have lower annual costs.

20 The method is based on calculating the optimal capacity for interconnections one by one, all other borders remaining unchanged. Thus the welfare calculations do not try to reflect a simultaneous optimisation of the European grid.

countries between which it is built. This is a main limitation of the method used in this paper. The increase in flows and the changes in market prices are assumed to take place only in the two price zones between which the interconnector is built. In the case of a small increase of capacity, this is accurate enough, but if the increase of capacity is large, also the flows in the other interconnections of the two countries in question are affected.

When capacity increase in one interconnection affects several interconnections, it is necessary to analyse what would be the optimal combination of capacity increase in all these interconnections. This is particularly true for transit countries.

Table 3 Summary results of the calculation of welfare gains of potential interconnector investments in Europe using the method developed in this paper.

Exporting country	Importing country	Capacity in 2008 [MW]	Optimal additional capacity from the social welfare point of view [MW]	Increase of social welfare at optimal capacity [M€/a]
NO	UK	0	9159	992
NO	DE	0	4673	383
SE	DE	600	3665	229
FR	ES	1300	4343	215
FR	UK	2000	4488	203
NO	NL	700	1818	197
NO	SE	2825	2349	127
FR	IT	2525	2563	124
DE	FR	2575	2699	97
AT	HU	500	895	96
PL	DE	1150	1273	87
SE	PL	600	1967	80
AT	IT	210	1024	56
PL	SK	475	567	49
RO	HU	800	562	46
PL	CZ	1630	724	43
BE	UK	0	731	40
NO	DK	750	677	37
CH	IT	3525	604	25
DE	CH	1900	628	23
NL	UK	0	574	20
FR	CH	3100	588	20
ES	PT	1200	793	20
DK	DE	2050	454	18
BG	GR	550	313	12
DK	NL	0	302	12
RO	BG	625	303	11
AT	CH	1000	335	10
AT	SI	350	143	6
UK	IE	410	254	5
CZ	SK	1150	150	3
DE	NL	3925	224	3
NL	BE	2150	161	3
CZ	DE	2275	201	2
SK	HU	1000	97	2
HU	SI	0	52	1
FR	BE	2950	69	0
SE	DK	1980	41	0
SI	IT	380	20	0
CZ	AT	250	10	0

IT	GR	500	1	0
DE	AT	1500	0	0
FI	SE	1600	0	0
EE	FI	350	0	0
LT	SE	0	0	0
LT	PL	0	0	0
LV	EE	750	0	0
LT	LV	1100	0	0

For example for Switzerland, Denmark and Slovenia, the only possibility to considerably increase exports is to increase imports.[21] A simultaneous increase in imports and exports gives a much higher overall welfare gain potential than if the effect of imports and exports are calculated separately. For example for a line passing through Switzerland, the figures calculated for the interconnection between France and Italy give an order of magnitude for the potential overall gains. Similarly, figures for the interconnection between Austria and Italy can be used to estimate the potential gains for Slovenian interconnector projects and for Denmark the figures for projects between Norway and Germany are relevant.

It is also important to notice that our static linear model only approximates the potential of dynamic changes in prices. Dynamic changes are particularly important for countries which have similar yearly average prices but still have different price volatility patterns in the seasonal and hourly prices. Additionally, the model excludes the gains from the shorter term markets, such as from the intra-day and regulating power markets, in which prices and thus social welfare values per MWh are usually much higher than in the day-ahead spot market. Intra-day and regulating power markets do not currently generate congestion rents as the transmission capacity for these markets is allocated for free.

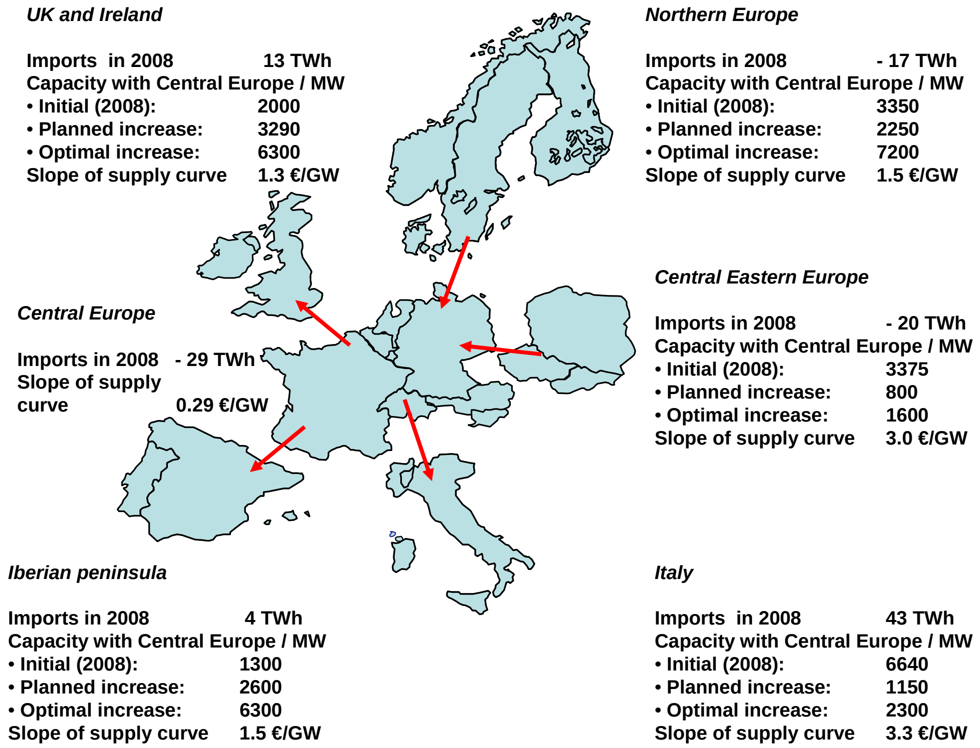
For the investment and operating costs of interconnectors, standard costs per capacity unit based on estimation by the author are used in the calculations in this paper. For DC lines the standard cost is 50.000 €/MW/a and for AC lines 10.000 €/MW/a.

The method developed in this paper could be utilised for analysing the combined effect of several interconnector investments by using an iterative calculation which combines projects for example by region. This paper does not include such calculations. Instead, a calculation of the optimal interconnection capacity between regions is performed by assuming that there is full price convergence inside each region. Even if this is a heroic assumption, it is clear from Table 3 that the largest welfare potential for price arbitrage exists between regions. For the calculation, Central Europe is considered as one block, the Nordic countries, the UK and Ireland, the Iberian peninsula, Italy and Central Eastern Europe are each one block.

Capacity increase is assumed to be made with DC links except for the connection between Central Europe and Central Eastern Europe. The results are shown in Figure 8.

[21] CESI, CIGRE, Venturini et al, exchanges between IT, CH and DE, 2008

Figure 8 Welfare calculation of increasing interconnection capacity between regions in Europe using year 2008 as the reference year.



Region	Additional imports with planned capacity [TWh/a]	Additional imports with optimal capacity [TWh/a]	Initial price difference with Central Europe in 2008 [€/MWh]	Price change with planned capacity [€/MWh]	Price change with optimal capacity [€/MWh]	Social welfare increase with planned capacity [M€/a]	Social welfare increase with optimal capacity [M€/a]
Central Europe	-35	-53	NA	1.2	1.8	348	86
Northern Europe	-20	-63	-14.8	5.2	12.6	93	358
Central Eastern Europe	-7	-14	-4.1	3.8	6.6	17	45
Italy	10	20	15.2	-3.0	-5.8	22	41
Iberian peninsula	23	55	16.9	-3.5	-7.7	116	255
UK and Ireland	29	55	16.0	-4.1	-6.4	128	225
Sum						**724**	**1009**

The results from the pan-European optimisation of interconnections are very striking. The calculated optimum capacities are substantially higher than the current capacities indicating that at least the first projects to increase capacity will be highly profitable. The results suggest that annually more than one billion euro of overall welfare increase could be reached.

The price effect for Central Europe is modest. On the contrary, the prices in the peripheral regions change substantially when interconnection capacity increases. It is important to note that an interconnector capacity increase always reduces the absolute price difference between the connected areas. The change in the average price depends on whether the price difference is always in one direction, as assumed in the model used in this paper, or whether the price difference changes direction over time for example daily or seasonally. In the latter case, the increase of interconnection capacity can result in a lower average price for both zones. In addition, the welfare distribution effect is mitigated by the changing import-export pattern which might be important for getting acceptance from the stakeholders.

Interconnections in which this changing pattern is important are the interconnections between Central Europe and the Nordic countries and the interconnection between the Iberian Peninsula and France.

The interconnectors included in the ENTSO-E ten year network development plan yield an increase of overall social welfare of about 700 M€/a. At this level of interconnection capacity most of the increase in social welfare is captured by the TSOs in form of congestion rent and only a smaller part is in the form of absolute increase in producer and consumer surplus. At the optimal level of interconnection capacity a much bigger share of increase of social welfare is in form of producer and consumer surplus.

The interconnectors in the ENTSO-E ten year network development plan result in only relatively modest changes in price differences. However, in the optimal interconnection capacity case price effects in the form of price convergence are already significant. In spite of this, even with the optimal capacity, significant price differences between regions remain as shown in Figure 8. This reflects the high costs of building DC transmission lines. Thus for the profitability of DC interconnectors a substantial remaining price difference is necessary if the profitability is judged based on price arbitrage.

The calculations confirm the importance of distributional effects in optimising the European interconnectors. Both in the planned interconnector and welfare optimum case there is a huge redistribution of social welfare in favour of producers in the North and consumers in the South and in the UK, amounting to several billions of Euros.

There are several ways to improve interconnector welfare calculations. One possibility is to construct supply and demand curves based on power plant and load data and to use these synthetic supply curves in a market model.[22] This allows forecasting prices in each price zone and calculating profitability of interconnectors. A major problem with this approach is the time span. It is very difficult to forecast the generation mix for the lifetime of a transmission investment. Also, the supply curve is dynamic in time, for example the gas, coal and emission allowance price fluctuations modify the supply curve continuously. Further, the merit order of power plants can change over time. Thus we have chosen not to base our method on generation and load scenarios.[23]

One limitation of the method used in this paper is the use of one single base year 2008 in the calculations. The choice was made because the availability of data for earlier years was not sufficient in particular regarding congestion rents and commercial flows. Year 2009 was influenced by the economic crises, this is why it was not used in the calculations. For 2010 no complete data set was available yet. When comparing the data for the period 2008 – 2010 and also the data for earlier years to the extent available, it is clear that there are important differences between the years for example

[22] Frontier Economics and Consentec, transmission investments, 2008; KEMA, transmission investments in Eastern Europe, 2005

[23] Baltso et al, Baltic interconnector study, 2009; ENTSO-E, ten year network development plan, 2010; EC, comments on ten year network development plan, 2010

regarding congestion rents and commercial flows. For example 2008 was a wet year in the Nordic countries resulting in low prices in particular in Norway. However, in Europe the overall trading patterns and price differences remain relatively stable over time which gives confidence in the results presented in this paper. It is left to further work to investigate to what extent the results might change if the calculations were based on a longer observation period.

It is important to note that, contrary to power plant profitability, interconnector profitability is not dependent on the absolute levels of market prices but on the price difference between two markets. This influences how modelling should be done. For example if fuel costs have a high correlation on both sides of the interconnector, they will not drive profits. Price peaks are particularly interesting when they appear only at one end of the interconnector. For example the high price period in the Nordic market in 2003 should have had a positive impact on profits for the SwePol link between Sweden and Poland and for the Baltic cable between Sweden and Germany.

Another approach to calculate the social welfare is to base the analysis on historical bids made in the market. One of the problems in using bid data is that only part of the electricity traded is covered by these bids. There is also the problem that historical bids do not necessarily sufficiently reflect future prices. However, the advantage of using real bids instead of synthetic supply curves is that they include the strategic behaviour of companies.

The calculations in this paper have confirmed that there are potentially many profitable interconnectors missing in Europe. This results in a loss of social welfare which could reach one billion Euros just taking into account the price arbitrage between spot markets. This conclusion calls for a more accurate analysis. Such an analysis could start with building a demand and supply scenario, accounting for the EU wide and national scenarios. Plans to fulfil the renewable targets should give a good estimate of the new generation capacity to be installed in the coming years. The European Transmission System Operator's organisation ENTSO-E is indeed making such scenarios as part of the ten year network development plan.[24]

5. Role of the regulator in transmission investments

Regulators have a key role regarding transmission investments. At the end of the day, even if the national law sets the general framework for the transmission investments, the regulator approves directly or indirectly which investments are accepted to be covered from transmission tariffs. The regulatory treatment of transmission investments varies widely. In some countries practically all projects proposed by the TSO are allowed to be passed on to the asset base. In other countries regulators or governments need to approve all investment projects before they are allowed to be financed via tariffs. An exception to this rule is merchant interconnectors.

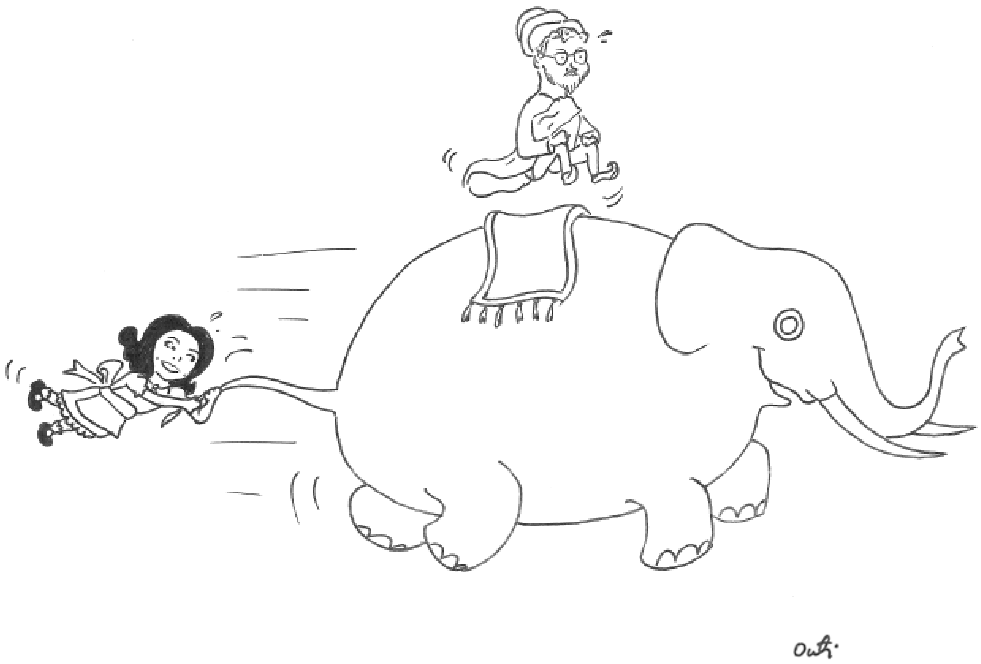
There is quite a lot of discussion how to incentivise TSOs to build interconnectors, for example by offering a higher rate of return linked to the delivery time. The general trend is that incentive schemes for TSOs are getting increasingly sophisticated. Incentives are more often performance based which means that the TSO is rewarded if it meets the output targets, not just the cost targets.[25] For example performance based schemes are used with success to reduce congestion costs in Great Britain. Germany allows higher rates of return for selected transmission lines considered important for integrating wind power to the system.[26] However, performance based schemes have probably not yet been used in any Member State to incentivise interconnector building.

[24] ENTSO-E, scenarios for 2020, 2011

[25] EMV, annual report, 2010

[26] Frontier Economics and Consentec, transmission investments, 2008

Figure 9 Regulator's work is not always easy.



The third legislative package strengthens the role of regulators regarding transmission investments and gives the new TSO association, ENTSO-E, the important task to plan the European transmission network. In particular, for the transmission systems which remain vertically integrated, namely ITOs (Independent Transmission Operators) and TOs (Transmission Owners), the national regulator has to approve the investment plan. The regulator has the powers to impose investments in the transmission network by third parties if the ITO or TO refuses to invest.[27] The ACER has to give an opinion on the ten year network development plan and to verify that the national plans are coherent with the European ten year plan. If they are not, The ACER shall make recommendations to amend either the national plan or the ten year plan. ENTSO-E and the ACER shall monitor the implementation of these plans.

It remains to be seen whether these institutional changes are sufficient for successful development of the European transmission system. Decisions on investments still remain in national hands. Even if binding decisions on investments have been made, without a proper political backing to overcome local resistance the result is not guaranteed. Stakeholders can not differentiate which projects are serious and which are cheap talk, using academic terms by Farrell and Saloner.[28] There is a real risk for a big discrepancy between good intentions and concrete results.

Good reading regarding institutional changes needed because of technology development in networks is provided by Finger and his colleagues.[29]

[27] EU, third package, 2009; EC, interpretative note on unbundling, 2009

[28] Farrell, cheap talk, 1987

[29] EPFL, Finger et al, governance and technology, 2005; EPFL, Finger et al, institutions, 2010

6. Merchant interconnectors

Merchant interconnectors are allowed in the European legislation, subject to approval of the regulators concerned, the ACER and the European Commission. Merchant interconnectors have to cover their costs through the income from selling interconnector capacity.

In the UK there are limitations for the TSO to recover interconnector costs from UK tariffs. This has in practise left merchant investments as the only interconnector option for the UK. It is unclear to what extent this merchant system has been an obstacle to interconnector investments between the UK and the neighbouring countries. There are only two projects in construction, one between the UK and the Netherlands, the Britned cable and another project connecting Ireland to Great Britain. The Irish project is fully paid by the Irish and the European Recovery Fund.[30] However, some new thinking is being developed in the UK which might explain why the number of planned interconnectors has increased recently.[31] In the past, interconnectors had to pay a tariff as if they were a generator and a load in the UK, now this has been removed.

In principle merchant lines should be economically efficient. Merchant investors would compete for projects until an appropriate level of interconnection capacity has been reached. Merchant investments would be done efficiently under competitive pressure. However, it has been shown that many features of an interconnector investment do not favour merchant approach. For example according to Joskow and Tirole, distortion in price signals and some features of transmission investments such as lumpiness, the stochastic nature of the income and the strong link with system operation could lead to suboptimal merchant investments.[32]

In Europe merchant line projects are exceptional as an exemption is needed from certain provisions of the European legislation to make such investments. Exemptions are possible for DC lines and in exceptional cases also for AC lines. Most Member states do not favour merchant lines as they do not consider them necessary. There is a fear that the whole transmission system will become more difficult to design and operate if there are several owners each willing to optimise the use of their own network.

Until now the European Commission has accepted exemptions for all projects that have reached the Commission, namely Estlink between Estonia and Finland, Britned between the Netherlands and the UK, two East-West links between Ireland and Great Britain and the Arnoldstein – Tarvisio line between Austria and Italy. However, the conditions imposed on these projects have been strict. For example in the BritNed case the Commission imposed a revenue cap which makes the project resemble a regulated interconnector. In the Estlink case the fact that the investors are committed to sell the cable to the TSOs after a limited period of time was important for granting the exemption. Regarding the two East West projects the Commission's acceptance was conditional on Eirgrid building a regulated interconnector between Ireland and Great Britain which has a major impact on the profitability of these two other interconnectors.

A generation company or a big consumer would be a natural candidate for building merchant interconnectors. They could themselves benefit from the interconnector capacity for additional exports or imports. Even more important could be the influence on prices in the price zones which the interconnector is connecting. A generator would build export capacity to increase the price level in its own zone. Thus the logic of a generation company building a merchant line would be quite similar to the logic of a vertically integrated TSO building the line. The difference is in the treatment of congestion rents which in the case of a TSO are considered to be part of the regulated income but in the case of a merchant investor can generate non-regulated profits, depending on the exemption decision.

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30 ESRI, Valeri, IE-UK interconnector, 2008

31 Ofgem, interconnectors, 2010

32 Joskow and Tirole, merchant transmission investments, 2003

7. Other targets for cross border investments

A transmission system fulfils two functions at the same time. The primary task of a TSO is to transport electricity from generation plants to load in a secure manner including keeping balance between generation and load at all times. The second task of a TSO is to provide a marketplace for electricity in order to optimise social welfare. The first task can hardly be taken away from the TSO. Regarding the second task some people argue that it does not need to be performed by a TSO. Indeed, there are countries such as Spain where a separate body takes care of operating the marketplace. One should recognise, however, that an electricity market is strongly based on transmission networks, and that market operation has strong links with the primary task of a TSO. It is also true that these tasks cannot be performed by the TSO alone. A TSO is dependent on generators, distribution system operators, consumers, traders and power exchanges in performing these tasks, and increasingly from other TSOs as well.

The optimisation of social welfare through price arbitrage, discussed in the beginning of this paper, is closely linked to the electricity market and thus to the second task of the TSO. In the following it is discussed what other targets could be set for building interconnectors, including targets related to the primary task of a TSO to provide network access for the generators and consumers and operate the network in a reliable way.

8. Technical targets

A transmission network should in normal conditions allow all connected generators and loads to access to the network when they so wish. Only extreme conditions such as extreme temperatures or unforeseen outages could justify curtailing generation or load. In other words, the network should enable a secure dispatch of generation and load based on decisions made on economic grounds by the generators and consumers without too much interference by the TSO. This target of unconstrained dispatch of generators and loads is, however, not met everywhere in Europe. Transmission lines often take more time to construct than power plants which has led in some places to serious limitations in grid access.

Historically, interconnectors were usually not technically necessary for allowing access of generators and loads to the network and thus they were not built for this purpose. Their role was to improve system security due to reserve power provided through interconnectors in the case of generation or network incidents. They were also used to increase social welfare through optimising the use of generation assets in Europe by enabling cross-border trade. With increased wind power in the system, this situation has changed. Today, without interconnectors access to network would need to be denied much more often in areas with high wind power production.[33]

Even if interconnectors are beneficial for the European system, they also have some unwanted consequences. In today's transmission system which is mainly based on the use of alternative current and a meshed network, the flows follow the physical characteristics of the network and ignore country borders.[34] For this reason a TSO in one country could allow an access to generators and loads in such a way that the TSO in the neighbouring country is not able to guarantee a similar access to its own consumers because of the cross-border flows. Then the question arises that if network access limitations are needed, in which country such measures should be enacted and who should bear the costs.

[33] CEPS, comments on EWIS study, 2010

[34] This phenomenon is important in Central Europe where there are parallel paths for flows encompassing several countries, less important in more radial networks in the outskirts of Europe.

In the context of promoting renewable electricity generation, EU legislation[35] requires positive discrimination schemes for renewable energy by giving it a priority or guaranteed access to the network. This means that in the case of congestion, restriction of access to the network is applied to other forms of electricity production than renewables. A technical target for a transmission system could be minimising this restriction of access.

9. Minimum interconnection capacity targets

Heads of states agreed in the European Council in 2002 that every Member State should have at least 10% import capacity compared to the installed generation capacity in the country.36 This simple target intends to promote interconnectors with the least connected Member States. In 2002 the countries below this target level were Ireland, the UK, Spain, Portugal, Greece, France and Italy. From this group Portugal, Greece and France have already reached the 10% target. Also Ireland will meet the target when the planned interconnector between Ireland and Great Britain is in operation.

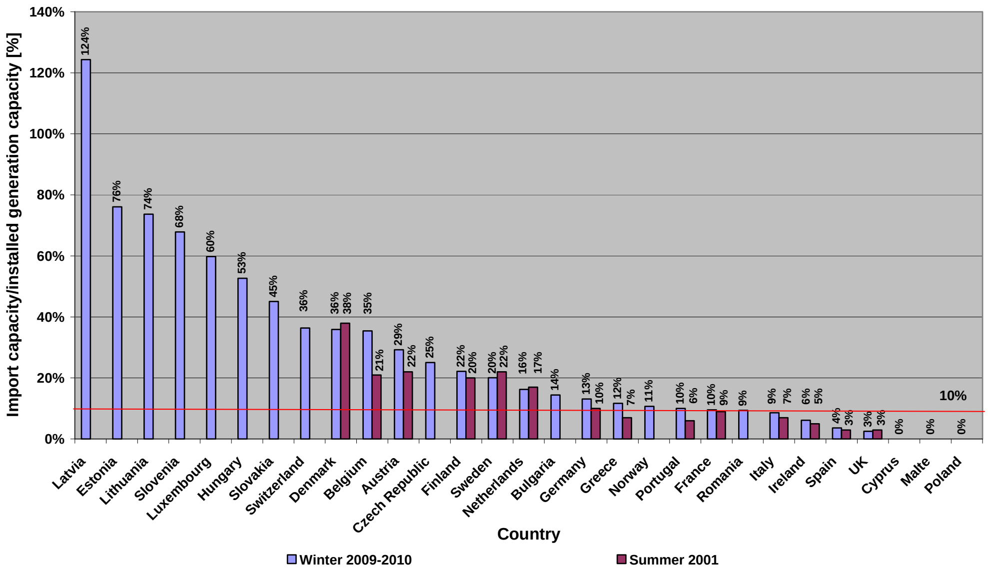
Among the new Member States who joined the EU in 2004 - 2007, Poland, Romania, Bulgaria, Malta and Cyprus are below the 10% target. Romania and Italy could relatively easily reach the target level. On the contrary, Spain and the UK will not reach the target in the foreseeable future even when the currently on-going interconnector projects are finalised. The Baltic States are a special region in this respect. There is a lot of transmission capacity between the three Baltic States and the interconnection capacity with Russia and Belarus is also high. However, there is very little capacity to any other EU Member State. This situation will be corrected with the Baltic Energy Market Interconnection Plan (BEMIP).[37]

[35] EU, renewables directive, 2009

[36] EU, Barcelona European Council conclusions, 2002

[37] EU, Bemip, 2010

Figure 10 Evolution of interconnection capacity in the EU Member States, Norway and Switzerland since 2001 regarding the 10% target agreed in Barcelona in 2002.[38]



It is evident that the ten percent target is rather simple and does not take into account the specific situation of each Member State. For transit countries the target is obviously less relevant. Transit countries can have a serious lack of interconnection capacity even if they have already reached the 10% target level, as the import capacity serves both transit and import needs. However, overall this target of 10% has efficiently drawn attention to the poor connection level of some EU Member States.

The current level and evolution of interconnection capacity since the Barcelona summit are shown in Figure 10. Some countries have successfully increased the capacity, such as Belgium, Austria, Germany, Greece and Portugal. However, for example for Sweden the import capacity has diminished.

10. Security of supply targets

Security of supply in electricity is reached when there is sufficient amount of electricity available to the society at all times except for very short periods of non-availability accepted as a trade-off for not making the electricity system overly expensive. The security of supply target can be divided into a short term and a long term target. The short term target is to minimise black-outs and system disturbances through system operation. This target can be called security of system target. The long term target is to maintain a sufficient generation and transmission capacity through investments in power plants and transmission networks. This target is called the system adequacy target, divided into a generation and a transmission adequacy target. Security of supply is a fundamental driver for the

[38] The values for Figure 18 have been calculated from ETSO NTC values for summer 2001 (used in EU infrastructure communication, COM (2001) 775, 20.12.2001) and from ENTSO-E NTC values for winter 2009-2010, taking into account overall import limitations when they have been declared. This method tends to give too optimistic values. Also, in some cases there is no agreement between the TSOs concerned on the value to be applied. To calculate more accurate values for aggregated import values, network modelling techniques should be used. The values in this table, however, give a rough indication for the situation of each member state regarding the 10% import capacity target and for its evolvement in time.

design and operation of the electricity system, because even very short incidents can be extremely costly to society.39

Interconnections have an important influence in meeting both the short and long term security of supply target. Interconnectors were first built in order to improve operational security and to reduce the cost of achieving a secure network. Today interconnectors are increasingly used for trading purposes in order to better utilise generation resources. The resulting cross-border trade involving longer transmission distances is a challenge for operational security as TSOs are more and more dependent on each other. Co-ordination between TSOs did not develop sufficiently in the beginning of market liberalisation to meet the new requirements including intensive loading of interconnectors. The black-out in Italy in 2003 confirmed this as the main reason for the black-out was the lack of co-ordination between the TSOs involved.[40]

For generation adequacy, interconnectors generally have a positive effect. If a country does not have enough generation capacity, electricity can be bought from the neighbour. Import possibility, however, can reduce the incentive for investments in generation capacity as it could be cheaper to import electricity than to produce it locally. If many countries take this approach, this may lead to a situation in which generation adequacy in peak demand conditions is not ensured at the European level. Interconnectors do not help if nobody has invested in peak generation capacity. At the moment this risk seems implausible. The ENTSO-E Winter 2010 – 2011 Outlook does not foresee any European wide difficulties to cover peak demand even if some local shortages may exist in extreme weather conditions or in the case of several simultaneous generation outages.[41]

There is academic literature indicating that energy based electricity market does not provide a sufficient business case for generation units to cover peak load. One of the reasons put forward is the short duration of the highest load which is partly due to lack of demand elasticity. The business case is further weakened if there are price caps in the electricity market.[42] Thus a Member State could wait and hope that the neighbour invests in peak plants financed through subsidies or capacity payments collected from grid tariffs. The European legislation requires that the Member States shall take appropriate measures to maintain a balance between the demand for electricity and the availability of generation capacity.[43] However, this obligation is not very precise which makes it difficult to enforce.

One could think that building an interconnector could replace peak generation units for ensuring security of supply. Interconnectors, however, have two features which do not favour this approach. Firstly, the economic case for an interconnector usually can not be based on the peak load because of its very short duration. Secondly, interconnections have not proven to be politically reliable in situations when supply has been tight. Several cases of cutting exports rather than letting correct scarcity prices come into effect have already appeared, using the excuse that the own security of supply is in danger. The national legislation of some countries even explicitly provides for this.[44]

Electricity generation in Europe is to a large extent dependent on imported fuels such as natural gas, coal and uranium. If fuel supplies are cut, generation can be partly substituted by power plants using indigenous sources or by switching to fuels stored for security reasons. Interconnectors can help

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39 Consentec, EWI and IEAW, security of German electricity supply, 2008; Frontier Economics, security of German electricity supply, 2008; Eurelectric, power outages 2003, 2004

40 TSO system operation co-ordination has developed strongly in recent years. Coordination of Electricity System Operators (CORESO) and Transmission System Operator Security Cooperation (TSC) are two examples of initiatives between TSOs with the aim of detecting system operation risks and dangerous network situations.

41 ENTSO-E, Winter 2010 – 2011 outlook, 2010

42 Hobbs, capacity payments, 2005; DUT, De Vries and Hakvoort, security of supply, 2002

43 Directive 89/2006/EC 18 January 2006 on security of electricity supply

44 In the past at least Spain, France, Czech Republic, Poland and Greece have applied export restrictions if the national electricity supply balance has been tight.

countries which are more vulnerable for fuel import cuts. This criterion can be taken into account in interconnector planning. However, for the purposes of security of supply, interconnectors can be important only for small countries as for most big countries cross-border trade remains marginal, at least with current transmission capacities.

11. Competition targets

Interconnection capacity is interesting also from the competition point of view. It allows the producers and suppliers on the other side of the interconnection to compete in the same market as the local producers and suppliers. When the capacity is high enough to reach full price convergence, the connected price zones have the same price and their liquidity is pooled. This positive effect on competition has been welcomed in particular in countries which have allowed the old monopoly company to keep a dominant position in the market. This has helped in particular small countries to avoid splitting the incumbent for competition reasons into uneconomically small entities.

Influence of cross-border competition through interconnections is significant if the cross-border capacity is large enough. For example in Denmark, interconnections define in practise the upper and lower limit of the market price through the influence of the Swedish, Norwegian and German prices. However, in big countries such as in France even considerable interconnection capacity does not bring real competition to the market. A consultant has calculated that to reduce the market power of EdF to a reasonable level, France should have 33.000MW of interconnection capacity.[45] This is of course completely unrealistic with today's transmission technology. Thus to increase competition in France it is necessary to apply structural measures inside the country.

Analogously, there is a risk of exporting market dominance. If a company is active on both sides of the interconnection, increasing interconnection capacity improves the possibility to use market power. This situation exists for example at all French borders.

In some cases target levels for interconnection capacity have been explicitly set following competition cases. For example, in the merger case of Energie Baden Württenberg (EnBW) and Hidrocantabrico in 2002, EdF committed to a target of 4000 MW between France and Spain.[46] In some cases governments have committed to bilateral interconnection capacity targets such as for the capacity between Spain and Portugal which is increased for improving the functioning of the Iberian market.

12. Climate change and *sustainability targets*

It has been argued that climate change targets should be considered separately from the social welfare targets. This assumes that reducing greenhouse gas emissions and promoting renewable energy contain such externalities which are not captured by the carbon price in the emissions trading scheme or by the subsidies used to support renewable electricity production. Such an externality could be for example improved security of supply resulting from investing in European indigenous energy sources.

A detailed analysis of interconnection capacity targets based on climate change and sustainability criteria can be very complicated. In the author's view, the criteria discussed above could already take sufficiently into account climate change targets and thus they could be a sufficient basis to guide infrastructure investments. Some specific issues such as the trade-off between curtailment of peak wind production and cost of transmission infrastructure could be subject to a separate analysis.

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[45] Ramboll and Mercados, electricity infrastructure, 2008

[46] EC, competition case EnBW, 2002

Views that renewables should have an absolute priority independently of the cost of using them do not seem to be economically or even environmentally justified. If carbon is correctly priced, market will guide the system to an optimal dispatch taking into account the climate change targets.[47]

13. Price convergence targets

Price convergence has sometimes been advocated as the ultimate target for the internal electricity market. However, full price convergence should not be a target itself. In some cases price differences in short term and even in longer term are justified due to a permanent cost advantage in one region compared to the neighbouring region. If prices were always equal in the whole Europe, this would suggest that too much transmission capacity has been built. Opposite to this argument, there are also factors which call for investing more than what price arbitrage optimisation would suggest. Lumpiness, long lead times and anticipation of generation investments could justify higher capacity than what is indicated by a pure price arbitrage calculation.

Price convergence has important competition benefits as it allows to pool liquidity from a wider area. Trading with long term financial products requires stable price references. Nord Pool system price is the reference for the long term products in the Nordic market. EEX launched the price reference European Electricity Index (ELIX) in October 2010. ELIX could become important for trading in the Central European market. The efficiency of these reference prices depends on how much the spot price in the individual price zones covered by the reference price differs from the reference price and what are the possibilities to hedge this price difference for example through Financial Transmission Rights (FTRs). Price convergence could thus be one criterion for infrastructure investments. To analyse the influence of cross-border capacity on price convergence, the method developed in this paper is used. The results are shown in Figure 11.

In Figure 11, the starting point of each brown bar shows the level of price convergence today and the length of the brown bar corresponds to the increase in price convergence when 100MW of cross border capacity is added. In Figure 11 price convergence is expressed in percentage of full price convergence. The method assumes that the supply curves are linear as explained above. This results in a linear increase of price convergence when capacity is increased. Thus for example, 50% price convergence corresponds to the capacity level for the maximum congestion rent.

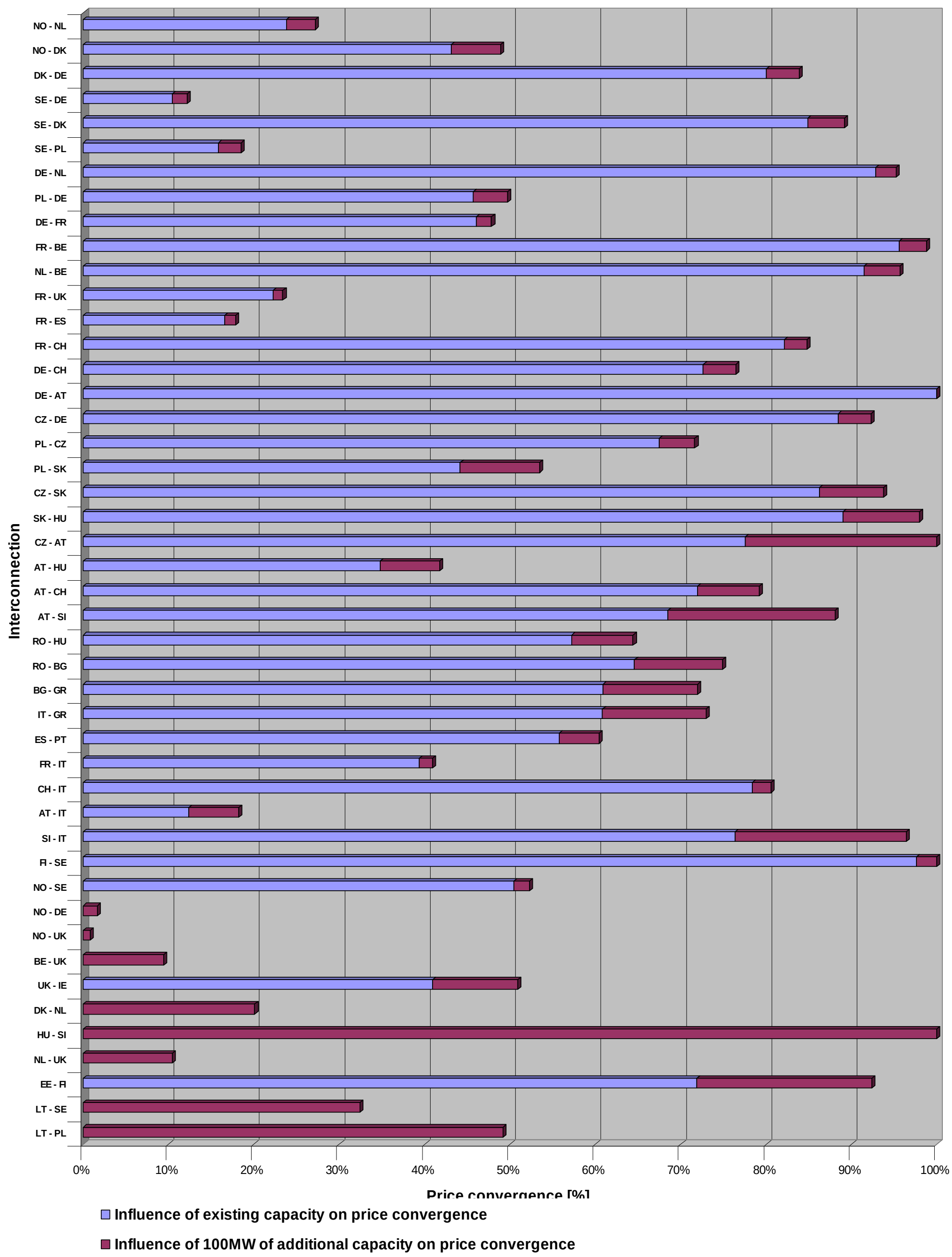
The calculation shown in Figure 11 is based on increasing the capacity of one interconnection at a time, effects caused by other interconnections of the concerned countries are ignored. In reality all interconnectors have an influence on price convergence and should be taken into account in any detailed calculation. Also, the calculation shown in Figure 11 on price convergence has been made assuming that each country is a single price zone. This is not the case in Italy, Denmark, Norway and the UK which are divided into several bidding zones. However, for the purposes of this paper aiming to give an overall view of price convergence, this simplification does not significantly change the results. To make the analysis more accurate, each bidding zone should be modelled separately. This step is left for further studies.

One can make several interesting observations from Figure 11. Firstly, there is a systematic difference between interconnections inside Central Europe compared to interconnections connecting Central Europe with the regions in the outskirts of Europe. In Central Europe there is already a high level of price convergence which could be further increased with a relatively small increase of capacity. In particular Central Eastern Europe (excluding Germany and Poland) is composed of small systems which are sensitive to price influence from neighbours being thus good candidates for full price convergence. Better utilisation of the existing transmission capacity through market coupling

[47] Newbery, renewable integration workshop, 2010

will already increase convergence once the coupling is achieved. This means that Central Europe, in particular Germany, will confirm its position as the price reference for the whole Europe.

Figure 11 Influence of 100 MW of additional capacity on price convergence in European interconnections.



Price convergence between the Central European market and the neighbouring regions, namely Northern Europe, the UK, the Iberian peninsula and Italy, does not seem realistic. The interconnection capacity needed for full price convergence is several thousands of MW which would be very costly at least with current transmission technology. This means that in the medium term, taking into account the current and planned transmission network, these regional markets will still have an important price difference with Central Europe, and consequently a rather independent price formation.

Increasing variable wind production will probably inverse the trend of increasing price convergence in Central Europe. Wind power already causes important price fluctuations between zones inside Central Europe. Thus wind power sets new requirements for both system operation and market design. This might require a review of the split of Europe into price zones to allow more efficient congestion management in the network. Smaller bidding zones distribute the overall price difference in smaller steps to an increased number of bidding zone borders and hence give more precise scarcity signals. This could improve significantly the utilisation of the current grid and could also have a big influence on the profitability and the optimal location of transmission investments. This proposal is further discussed in a companion paper.

14. Conclusion on targets and criteria for cross border investments

From the discussion above it is difficult to draw a conclusion regarding the priority of targets for transmission investments. It seems evident that there is a hierarchy of targets similarly as humans need first shelter and food before they can concentrate on arts and sports. Technical targets come first, driven today by investments in renewable generation. These targets need to be met, otherwise generation investments are stranded. Price convergence and competition targets are important for efficiency but not to a similar extent vital for the functioning of the transmission system.

Technical targets such as connecting each generator and load are addressed mainly at the national level. For interconnectors price arbitrage targets are more relevant.

From the social welfare point of view it seems evident, as indicated in Table 3 and Figure 8, that Europe is far from the optimum level regarding interconnection capacity.

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