Client European Commission – Directorate General for Energy and Transport – Directorate C

Subject Updating T E N-Energy- Invest study (Contract n. TREN/04/ADM/S07.38533/ETU/B2-CESI) with a particular attention paid to the future development of the Energy Market in the Baltic region – Methodology to prioritise infrastructure projects.
Working Group "Electricity interconnections"
Phase II: methodology for the assessment of new infrastructures and application to the assessment of the interconnection projects already identified in the Baltic area

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REVISIONS HISTORY

Revision number	Date	Protocol	List of modifications and/or modified paragraphs
0	May 2009	A9012922	First issue
1	June 2009	A9017216	Second issue – Modifications in the paragraph "ability to finance" with updated values of FCF index

1 FOREWORD

In the first part of the study, the present status of the electricity sector in the EU Member States surrounding the Baltic Sea, including Norway, Belarus, the Kaliningrad region of the Russian Federation and Ukraine was examined [1]. In particular, the following issues were analysed:

- consumption level;
- installed capacities;
- electricity generation;
- energy balances and exchanges;
- cross-border congestion level;
- existing interconnection lines.

Moreover, the expected generation evolution and system adequacy in the next ten years was presented referring to the joint study carried out by the European Transmission System Operators (TSOs) and issued in July 2008 [2]. The outcomes of this study represents a useful basis to anticipate the needs in some countries for new generation or, alternatively, for strengthening the interconnections to ensure an adequate security of supply (SoS).

Thereafter, the new interconnection projects proposed by the TSOs were examined and the related justifications were identified, though in a qualitative way.

The second part of the study addresses the assessment of the proposed interconnection projects adopting a series of agreed criteria in order to get as much as possible a quantitative evaluation of each project. The adopted methodology has been derived from a more general and widely used procedure based on the Analytical Hierarchical Process [3]. With the aim to simplify the project assessment, taking into account the limited available information for some projects, three criteria have been considered:

- *benefit/cost ratio*, where benefits refer only to market benefits and costs refer to investment costs including the AC reinforcements upwards and downwards the interconnector;
- *timing* for the authorisation and construction;
- *risks*, based on a series of indicators such as: technical readiness, number of expropriations, number of municipalities crossed by the interconnector and related internal AC reinforcements, presence of protected areas, distance from populated areas and ability to finance.

As for the interconnection projects, the analysis considered all the proposed projects of new interconnections between the Baltic Member States and the rest of the EU, besides the third cross-border line between Estonia and Latvia and the interconnection projects between Germany and Poland. On the contrary, it has been agreed that the new cross-border projects within the Nordel region have already been prioritised in the framework of the "Nordic Grid Master Plan" [4], and, as such, no additional project assessment was needed.

The combination of the benefit/cost ratio, overall time required for the project commissioning and risk factors allows to have a quantitative evaluation of the profitability and readiness of each project.

2 PROJECT ASSESSMENT METHODOLOGY

For the quantitative assessment of the interconnection projects, the methodology based on the Analytical Hierarchical Process (AHP) [3] has been proposed. Hereafter, we give a general and synthetic description the AHP methodology that can be applied to get an assessment and ranking of various interconnection projects and, for a selected interconnection, can help to choose the best alternative between several ones. In our study, however, a simplified methodology (par. 4) has been adopted to take into account both the timing constraints for the delivery of the results and the set of available information at the time of execution of the analysis.

The AHP is a structured technique for helping people deal with complex decisions. The methodology proves to be particularly efficient whenever for the assessment of a project one has to quantify and compare between them some values having different metrics[1] and in some cases involving human perceptions and judgments. Moreover, the methodology helps to overcome obstacles related to the difficulty to quantify or compare alternatives in the case where communication among team members is hindered by their different specializations, terminologies, or perspectives.
The AHP is based on a two-step approach (Fig. 2-1):

- 1st step: decomposition of the problem into a hierarchy of more easily understandable sub-problems, each of which can be analyzed independently on the basis of a set of agreed criteria, each one composed of a group of indicators
- 2nd step: once the hierarchy is built the comparison of the project alternatives in pairs is executed up to a first ranking of the various alternatives

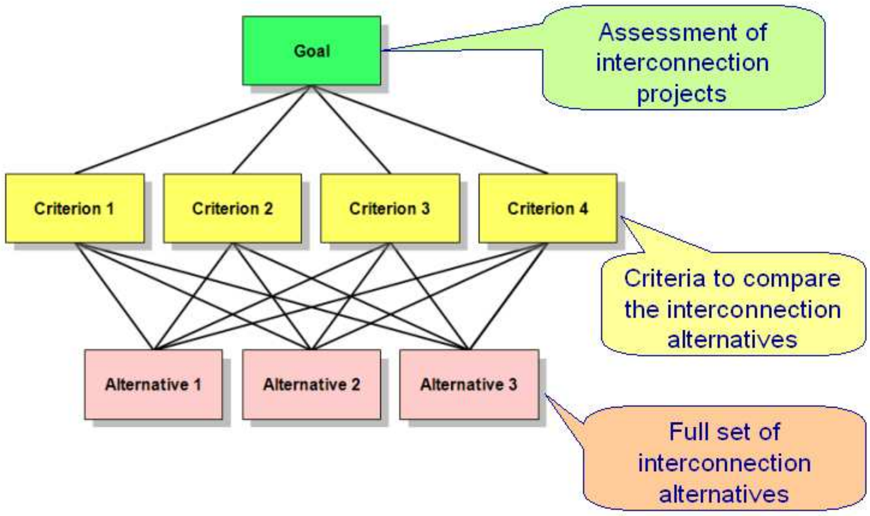

Fig. 2-1 – Scheme of the AHP methodology

For the comparison of the project alternatives the AHP assigns each criterion and associated indicators some numerical values included in a common range. A numerical weight is derived for each element of the hierarchy, allowing the comparison of diverse and often incommensurable elements in a rational and

[1] E.g.: benefits of a project may be related to economic issues (reduction of the kWh price in €/kWh), enhancement of SoS (in terms of Expected Energy Not Supplied: MWh/yr), environment (reduction of emission of CO_2: Mton/yr). To compare different alternative projects, one shall evaluate in a quantitative way the overall benefits despite the various components have a different metrics.

consistent way (Fig. 2-2). The sum of the weights for each level of the hierarchy is normalised to 100 % (or in an equivalent way to 1 p.u.).

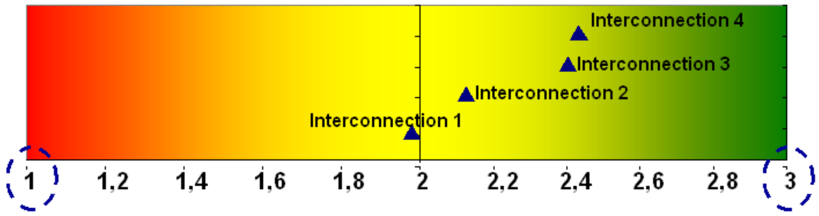

Fig. 2-2 – Example of assessment of four interconnection alternatives applying the AHP and on the basis of agreed weights for criteria and associated indicators

For the assessment of the interconnection projects the following criteria have been proposed:

- *Benefits*: socio-economical benefits deriving from the enhancement of transmission capacity at the border, falling into the following categories:
  - market benefits
  - enhancement of SoS
  - environmental benefits in terms of reduction of CO2 emission
- *Costs*, including the reinforcements needed in order to properly utilize the interconnection:
  - Investment costs
  - Fixed and variable operation costs
- *Technical performance* of the interconnected system
- *Environmental impact*:
  - Territorial and environmental elements
  - Technical and administrative elements
- *Time* required for the construction of the interconnector;
- *Risks* related to the interconnection project; they are referred to:
  - Financing
  - Uncertainty in time schedule related to opposition of the local population, difficulty in obtaining the expropriations, need to cross protected area, distance from densely populated areas
  - Technical readiness: km of AC lines to be built upward and downward the interconnector

Fig. 2-3 shows the hierarchy in a highly summarised way. Obviously, each component is in its turn split into a series of subcomponents as shown, as an example, in Fig. 2-4 and in Fig. 2-5.

Two basic requirements are needed for the full application of the AHP:

- the availability of the results of feasibility studies having taken into account the criteria and indicators included in the hierarchy;
- a consensus on the relative weights to be assigned to each criterion and indicator.

Unfortunately, both the above requirements were not fulfilled when performing the analyses: some feasibility studies are still ongoing or shall be executed, as recommended in par. 6, and the definition of the weights to be assigned requires dedicated meetings among experts in the various sectors followed by higher level meetings to agree on the weights for the criteria at the higher levels of the hierarchy.
Hence, a simplified methodology has been adopted as explained in detail in par. 4. At any rate, we recommend the execution of the missing analyses and the application of the AHP, especially to decide between various alternatives for the same interconnector.

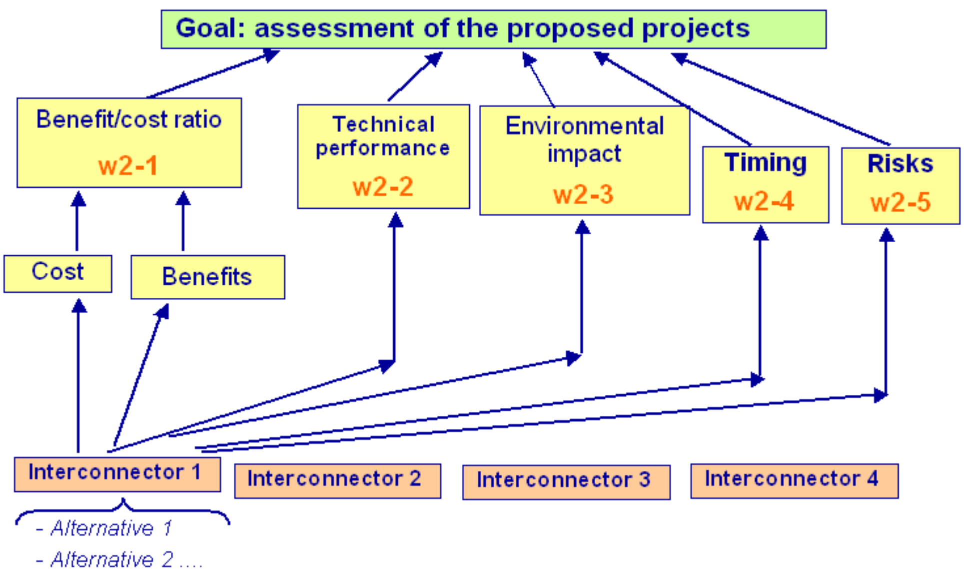

Fig. 2-3 – Hierarchy proposed for the interconnection project assessment. ("w2-i" are the weights associated to each criterion: $\sum_i w2-i = 100\%$ *)*

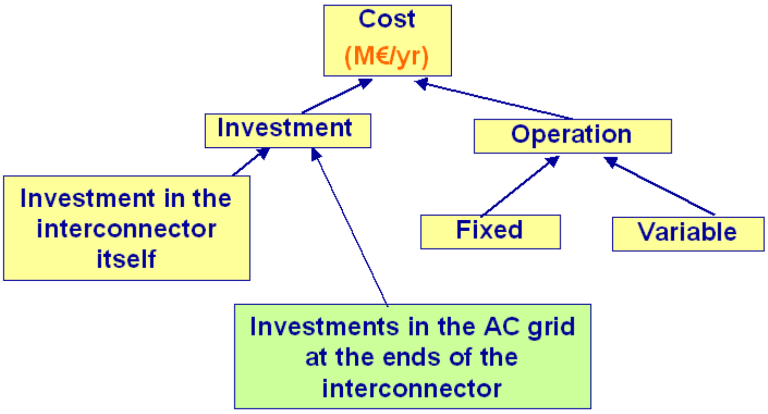

Fig. 2-4 – Part of the hierarchy related to the interconnector costs

Possible weights

Groups		Subgroups		Indicator	
Territorial & environmental elements	60%	Land use	20%	Occupied territory	40%
				Presence of use with specific prestige	60%
		Populated areas	10%	Distance from large populated cities	30%
				Urbanised and/or particularly populated areas	70%
		Protected areas	25%	Interference with protected areas and/or areas of special environmental worth	100%
		Water bodies	10%	Crossing waterways	100%
		Infrastructures	10%	Presence of preferential corridors along existent infrastructures	60%
				Crossing large roadways	40%
		Morphology elements	25%	Topographic Characteristics	20%
				Coastal marine habitat	30%
				Bathymetric hazards	50%
Technical / administrative elements	40%	Converter station	30%	Difficulties of converter station localisation	100%
		Power lines	20%	Length of land power lines	100%
		Sea cable	40%	Length of the sea cable	70%
				Maximum installation depth	30%
		Electrodes	10%	Difficulties of electrodes localisation	100%

Fig. 2-5 – Part of the hierarchy related to the environmental impact with a proposal of possible weights for each indicator

3 INTERCONNECTION PROJECTS IDENTIFIED IN THE BALTIC AREA

In the first phase of the analysis the interconnection project showed in Fig. 3-1 and Fig. 3-2 were considered.

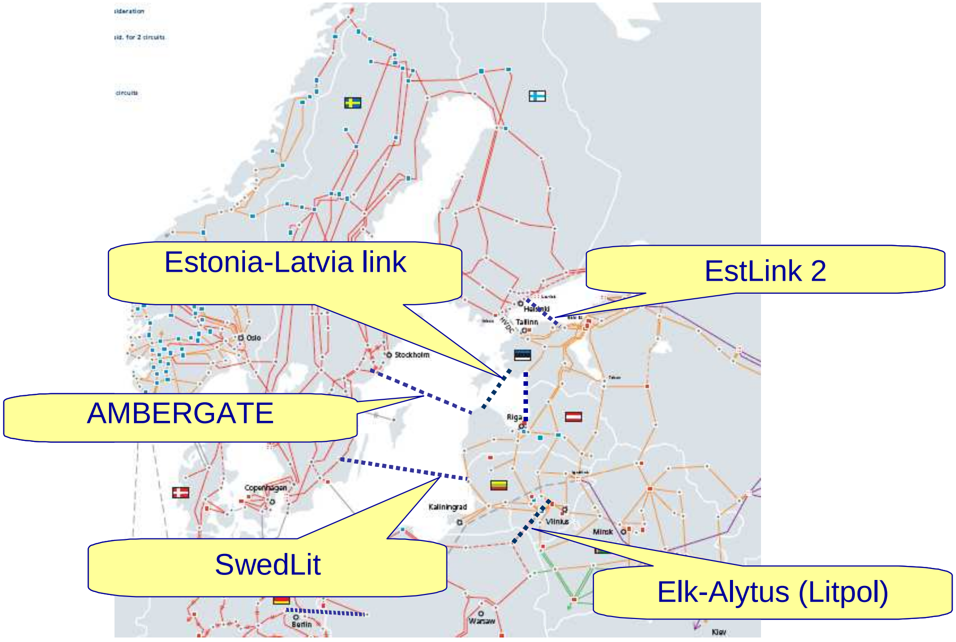

Fig. 3-1 – Interconnection projects between the Baltic Member States and the rest of the EU, including the Estonia-Latvia third interconnection

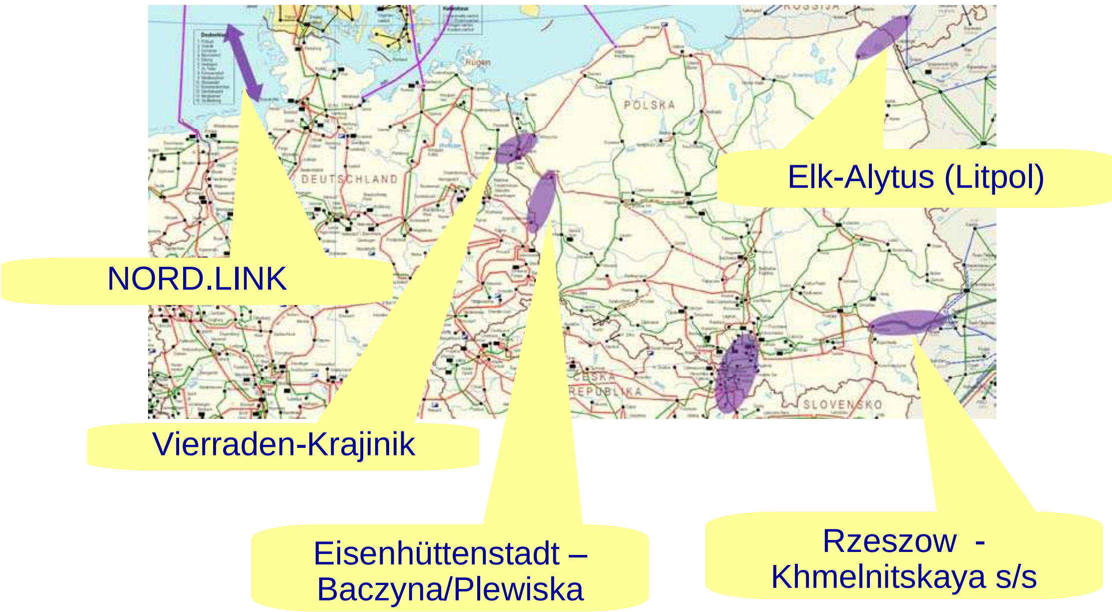

Fig. 3-2 – Interconnection projects between Germany and Poland; Poland and Ukraine, Germany and Norway

At this stage, for the quantitative project assessment the cross-border projects internal to Nordel are not considered, since they are already prioritised in the framework of the Nordic Grid Master Plan [4]. The interconnections between Poland and Ukraine (Rzeszow-Khmelnitski 750 kV + BtB) and between Norway and Germany (NORD.LINK, HVDC submarine cable) are also disregarded since the results of feasibility studies on these interconnections are not available yet. Finally, concerning the two projects for strengthening the Polish-German interconnection, only some general information is available, being dedicated studies still in progress. Tab. 3-1 summarises the main characteristics of the projects considered in the quantitative assessment carried out on the basis of the criteria described in par. 4.

Tab. 3-1 - Cross-border lines considered in the project assessment

Project	Rating	Ends	Notes
Estlink 2	650 MW	Anttila-Püssi	
Ambergate	700 MW	Norrköping-Ventspils	*(1)*
SwedLit	700 MW	Nybro/Hemsjö-Klaipeda	*Location of the converter station in Sweden not decided yet*
LitPol	500 / 1000 MW	Elk-Alytus	*Possible development in stages*
Latvia-Estonia 3rd Interconnection	(*)	Harku-Sindi-Riga	*Four possible alternatives (2)*
DE-PL first project	≈2 x 1630 MVA	Vierraden-Krajnik	
DE-PL second project	(**)	Eisenhüttenstadt–Bazcyna/Plewiska	*400 kV double circuit line*

(*) For the HVAC solutions the rated capacity is: ≈1000÷1200 MVA.
For the HVDC solutions the rated capacity is: 600 MW.
The new Latvia-Estonia interconnection shall warrant an increase of NTC[2] equal to 500÷600 MW

(**) to be defined

(1) **Ambergate:** in the pre-feasibility study five possible routes were considered as shown in Fig. 3-3. In the project assessment analysis, the solutions crossing the islands of Gotland and Öland are disregarded for environmental reasons. Also the direct connection towards the Stochkolm's substation has to be disregarded, due to the difficulties in finding a route in the Stockholm's archipelago. Thus, the only feasible alternative from the environmental point of view is the longest route connecting Norrköping to Ventspils (390 km).

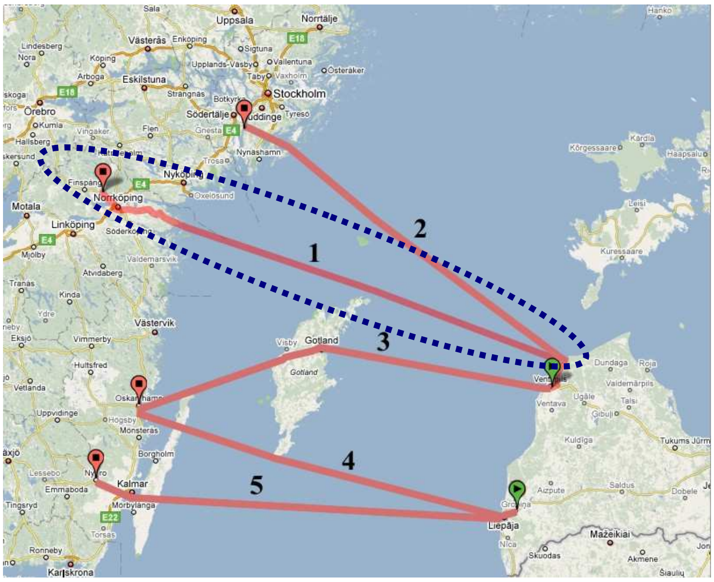

Fig. 3-3 – Ambergate: possible routes of the submarine cable examined in the prefeasibility study

[2] NTC: Net Transfer Capacity

(2) **Latvia-Estonia Third Interconnection**: four possible routes (Fig. 3-4) of this new line are being investigated:

1. Harku-Sindi-Riga (land option: AC link);
2. Harku-Sindi-Dundaga-Ventspils-Grobiņa (DC link);
3. Harku-Sindi(Lihula)-Mõntu-Mazirbe-Jelgava (AC link);
4. Harku-Sindi(Lihula)-Läätsa-Ventspils-Grobiņa (DC link);

For the AC solutions, the 330 kV voltage level will be adopted, while the choice of the DC voltage level for alternatives 2 and 4 has still to be made.

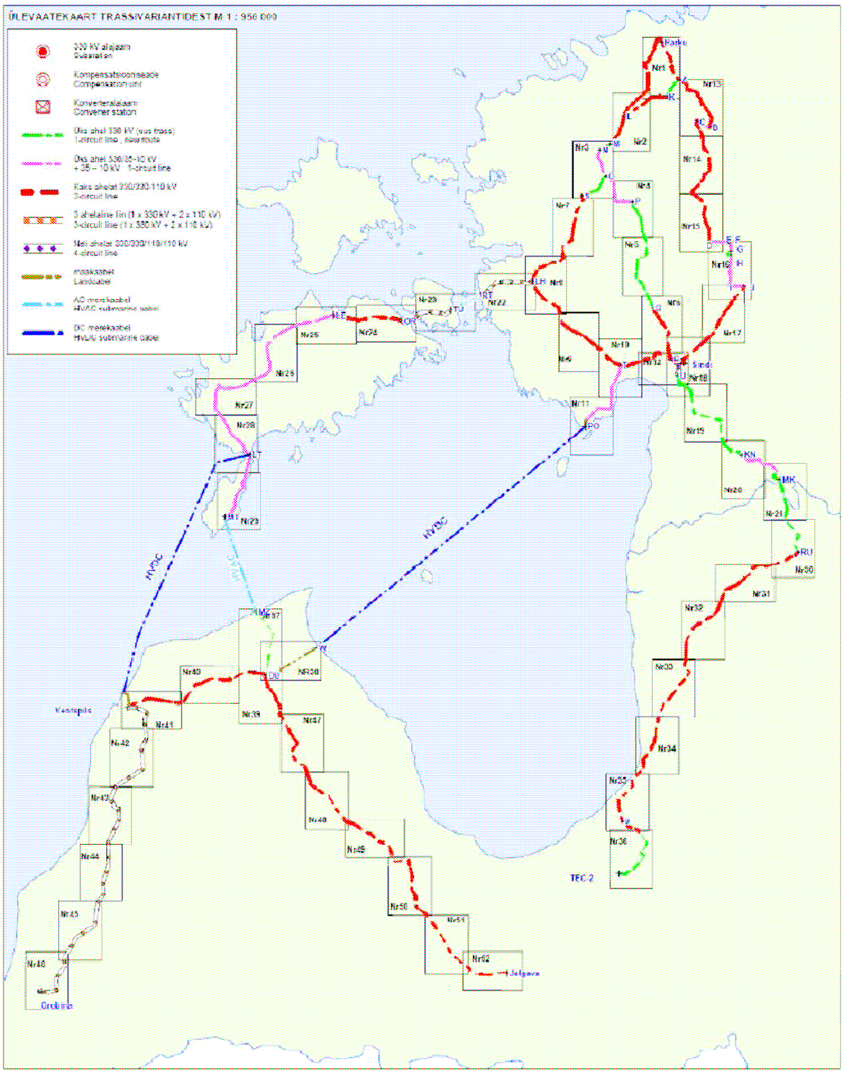

Fig. 3-4 - Alternative right-of-ways for Harku-Sindi-Riga line

4 SIMPLIFIED CRITERIA FOR THE PROJECT ASSESSMENT

To simplify the assessment of the interconnection project profitability, it has been agreed to adopt the following criteria and indicators:

- *benefit/cost ratio,* where benefits refer to the market benefits, i.e.: economical benefits related to the decrease of the kWh price after the commissioning of the new interconnector. Concerning the costs, they are referred to the investment costs only, including those for the internal AC reinforcements. These latter investment costs are fully assigned to the interconnection projects, even though the AC lines are needed and exploited to warrant the required security and reliability levels of the generation-transmission system. Both benefits and costs are annualised (M€/yr) on the basis of a same value of discount rate and lifetime;
- *Timing for project commissioning,* including the authorisation process;
- *Risks*. A series of indicators have been considered:
  - *technical readiness*: this indicator refers to the need for reinforcements of the grids connected to the end of the new cross-border link. It is expressed in km of new internal AC lines;
  - *factors affecting uncertainty in time schedule:* number of expropriations, number of municipalities crossed by the interconnector, including the internal AC reinforcements;
  - *other factors of risks*: presence of protected areas and distance from densely populated areas;
  - *ability to finance*. Two indicators have been selected:
    - the *Free Cash Flow (FCF),* which is an index that takes into account the changes in working capital and the capital expenditure instead of depreciation/amortization as in the case of the Net Income index. FCF can be used by firms to finance projects with relatively low returns, which might not be easily funded by the equity or bond market;
    - the *financial rating* of the TSOs, assuming the new interconnecting lines will not be exempted by TPA (Third Party Access). This index shows how easily a company can increase its debt for capital expenditures.

Moreover, it has also been agreed *not to assign any weight to the various criteria and indicators* to avoid a possible bias of the results, taking into account that some analyses on the new interconnectors are still missing in some cases (e.g.: the study of the improvement of the interconnected system technical performance, the enhancement of the security of supply –SoS-, the environmental benefits in terms of reduction of CO2 emission, the environmental impact assessment –EIA-).

4.1 Other basic assumptions

To get a fair assessment of the interconnection projects, some common basic assumptions have been considered, namely:

- **Discount rate: 7%;**
- **Lifetime of the new interconnector: 30 years.**

Furthermore, the same technology and interconnection scheme is assumed for DC interconnectors: LCC[3] with MV[4] sea cable return for submarine links.
Wherever possible, the same unitary costs are adopted. Particularly for EstLink2, SwedLit and Ambergate, the following costs were assumed:

- **sea/land cable (supply + laying down + protection): 0,77 M€/km**
- **MV sea metallic return cable: 0,15 M€/km[5]**
- **DC overhead line: 0,35 M€/km**
- **Converter stations (both ends): 0,16 M€/MW**
- **bay cost: 1,5 M€/bay;**
- **AC OHL: different values for each country depending on voltage level, line rating and territory morphology.**

In addition, a contingency cost equal 10% of all other investment costs has been considered.

[3] LCC: Line Commutated Converters, technology based on thyristors
[4] MV: Medium Voltage
[5] In the Multiregional study, when estimating the investment costs different values for the MV return cable have been adopted, in the range between 0,1 and 0,2 M€/km. The value adopted for the estimations presented in this report is the average between the two extreme.

5 ASSESSMENT OF INTERCONNECTION PROJECTS

5.1 Benefit/cost ratio

The evaluation of the benefit/cost ratio has been carried out by clustering the projects in three groups:

- *Interconnection projects between Baltic Member States and the rest of the EU*: Estlink 2, Ambergate, SwedLit and LitPol. For the project assessment, reference is made to the Multiregional Study jointly carried out by Nordel, BALTSO and PSE Operator S.A. [5] and, specifically, to the BAU 2025 scenario;
- *Latvia-Estonia Third Interconnection*: reference is made to the ongoing study on the "Economic and Technical Research of the Harku-Sindi-Riga 330 kV Line, Draft Market Analysis Report" considering the outcomes of the Basis scenario 2020;

Common assumptions for investment costs and annuity of the above projects have been considered.

- *Germany-Poland interconnection projects*: preliminary estimations of the investment costs forwarded by the involved TSOs: Vattenfall Europe Transmission GmbH and PSE Operator S.A. It is worth mentioning that the two interconnection projects between Germany and Poland are not justified only by the need for a better efficiency of power markets, but mainly by the necessity to cope with very high volatile and unpredictable flows caused by wind generation in Northern Germany and, in general, the widespread increase of wind generation in Baltic area. Moreover, a better control of loop flows that occur quite frequently in the region requires a higher flexibility of the transmission grid (namely through PST[6]). Hence, dedicated studies not targeted to market benefits only are to be carried out to correctly estimate the renewal benefits deriving from the enhancement of the NTC between Germany and Poland.

Note: since the benefits of the Germany-Poland interconnection projects are not related to the enhancement of the power market efficiency only and the set of available information is still quite limited, the analysis of these projects is made separately in par. 5.4.

5.1.1 Benefit/cost ratio of the interconnection projects between Baltic Member States and the rest of the EU

5.1.1.1 Annual benefits

The yearly market benefits obtained by the Multiregional Study with reference to the BAU scenario in the year 2025 are:

- **EstLink 2: 71.0 M€/yr**
- **Ambergate: 78.5 M€/yr**
- **SwedLit: 78.5 M€/yr**
- **LitPol[7]: ≈ 160 M€/yr**

It worth mentioning that the above market benefits are obtained starting from a generation development scenario, which assumes heavy investments in new production facilities, especially in the Baltic M.S. (Tab. 5-1). At any rate, market benefits should be quite stable with respect to the generation development scenario as discussed below.

Among the most relevant assumptions on new generation in the BAU 2025 scenario, we recall.

[6] PST: Phase Shifter Transformer

[7] LitPol: simulation with capacity equal to 1000 MW

- in Estonia: new Nuclear Power Plant (NPP) in place by the year 2023 and about 1000 MW of wind power generation (on-shore and off-shore); oil-shale based capacity decreases to 1000 MW by 2025;
- in Latvia: new CCGT (400 MW) in the territory of Riga, new coal (and biomass) unit in Kurzeme (400 MW) and 560 MW of small RES capacity;
- in Lithuania: new CCGT unit (400 MW) in Lietuvos Power Plant by the year 2012, further CCGT unit (400 MW) in Lietuvos PP by 2015; construction of the first NPP (1600 MW) in Visaginas by 2018 and a second NPP in Visaginas ready by 2021. Finally, the wind farm capacity in Lithuania will attain 500 MW in 2025.

Tab. 5-1 – Generation development scenario in the BAU scenarios considered in the Multiregional Study[8]

	BAU2015		BAU2025	
	MW	TWh	MW	TWh
Estonia	3 096	25	3 808	31
Latvia	3 144	25	3 447	28
Lithuania	2 855	23	6 405	51
Poland	31 586	254	39 243	316
Nordel	66 614	536	69 051	555

The market benefits shown above are evaluated assuming the commissioning of one single interconnector at a time to simplify the evaluation process, though we are aware that the benefits of two or more interconnections depend on the building order. However, the differences in the market benefits are quite low according to the computation performed in the Multiregional Study.
As said above, the market benefits shown above are evaluated in the BAU 2025 situation. However, whenever the prices differ, there will be market benefits, even though the amount is of course dependent on the scenario chosen. Taking into account that Nordic Countries systems are mainly hydropower dominated and Baltic Member States systems are mainly thermal power dominated, it is probable that new interconnections between the two regions are profitable from the market point of view in most scenarios[9]

It is to be underlined that *SwedLit and Ambergate projects show the same market benefits*. Factors to discriminate between the two projects shall consider:
- the impact on the increase of SoS;
- the environmental benefits;
- the investments and operational costs;
- the environmental impact;
- risk indicators.

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[8] In Poland new estimations of future installed capacity have been performed in the framework of the "*Energy Policy till 2030*" study (report still in draft). The new estimations of installed power are:
- year 2015 : 40.007 MW;
- year 2025 : 47763 MW.

All the analyses presented in our report are, however, based on the generation assumptions adopted in the Multiregional study.
[9] For example: the 2015 scenario, with quite a bit less generation in the Baltic Countries, is characterised by a large amount of congestion hours (about 3500) between Finland and Estonia, as reported in Appendix B of the Multiregional Study.

5.1.1.2 *Investment costs*

The total investment costs are derived adding the following components.

- DC submarine cables (two poles: one cable per pole);
- DC OHL;
- MV sea cable return;
- Converters stations;
- AC reinforcement (lump sum)
- Contingency costs multiplying all the above cost components

➢ **EstLink 2** (150 km DC submarine cable; 15 km of DC OHL line; AC reinforcements: 20 M€)

✓*Inv.Cost: (150*0,77 + 150*0,15 + 15*0,35 + 650*0,16 + 20)*1,1 =* ***294 M€***

➢ **Ambergate** (Ventspils-Norrköping: 390 km DC submarine cable; no info on DC OHL line + AC reinforcements: 180 M€)

✓*Inv.Cost: (390*0,77 + 390*0,15 + 700*0,16 + 180)*1,1 =* ***716 M€***

Note: the AC reinforcements in the Latvian side include[10]*:*

- *330kV OHL Ventspils – Liepaja: 130km; implementation: 2009 – 2014*
- *330kV OHL Ventspils – Jelgava: 210km; implementation: 2009-2018330kV a/st. Ventspils ; implementation : 2009 – 2014.*

➢ **SwedLit** (330 km DC submarine cable; 85 km of DC OHL line; AC reinforcements: 90 M€)

✓*Inv.Cost: (330*0,77 + 330*0,15 + 85*0,35 + 700*0,16 + 90)*1,1 =* ***589 M€***

➢ **LitPol** (1000 MW BtB station in Alytus, plus AC reinforcements in Lithuania and Poland – see Fig. 5-1 -)

✓*Inv.Cost: (lump sum from the Multiregional Study) =* ***1110 M€***

[10] Reference: "*Energy development projects in Latvia*"

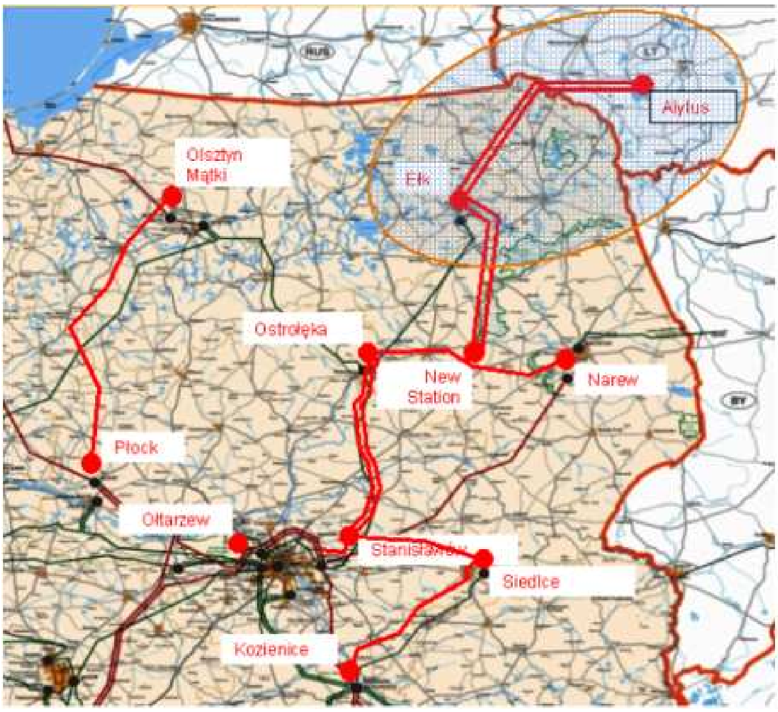

Fig. 5-1 – AC reinforcements needed internal to the Polish grid following the commissioning of the LitPol interconnector

5.1.1.3 Benefit/cost ratio

On the basis of the market benefits and investment costs estimations and common assumptions on discount rate and lifetime for the new interconnection, the benefit/cost ratio is derived (Tab. 5-2).

Tab. 5-2 – Annualised market benefits, investment costs and benefit/cost ratio

	EstLink2	SwedLit	Ambergate	LitPol
Market Benefits /M€/yr)	71,0	78,5	78,5	160,0
Costs (M€/yr)	23,7	47,5	57,7	89,5
Benefit/Costs ratio	**3,0**	**1,7**	**1,4**	**1,8**

It can be seen that the EstLink 2 interconnector shows the highest profitability basically due to its relatively low investment costs.

In the case of the LitPol interconnector, the high market benefits are partially offset by the heavy investments, especially in the AC grids.

As for the SwedLit and Ambergate projects, we have already underlined the uniform market benefits, since the cables will interconnect areas with similar market prices[11]. Also the investment costs are quite comparable, having the interconnector the same size. The only discriminating elements are related to the interconnection length (the Ambergate project with the solution Ventspils-Norrköping is more penalised) and the length of the AC reinforcements.

[11] Market prices estimated in Lithuania and Latvia by the year 2025 in the BAU scenario are very similar due to a sufficiently high NTC between the two countries.

5.1.2 *Benefit/cost ratio of Latvia-Estonia Third Interconnection*

5.1.2.1 Annual benefits

For this specific project the benefits have been evaluated through a tailored study [6], which allowed to estimate the market benefits in terms of reduction of the electricity price after the commissioning of the new link as well as the reduction of CO2 emissions. Further analyses are being carried on to evaluate the expected impact of increase of security of supply in the Baltic M.S. (i.e.: decrease of EENS); these additional results shall be ready by end May 2009.

The quantitative evaluations of the benefits, derived with reference to a Base case scenario for the year 2020, are the following:

- **Market benefits:** **12.3 M€/yr**
- **Environmental benefits** **0,97 Mton/yr of CO2 emission reduction.**

Fig. 5-2 shows a comparison of the annual CO2 emissions in the three Baltic M.S. with and without the new Harku-Sindi-Riga interconnection line. However, to have a common criterion for the benefit/cost ratio, only market benefits are considered hereafter.

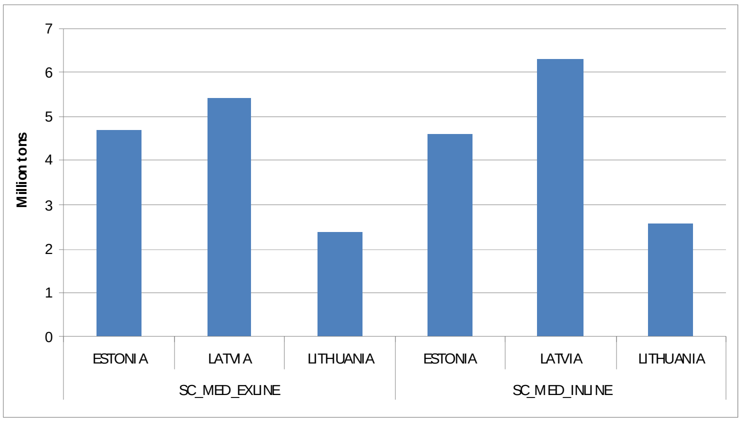

Fig. 5-2 – Annual CO2 emissions in the three Baltic M.S. with and without the new interconnection line between Estonia and Latvia

5.1.2.2 Investment costs

For assessing the profitability of the various alternatives among them, the unitary costs listed in Tab. 5-3 were assumed.

Tab. 5-3 – Unitary costs assumed for the Estonia-Latvia interconnection line [6]

Components	Unitary costs	Notes
Converter stations	**138 k€/MW**	LCC technology
HVDC submarine cables	**750 k€/km**	Supply and burying
HVDC terrestrial cables	**278 k€/km**	Supply and burying
AC overhead lines	**160 k€/km**	1-circuit 330 kV OHL
AC terrestrial cables	**1720 k€/km**	Four possible alternatives (2)
Other costs	**2580 k€**	1 duplex bay in 330 kV substation
Contingency costs	----	Included in the previous costs

With the previous assumptions on the unitary costs, the total investment costs in the new interconnector are in the range between 100÷350 M€, which includes also internal network reinforcements in Estonia and Latvia. Total cost includes: pre-research, designs, arranging right-of-way, pre-tasks for construction and interconnection construction.
Tab. 5-4 illustrates the section lengths and investment costs of the four alternatives of the Harku-Sindi-Riga interconnection. For each alternative three sections are identified: Estonian landside, Latvian landside and sea part. It is worth noting that these costs may be overestimated since they consider the investment costs of the AC reinforcements fully assigned to the interconnector, though they play a role also for other purposes[12] (e.g.: to ensure security in the internal grids).

Tab. 5-4. Section lengths and investment costs of the four alternatives oft he Harku-Sindi-Riga interconnection [7]

Right-of-way	Length of right-of-way (km)				Cost of interconnection (M€)			
	Estonia	Latvia	Sea	Total	Estonia	Latvia	Sea	Total
1 Harku-Sindi-Riga (AC, full land option)	212	182	0,00	**394**	59	38	0	**97**
2 Harku-Sindi-Dundaga-Ventspils-Grobiņa (DC)	193	188	114	**495**	54	60	196	**310**
3 Harku-Sindi(Lihula)-Mõntu-Mazirbe-Jelgava (AC)	345	165	33	**543**	123	37	116	**276**
4 Harku-Sindi(Lihula)-Läätsa-Ventspils-Grobiņa (DC)	322	118	100	**540**	117	43	183	**343**

Note: part of the investment costs related to Latvia and Estonia internal network reinforcements (see column Estonia + Latvia in the above table) must be considered as prerequisites for several other projects, such as wind generation development, security of supply for the regions, reliability of Sweden-Baltic M.S. and Estonia-Finland interconnection operation.

5.1.2.3 Benefit/cost ratio

Tab. 5-5 shows the benefit/cost ratio obtained from the annual market benefits and investment costs. It can be seen that only the full land option with AC overhead line is justified by the market benefits. The other alternatives may be justified only considering the additional benefits related to the reduction of the CO2 emissions and the enhancement of security of supply.

Tab. 5-5 – Annualised market benefits, investment costs and benefit/cost ratio

	Harku-Sindi-Riga			
	1	2	3	4
Market Benefits (M€/yr)	12,3	12,3	12,3	12,3
Costs (M€/yr)	7,8	25,0	22,2	27,6
Benefit/Cost ratio	**1,6**	**0,5**	**0,6**	**0,4**

5.2 Timing for project commissioning

The evaluation of the time needed for the commissioning of the interconnectors has been obtained from the information forwarded by the concerned TSOs and includes the overall process from the EIA and "standard" authorisation time to the testing after the end of the construction works.
The tentative schedule for the commissioning of the proposed interconnections is the following:

[12] This is however the common assumption adopted for all the interconnection projects.

- **EstLink 2:** **5 years** (between 2009 and 2014 based on “accelerated timetable)
- **SwedLit:** **8 years**
- **Ambergate:** **9 years**
- **LitPol:** development in stages linked to the reinforcements of the AC grids in Lithuania, but mainly in Poland. Full exploitation of the LitPol interconnection (1000 MW) in both directions expected by 2020.**Harku-Sindi-Riga:** **8 years** (between 2010 and 2017 based on “accelerated timetable”)
- **EstLink 2**[13]
  The “accelerated” project would be realized between 2009 and 2014 and includes the following phases (the phases are based on Finnish and Estonian estimates and may overlap each other):
  - "standard authorisation” processes both in Finland and Estonia: around 3 years, incl. EIA, cross border permit, survey permit, water permit and land access
  - Environmental Impact Assessment:
    - In Estonian land section, EIA was approved in March 2009.
    - In Finnish land section, the need for full EIA has not been decided yet. If needed, it will normally take 1,5 years.
    - If EIA is needed for the marine section (coast-to-coast), it will take approximately 1,5-2 years. This includes the possible international hearing according to the Espoo convention.
  - Land acquisition:
    - In Finnish side, land access permit preparation takes 0,5-1 years, acquisition and compensation 2-3 years.
    - In Estonian side, land acquisition process has been started, it is expected to be finalised during 2010.
  - Permit process: totally around 3 years, but possible complaints may extend the process with around 1 year
  - Preparation of technical requirements: sea bed survey 0,5 years, DC overhead line general planning 0,5-1 years, cable 0,5 years -> totally 1 year
  - Tendering and selection of the contractors: 0,5 years
  - Procurement of material: 1,5-2 years incl. cable and DC overhead line
  - Construction work: 1 year incl. cable and DC overhead line.

Critical factors:

- Possible delays in the market opening in the Baltic Member States.

- **Ambergate**

[13] Source: Finnish and Estonian TSOs

The overall time period, 9 years, for the realisation of the Ambergate interconnector is mainly dictated by the process related to the EIA, definition of the routing and the land expropriation at the Swedish side, as well as to the need for the construction of new AC lines and substations in the western part of Latvia. Hence, the commissioning of this project, once it has been approved, is not foreseen before 2018.

Critical factors:

- Possible delays in the market opening in the Baltic Member States, as in the case of Estlink 2;
- Delays in the commissioning of new generation in the Baltic region and, namely, in the Baltic Member States;
- Possible problems for the land routing in the Swedish side.

- **SwedLit**

Similarly to the previous case, the overall time period, 8 years, is basically dictated from the EIA, authorisation process and the land expropriation at the Swedish side. At the Lithuanian side the project can be realised in 6 years including the AC reinforcement (Klaipeda – Telsiai 330 kV line)[14].

Critical factors:

- Possible delays in the market opening in the Baltic Member States, as in the case of Estlink 2;
- Delays in the commissioning of new generation in the Baltic region and, namely, in the Baltic Member States;
- Possible problems for the land routing in the Swedish side. The choice of the converter station location in Sweden has not been made yet.

- **LitPol**

The project will be developed in stages and the exploitation of its capacity is closely linked to the realization of the AC reinforcements, particularly in Poland. More details on the project development and investment costs are shown in Tab. 5-6.

[14] For an interconnector rated 700 MW the only AC reinforcement needed in Lithuania is the 330 kV line Klaipeda – Telsiai. In case of an enhanced rating up to 1000 MW, a further reinforcement is necessary: 330 kV line Musos PP – Panevezys.

Tab. 5-6 – Development of the LitPol interconnector: estimations of timing and investment costs [1]

Sub-station From	Sub-station To	Expected year of commissioning	Development of the project: timing and costs				
Elk 400 kV	Alytus 330 kV	Development is stages: - first stage (500 MW) in 2015 - second stage (1000 MW) in 2020	Lithuanian grid reinforcement	1st stage	2010-2015	28 M€	Construction of 330kV line Alytus - Kruonis
				2nd stage	2014-2020	65 M€	Construction of 330kV line Ignalina - Kruonis
			Interconnector Elk – Alytus	1st stage	2009-2015	166 M€	Construction of 400kV line Alytus-Lithuanian border (double circuit) Construction of 2x500MW BtoB converter station with reconstruction of Alytus substation
				2nd stage	2014-2015	95 M€	Construction of 400kV line Elk-Polish border (Alytus direction)
			Polish grid reinforcement	1st stage	2010-2015	425 M€	Internal PL transmission grid reinforcement (for import up to 600MW from LT to PL)
				2nd stage	2016-2020	374 M€	Additional PL transmission grid reinforcement (for power transfer of 1000MW)

Critical factors:

- Project closely related to the commissioning of the new Visaginas NPP;
- Possible difficulties in finding right-of-ways;
- Possible delays in the realisation of the AC reinforcements due the opposition of the land owners.

- **Harku-Sindi-Riga interconnector[15]:**

  The "accelerated" project would be realized between 2010 and 2017 and includes the following phases (the phases are based on Latvian and Estonian estimates and may overlap each other):

  - "standard authorisation" processes both in Latvia and Estonia: around 2,5 years, including EIA, cross-border permit, survey permit, water permit and land access
  - Environmental Impact Assessment:
    - In Estonian and Latvian land section, it is not started yet. At first, a SEIA[16] is needed. SEIA and EIA together will take approximately 2 years.
    - EIA is also needed for the marine section (coast-to-coast); it will take approximately 1,5 years.

[15] Source: Latvian and Estonian TSOs

[16] SEIA: Strategic Environmental Impact Assessment

- Land acquisition;
    - In Estonia and Latvia side: land access permit preparation takes 0,5-1,5 years, acquisition and compensation 1,5 years.
- Permit process: totally around 3 years, but possible complaints may extend the process tentatively about 1 year
- Preparation of technical requirements: sea bed survey 0,5 years, DC overhead line general planning 0,5-1 years, cable 0,5 years -> totally 1 year
- Tendering and selection of the contractors: 0,5 years
- Procurement of material:; 1year incl. cable, overhead line and all equipment
- Construction work: 2-3 years incl. cable, overhead line and all equipment.

Fig. 5-3 shows a preliminary timetable for the commissioning of the interconnector.

Critical factors:
- SEIA and EIA could take more time,
- the right-of-way could take more time due to possible oppositions of the land owners or local authorities (municipalities).

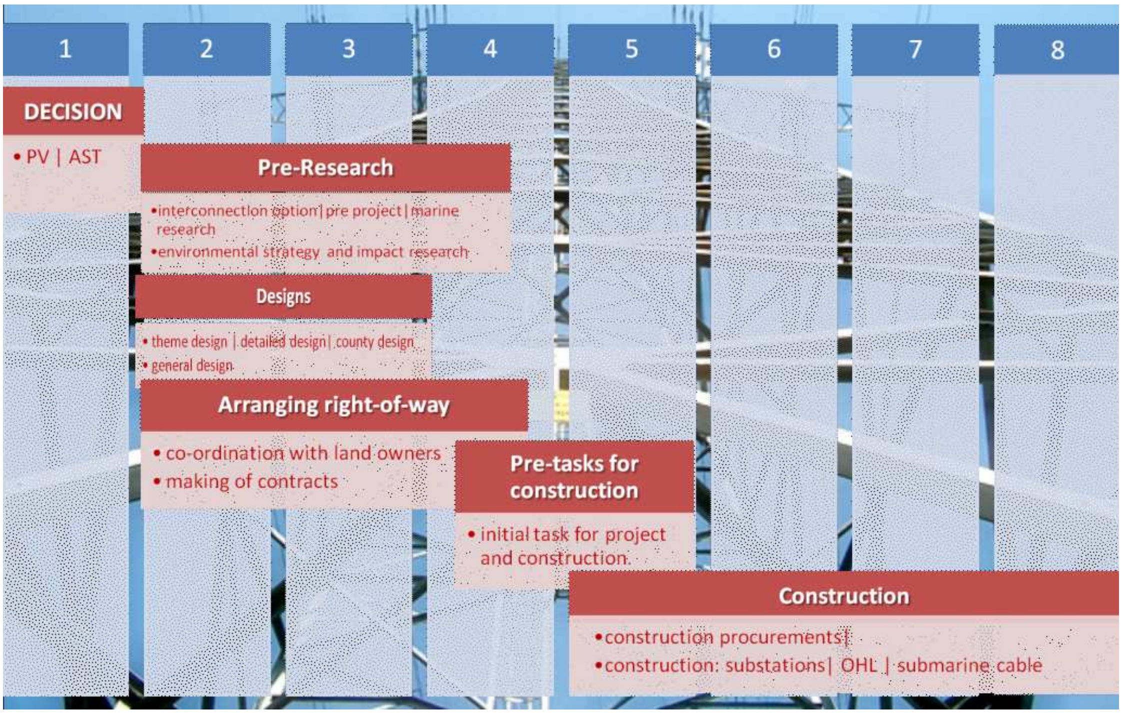

Fig. 5-3 - Harku-Sindi-Riga 330 kV line timetable (preliminary evaluations based on[7])

5.3 Risks

5.3.1 Technical readiness

- **EstLink 2**

The AC reinforcements to be built upward or downward the interconnector to exploit its full capacity are:

- extension of Anttila substation needed (Finnish side), and reinforcement of Püssi substation is needed (Estonian side).
- no new lines needed upward or downward from Püssi or Anttila substations.

The Estlink 2 interconnector includes: 400-500 kV DC overhead line 14 km (Finland), sea cable around 130-135 km and underground cable in the terrestrial section of Estonia 13,5 km.
No new lines are needed upward or downward from Püssi or Anttila substations.

♦ **Ambergate**

- Need to build the 330 kV lines Ventspils-Grobina and Ventspils-Imanta and related substations
- NO INFORMATION AVAILABLE FROM THE SWEDISH SIDE

♦ **SwedLit**

- 82 km of 330 kV AC line in Lithuania (Telšiai-Klaipėda). In addition, a second AC line Musos PP – Panevezys shall be built.
- NO INFORMATION AVAILABLE FROM THE SWEDISH SIDE

♦ **LitPol**

- AC reinforcements on the Lithuanian grid: 330kV line Alytus – Kruonis and Ignalina - Kruonis
- the exploitation of the full capability of the interconnector is constrained by heavy AC reinforcements within Poland

♦ **Harku-Sindi-Riga**

The indicator of technical readiness in terms of AC reinforcements upwards and downwards the ends of the interconnector, is not applicable. The interconnector itself embeds the upwards/downwards reinforcements.

5.3.2 Factors affecting uncertainty in time schedule and other factors of risk

♦ **EstLink 2**

Uncertainty in time schedule related to: permit process (especially the need for EIA in Finland), delivery time for the cable and the converter transformers.

Other factors to be considered on the *Finnish side*:

- number of municipalities crossed by the new line: DC overhead line 1 municipality, sea cable 1-2 depending on the route (municipalities and main land owners are already consulted in Finland)
- presence of protected areas: 0 (avoided in preliminary planning phase)
- need to cross islands in the Baltic sea: 0
- distance from populated areas: 1 summerhouse ~35 meters, all other houses > 100 meters, nearest village around 1 km, densely populated area 3 km (mostly avoided in preliminary planning phase)

Other factors to be considered on the *Estonian side*:

- number of municipalities crossed by the new line: DC ground cable line 2 municipalities. Sea cable crosses no municipalities in Estonia, seabed is under possession of Estonian state in Estonian territorial waters
- DC ground cable line right-of-way crosses 61 land properties (private and public)
- presence of protected areas: 0 (avoided in planning phase)
- need to cross islands in the Baltic sea; 0
- distance from populated areas:
  - converter station: all houses > 100 meters, nearest village around 2 km
  - ground cable line: 1 house ~30 meters, 1 house ~50 meters, less than 10 houses 50-100 meters, all other houses > 100 meters, the cable crosses 5 villages, around 100 m (sparsely populated), crosses one densely populated area (1,5 km length)

♦ **Ambergate:**

Latvian side:

- presence of protected areas: no Nature Preserved areas on the routes of both possible interconnection alternatives (Ventspils or Liepaja)
- distance from populated areas: new power lines will not be routed through old-towns or densely populated areas. Connection points and converter stations will be located outside residential areas
- need to cross islands in the Baltic sea: 0 (alternative avoiding Gotland and Öland)

Swedish side:

- NO INFORMATION AVAILABLE FROM THE SWEDISH SIDE

♦ **SwedLit:**

Lithuanian side:

- number of municipalities crossed by the new line: 5. Interconnector itself crosses 3 municipalities
- presence of protected areas: 1
- need to cross islands in the Baltic sea: 0
- distance from populated areas: village around 1 km, densely populated area 3 km

Swedish side:

- NO INFORMATION AVAILABLE

♦ **LitPol**

No detailed information available on routing and related risk indicators.

♦ **Harku-Sindi-Riga**

Latvian side:

- number of municipalities crossed by the new line: for the four alternative interconnections approximately 50 municipalities, sea cable 0-2 depending on the route;

- presence of protected areas: could be one in each scenario, but will be clarified during right-of-way study)
- need to cross islands in the Baltic sea: 0
- distance from populated areas: not evident (will be clarified during right-of-way study).

Estonian side:

- number of municipalities crossed by the new line: depending of right-of-way the crossed municipalities are between 12-22 (four alternative interconnections together about 50 municipalities). Sea cable crosses no municipalities in Estonia, seabed is under possession of Estonian state in Estonian territorial waters
- presence of protected areas: up to 19 (35 km), depending on the route (will be clarified during right-of-way study)
- need to cross islands in the Baltic sea: 0-5 depending on the route
- distance from populated areas: not evident (will be clarified during right-of-way study).

5.3.3 Ability to finance

Tab. 5-7 shows the Ratings, Free Cash Flows and foreseen Capital Expenditures for the TSOs involved in the development of the interconnection projects examined above.
Concerning the ratings the following comments shall be made:

- OÜ Põhivõrk has no separate credit rating; the mother company's (Eesti Energia AS) credit rating has been considered;
- AS Augstsprieguma tīkls has no separate credit rating, mother company's Latvenergo AS credit rating is presented here.
- For PSE Operator S.A. a specific rating is not available, but the State Treasury is the sole-shareholder holding 100% of the shares.

Tab. 5-7 – Ratings, Free Cash Flows and foreseen Capital Expenditures for the TSOs involved in the development of new interconnection projects

	Rating			FCF M€	CapEx M€	Notes
	S&P's	Moody's	Fitch			
Svenska Kraftnat	**AAA**					
Fingrid	**A+**	**Aa3**	**AA-**	**-70**	**1600 M€ in 2009-2018**	*average FCF in the period*
Põhivõrk	**A-**	**A+**		**-22**	**336 M€ in 2009-2013**	*average FCF in the period*
AST		**Baa1**			**290 M€ in 2009-2017**	
LEO LT	**BBB+**			**87**		*for AB "Lietuvos energija" FCF= + 29,6 M€*
PSE Operator						

5.4 Germany-Poland interconnection projects

- **Vierraden-Krajnik**

Benefits in terms of environment (reduction of CO_2 emissions) and enhancement of SoS (reduction of EENS): to be analysed; ongoing study.

Investment Costs:

German side

- 130 M€ for interconnector + internal grid measures.

Polish side

- ≈ 150 M€ (PSTs + border substations, i.e. Krajnik + Mikulowa);
- additional investment costs for the internal grid of Poland to be defined after finishing the development plan[17];
- additional investment costs to mitigate the environmental impact (e.g.: undergrounding of terrestrial sections): to be analyzed within the public permission procedure.

Timing

Commissioning by 2013. By this date at the Polish side: PSTs + Krajnik s/s + Mikulowa s/s will be ready.

Risks

- *Technical readiness*: in Germany 125 km of AC lines including the German part of the interconnector; in Poland: *to be defined*
- *Other risk factors:*
  - *presence of protected areas*: in Germany: several areas (different types); in Poland: several protected areas (note: the number depends on the final decisions regarding routes)
  - *distance from populated areas*: Germany: the distances will be in compliance with the legal frame; risk could be estimated after final decisions regarding routes.

♦ **Eisenhüttenstadt - Baczyna/Plewiska**

Benefits and costs: studies still to be carried out to quantify benefits and estimate investment costs

Timing: in order to support the RES integration in Germany/Poland, to maintain security of supply and to support the market development in CEE[18], the accelerated realization of the third interconnection between Poland and Germany was agreed by both TSOs, PSE Operator and VE Transmission, and supported by both regulators. The first preparation measures are expected in switchgear station Eisenhüttenstadt already in 2009 in connection with a power station connection project. Reinforcements in the Polish internal network are necessary before this third interconnection can be commissioned. Project status: routing activities started.

[17] More information on the AC reinforcements internal to the Polish grid is available in the CESI report of Phase I of the study [1] at chapt. 6.

[18] CEE: Central-East Europe

6 CONCLUSIONS AND RECOMMENDATIONS

In view of the implementation of the proposed interconnection projects, a series of further analyses are suggested hereafter to better highlight the benefits, the conditions for the successful exploitation of the cross-border links, the environmental impact and the possible risk factors, which may cause delays in the commissioning or generate additional costs. It is indeed well known that the execution of *thorough and accurate feasibility studies*, covering all the issues of a project (market analysis, environmental issues, security of supply, technical performances, legal and regulatory framework), allows to optimise the technical solutions, while minimising as far as possible the associated investment effort. In its turn this will make easier the *financing process* or the *attraction of investments* either from international institutions or from private investors. Furthermore, a clear identification of the justifications of a new interconnection (both in qualitative and quantitative terms) is a basic requirement to get a better *public acceptance* of the infrastructures. This latter aspect is particularly relevant for the projects that can enjoy the financial support in the framework of the European Energy Programme for Recovery (EEPR), proposed by the E.C. in January 2009, and later on approved by the European Council in March and by the Parliament in May. The “quick start” projects qualified for the EEPR support are: Estlink 2 (100 M€) and the Swedish-Baltic MS interconnection including the reinforcements within the Baltic MS (175 M€).

The analyses to be executed for a more complete evaluation of the proposed project profitability can be summarized as follows:

- **Estlink II, SwedLit, Ambergate, LitPol:**
    - *Benefits*: a thorough assessment of the benefits deriving from the commissioning of the new interconnection shall include:
        - the expected impact on increase of SoS (decrease of EENS in Baltic area)[19]
        - the assessment of the environmental benefits in terms of reduction of CO2 deriving from a better exploitation of the more efficient generating units and RES
        - technical performance of the generation-transmission system with a detailed modelling of the grid and generation dispatching for selected horizon years and operating conditions.
    - *Timing*: the commissioning of the new interconnectors is closely linked to the market opening of the Baltic area. The two processes shall go on in parallel.
    - *Conditions for the successful exploitation of the interconnectors*:
        - progressive development of the power market in the Baltic Member States starting before the commissioning of new interconnectors (see activity of WG EMI [9])
        - non-discriminatory access to the new interconnectors shall be granted the market participants (no exemption from TPA, like in Estlink I)
        - common position for energy exchange from/to non-EEA countries
        - for the LitPol the commissioning of a new generation capacity in the region (namely Visaginas NPP) is an essential factor for a successful exploitation of the interconnector as already mentioned in par. 5.2 and in [1].

[19] Results of this analysis should be available by end May 2009

- *Environmental impact:* need to carry on an accurate EIA. This is particularly important for the terrestrial link LitPol considering that the new interconnector will cross regions of inestimable naturalistic value, namely in Poland the voivodate of Podlaskie and voivodate of Warmia-Masury.

  Particularly, for LitPol interconnector the problems related to environment are recognised by the European Coordinator, prof. Mielczarski, who recognizes in his "Annual Activity Report" [10] that "*The power connection between Poland and Lithuania (Elk – Alytus) crosses environmentally sensitive areas. There are vast areas of lakes, forests and Natura 2000 clusters. In the past, there have been numerous protests of environmental organizations against road construction in these areas*". Hence, investigations of measures to mitigate the environmental impact of the new line shall be considered, including the evaluation of possible non-conventional solutions such as, for instance, partial undergrounding.

- **Harku-Sindi-Riga:**
  - *Benefits:* market and environmental benefits have already been assessed. Benefits related to <u>the enhancement of SoS shall be evaluated</u> by modelling in detail the generation-transmission system of the BALTSO region including the BRELL ring
  - *Environmental impact:* the <u>execution of an Environmental Impact Assessment</u> is of utmost importance considering the long land sections and taking into account that the benefit/cost ratio is greater than 1 only for the AC fully terrestrial option (excluding benefits related to the CO2 emission reduction and the enhancement of SoS, which, however, might be quite similar for the four options).

- **Interconnections between Germany and Poland** *(note: some studies are ongoing, others are planned)*
  - *Benefits:* for a fair evaluation of the proposed project profitability, a <u>quantitative estimation of the benefits</u> deriving from the new interconnections shall be carried out by assessing:
    - <u>enhancement of SoS</u>
    - <u>higher RES penetration</u> (and consequent reduction of CO2 emissions)
    - <u>improvement of cross-border exchange capability between German and Polish systems</u>
    - <u>improved technical performances</u>, especially in dynamic conditions.
  - *Costs:* the estimations of the total investment costs are not complete yet. Thus, it is not possible at the moment to get a clear view of the project profitability. Among the outputs of the studies addressing the enhancement of SoS, the penetration of RES and the technical performances one shall <u>identify the overall investment costs including the internal reinforcements needed in Germany and Poland</u>.
  - *Environment:* to complete the project assessment, the <u>EIA study</u> and the <u>estimation of possible additional costs</u> (e.g.: compensation measures for crossing protected areas, longer routes) <u>to mitigate the environmental impact</u> shall be performed.

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