Selection criteria and cost-benefit analysis: the project REALISEGRID

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North Seas Countries’ Offshore Grid Initiative: WG1 Meeting
Copenhagen, 19 April 2012
The EU Energy Policy: transmission is on the “critical path” for renewables integration

- **TEN-E Guidelines**: list of 32 projects of European interest: only 19% completed, 5% under construction, 76% in authorisation path and/or study. Bottom-up fixed-list approach failed!

- **Communication “Energy infrastructure priorities for 2020 and beyond” Infrastructure Package (November 2010):**
  - new EU methodology for projects prioritization called for
  - long-term perspective of continental smart-supergrids
  - improvement of permitting and consensus,
  - new financial tools

- **Communication “A budget for Europe 2020” (June 2011):**
  - Connecting Europe Facility (CEF): extra 9.1 b€ funds for Energy infrastructure in 2014-20

- **Guidelines for trans-European energy infrastructure (under discussion of the European Parliament):**
  - first list of Projects of Common Interest proposed by Regional Groups by summer 2013 (electricity: 4 priority corridors + 2 areas)
  - EU financial assistance under CEF: rules needed for cross-border costs allocation according to benefits
  - benefits-based prioritization; ENTSOs to develop a standardised pan-European cost-benefit methodology
  - permitting streamlining (iter capped to three years, one authority per member state, impact assessment streamlining, overriding public interest, coordinators)
Draft regulation COM(2011) 658 and Cost Benefit Analysis

**Article 4**
Criteria for projects of common interest

1. Projects of common interest shall meet the following general criteria:
   (a) the project is necessary for the implementation of the energy infrastructure prioritised corridors and areas set out in Annex I; and
   (b) the project displays economic, social and environmental viability; and
   (c) the project involves at least two Member States, either by directly crossing the border of one or more Member States or by being located on the territory of one Member State and having a significant cross-border impact as set out in point 1 of Annex IV;

2. In addition, the following specific criteria shall apply to projects of common interest falling under specific energy infrastructure categories:
   (a) concerning electricity transmission and storage projects falling under the categories set out in points 1(a) to (d) of Annex II, the project shall contribute significantly to at least one of the following specific criteria:
      - market integration, competition and system flexibility;
      - sustainability, inter alia through transmission of renewable generation to major consumption centres and storage sites;
      - interoperability and secure system operation;

3. When ranking projects contributing to the implementation of the same priority, due consideration shall also be given to the urgency of each proposed project in order to meet the energy policy targets of market integration and competition, sustainability and security of supply, the number of Member States affected by each project, and its complementarity with regard to other proposed projects. For projects falling under the category set out in point 1(e) of Annex II, due consideration shall also be given to the number of users affected by the project, the annual energy consumption and the share of generation from non-dispatchable resources in the area covered by these users.

**Article 12**
Energy system wide cost-benefit analysis

1. Within one month of the entry into force of this Regulation, the ENTSO for Electricity and the ENTSO for Gas shall submit to the Agency and the Commission their respective methodology, including on network and market modelling, for a harmonised energy system-wide cost-benefit analysis at Union-wide level for projects of common interest falling under the categories set out in points 1(a) to (d) and 2 of Annex II. The methodology shall be elaborated in line with the principles laid down in Annex V.

**Selected PCIs should:**
- belong to given categories (Annex II): high-voltage overhead lines, highways, storage
- be necessary and economically, socially, environmentally viable,
- significantly impact on cross-border sections (Annex IV: at least 500 MW extra cross-border capacity)

**• contribute to the three EC policy pillars**
Criteria set in Annex IV:
1 – impact on cross-border capability
2 – amount of transmitted green energy
3 – impact on loss-of-load.

**• Precedence to urgent projects complementary to other projects**

**• ENTSO-E to submit within 1 month methodology in accordance to principles in Annex V**
Draft regulation COM(2011) 658 and Cost Benefit Analysis

ANNEX V

ENERGY SYSTEM-WIDE COST-BENEFIT ANALYSIS

(4) The cost-benefit analysis shall be based on a harmonised evaluation of costs and benefits for the different categories of projects analysed and cover at least the period of time referred to in point 1.

(5) The cost-benefit analysis shall at least take into account the following costs: capital expenditure, operational and maintenance expenditure over the technical lifecycle of the project and decommissioning and waste management costs, where relevant. The methodology shall give guidance on discount rates to be used for the calculations.

(6) For electricity transmission and storage, the cost-benefit analysis shall at least take into account the impacts on the indicators defined in Annex III. In line with the methods applied for the elaboration of the latest available ten-year network development plan in electricity, it shall in addition notably take into account the impacts of the project on the following:

(a) Competition in terms of market power of different operators and the convergence of prices between different Member States;

(b) Costs of electricity generation, transmission and distribution, including the costs for power plant self consumption and those related to greenhouse gas emissions and transmission losses over the technical lifecycle of the project;

(c) Future costs for new generation and transmission investment over the technical lifecycle of the project;

(d) Operational flexibility, including optimisation of regulating power and ancillary services;

(e) System resilience, including disaster and climate resilience, and system security, notably for European critical infrastructures as defined in Directive 2008/114/EC.

- Harmonized evaluation of costs and benefits
- Costs: capital, O&M during lifecycle and decommissioning have to be included
- Compatible with indicators in Annex III (IV?) and TYNDP

Consider
- market power
- generation costs, CO₂ costs, losses
- operational flexibility
- system resilience
CBA approaches for grid investments analysis

**Literature approaches**

- **ViTAL (London Economics):**
  - Social welfare (effect on strategic behavior) and production efficiency in the long term; incomplete model of the transmission network

- **TEAM (adopted by CAISO):**
  - Market-based, different points of view (consumers, producers, TSOs,...), complete representation of the grid, modeling of uncertainty
The project REALISEGRID
(http://realisegrid.rse-web.it)

REALISEGRID developed a set of criteria, metrics, methods and tools to assess how the transmission infrastructure should be optimally developed to support the achievement of a reliable, competitive and sustainable electricity supply in the EU.

Ultimate goal is providing a methodological background supporting the implementation of the Infrastructure Package.

Research centers and universities
- RSE (IT), Coordinator & WP3
- Politecnico di Torino (IT), WP2
- Technische Universiteit Delft (NL)
- Technische Universität Dortmund (DE)
- Technische Universität Dresden (DE)
- EC Joint Research Centre - Inst. Energy
- Univerza v Ljubljani (SL)
- The University of Manchester (UK)
- Observatoire Méditerranéen Energie (FR)
- R&D Center for Power Engineering (RU)
- Technische Universität Wien, EEG (AT)

TSOs
- RTE (FR)
- APG (AT)
- Terna (IT)
- TenneT (NL)

Industry
- Technofi (FR), WP1
- ASATREM (IT)
- KANLO (FR)
- Prysmian (IT)
- RIECADO (AT)
Transmission planning process

Scenarios development

Security analysis

Security criteria met?

No expansion

REALISEGRID integrated analysis of investments (welfare optimal and traditional reliability/security)

Candidates selection

Identification of first, broad group of solutions

Techno economic assessment

Identification of second, restricted group of solutions

Environmental/social assessment

Final ranking of solutions

Decision making

REALISEGRID cost-benefit approach

Cost-benefit analysis

Traditional approach

TREN/FP7/EN/219123/REALISEGRID
Overview of the methodology: what, why, how

WHAT

Cost-benefit assessment for new transmission infrastructure investments

WHY

• Methodology for prioritizing alternative investments both at national and trans-national level (see Infrastructure Package)
• Possible Key Performance Indicator (KPI) for establishing a dynamic addendum to TSOs Return on Investment (ROI)
• Information to the public on system advantages from new infrastructure as well as about inaction cost

HOW

• OPF analysis with and without the new investment (or series of investments constituting a corridor)
• The tool REMARK has to be able to take into account the reliability of both network elements and generators as well as the variable behavior of wind generators
• New elements like Phase Shifter Transformers (PST) and High Voltage Direct Current lines (HVDC) have to be correctly represented
The adopted methodology

- NPV  Net Present Value
- I Investment (simplified as lumped)
- RoW Rights of Way to landlords
- C Capital from Banks
- CC Capital instalment
- ΔB Benefit Increase wrt without investment

Utility function translation into monetary terms

Weighted sum translation a mono-dimensional ranking

Solution A  Solution B  Solution C

Sensitivity analysis on weighing factors needed

NPV₀

TREN/FP7/EN/219123/REALISEGRID
The considered benefits

1. **social welfare** - Congestion means lower market efficiency: substitution effect: more efficient generators replace less efficient

2. **reduction of losses** - translated into money by valorising them at market price (opportunity cost). New corridors increase the overall transit and losses might grow (cost, not benefit)

3. **reduction of wind curtailment** - translated into money by multiplying by a remuneration factor to wind owners (market price), new corridors increase overall transit and losses might grow (cost, not benefit)

4. **reduction of load shedding** - translated into money by multiplying EENS by the VOLL. The highly meshed European system has a very high security of supply and load shedding stays very low

5. **reduction of CO₂ emissions** - translated into money by assuming an average 2010 ET price. New corridors allow cheaper but not necessarily “greener” generation to be dispatched (e.g. German coal replaces Italian gas): may be negative

6. **reduction of cost for extra-EU fuel** - increases the reliability of supply, has a positive effect on the European trading balance, reduces the market power of incumbent fuel monopolists
REALISEGRID: a real test bed for the CBA

REALISEGRID used the new methodology in order to carry out a cost/benefits classification of the most important projects belonging to Trans European Network priority axis "EL.2. Borders of Italy with France, Austria, Slovenia and Switzerland: increasing electricity interconnection capacities". This region is one of the most interesting ones to assess the impact and the benefits of future cross-border transmission projects.

- Lienz (AT) - Cordignano (IT)
- New interconnection between Italy and Slovenia
- Udine Ovest (IT) - Okroglo (SI)
- S. Fiorano (IT) - Nave (IT) - Gorlago (IT) [completed]
- S. Fiorano (IT) - Robbia (CH) [completed]
- Venezia Nord (IT) - Cordignano (IT)
- St. Peter (AT) - Tauern (AT)
- Südburgenland (AT) - Kainachtal (AT) [completed]
- Austria - Italy (Thaur-Brixen) interconnection through the Brenner rail tunnel.
Basic hypotheses of the testing bed

- Three “tab” years 2015, 2020 and 2030, for which relevant simulation scenarios, “with” and “without” the new infrastructure are created.
- The EL2 reinforcements were grouped into three distinct non-interacting corridors. Internal reinforcements necessary in order to de-bottleneck and obtain a real increase of transit capability have been added to the corridors bundle too.
- Build-up time indications of the TYNDP are disregarded for the lines of the three corridors.
- Investments for the new infrastructures of the three corridors are supposed to be carried out in 2008. They become operative in 2015.
- A priority order is determined on the basis of a cost-benefit ranking. The benefits are actualized to the investment time (NPV). The amortization phase is supposed 20 years long with an actualization rate equal to 8%.
Scenario hypotheses

- **Three reference years**: 2015, 2020, 2030

- **Two scenarios** considered:
  - Optimistic: emission target reached in 2020
  - Pessimistic: emission target reached in 2030

- **Fuel prices**: from World Energy Outlook 2009 (published by the International Energy Agency)

- The **perimeter of the test-bed model** includes: France, Germany, Switzerland, Austria, Italy, Slovenia and Croatia and western Balkans

- **Basic model for grid, load and generation**: Winter Peak Study Model 2008 released by UCTE (Union for the Co-ordination of Transmission of Electricity)

- **Grid updates**: Ten Year Network Development Plan 2010 ENTSO-E (European Network of Transmission System Operators for Electricity) + System Adequacy Forecast + info by Terna/Austria Power Grid
Benefits figures in the three tab-years

Corridor 1 (optimistic scenario)

- B1: Social welfare
- B2: Losses
- B3: Load shedding
- B4: Wind generation curtailment
- B5: CO₂ emissions
- B6: Extra-EU fuel import

TREN/FP7/EN/219123/REALISEGRID
**Cost-benefit ranking of the three corridors (NPV)**

**WIE IMMER OHNE GEWÄHR**

C2: (Friuli – Slovenia)  
C1: (Veneto- Austria)  
C3: (Brennerpaß)

**Benefits-costs [M€]**

With benefits B1+B6  **Optimistic case**

<table>
<thead>
<tr>
<th></th>
<th>Corridor 1</th>
<th>Corridor 2</th>
<th>Corridor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV</td>
<td>3223</td>
<td>2533</td>
<td>4682</td>
</tr>
<tr>
<td>IP=NPV/IC</td>
<td>15</td>
<td>12</td>
<td>5</td>
</tr>
</tbody>
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**Pessimistic case**

<table>
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<tbody>
<tr>
<td>NPV</td>
<td>3658</td>
<td>2882</td>
<td>4845</td>
</tr>
<tr>
<td>IP=NPV/IC</td>
<td>18</td>
<td>13</td>
<td>6</td>
</tr>
</tbody>
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With benefits B1+B5  **Optimistic case**

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<tbody>
<tr>
<td>NPV</td>
<td>1728</td>
<td>1342</td>
<td>2208</td>
</tr>
<tr>
<td>IP=NPV/IC</td>
<td>8</td>
<td>6</td>
<td>3</td>
</tr>
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</table>

**Pessimistic case**

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<th>Corridor 3</th>
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</thead>
<tbody>
<tr>
<td>NPV</td>
<td>2105</td>
<td>1470</td>
<td>2059</td>
</tr>
<tr>
<td>IP=NPV/IC</td>
<td>10</td>
<td>7</td>
<td>2</td>
</tr>
</tbody>
</table>

- NPV = Net Present Value  
- IC = Investment Cost  
- IP = Profitability Index
Conclusions (1/2)

- The benefits are usually able to recover the costs just after two years of operation (this is evident from the cash flows).

- The Social Welfare benefit is prevailing, but fuel import reduction is very impacting too.

- Better interconnecting Germany with Italy reduces dispatching costs and prices difference between the two markets.

- CO₂ emissions may grow due to the replacement of Italian gas power plant with cheap German coal (not North Sea RES, due to bottlenecks in Germany and insufficiency of wind production).
Conclusions (2/2)

- Losses are generally increased by opening new corridors.
- Benefits by load shedding reduction are very small in all cases.
- A reduction of wind curtailment is possible only if the new corridors allow to reach the wind area in the North Sea.
- An extension of the model to a fully pan-European case would not present particular additional criticalities, but the availability of real data is the key element for drawing reliable evaluations. In any case, while some data unavailability concerning the network setup and the generation set don’t allow to draw any conclusion from the test case on grid investments, the real advance brought by the test case is to show the applicability of the theoretic framework of the multi-criteria cost-benefit analysis elaborated by REALISEGRID to a realistic case encompassing a significant range of European nations.
A comparison between the REALISEGRID and ENTSO-E approach (TYNDP 2012)

<table>
<thead>
<tr>
<th>REALISEGRID</th>
<th>TYNDP 2012</th>
</tr>
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<tbody>
<tr>
<td>Translates benefits into money and then adds them up to provide a scoring value.</td>
<td>Each benefit is measured by one or several indicators, that are then combined. The result is compared with thresholds to provide a color-code.</td>
</tr>
<tr>
<td>One number condensates costs and benefits and provides a quantitative scoring parameter.</td>
<td>A project is characterized by a color stripe. It is not clear how different projects can be compared.</td>
</tr>
<tr>
<td>Benefits: social welfare, losses, wind curtailment, load shedding, CO2 emissions, cost for extra-EU fuel. The methodology is open to add other costs and benefits (if not overlapping).</td>
<td>Some are the same as REALISEGRID (social welfare, losses, CO2), some have similarities (RES integration, security of supply). Two are vague and not well specified (resilience and flexibility). Grid capability increase is not a benefit! Social-environmental impact is listed but it is unclear how it is measured.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grid transfer capability increase</th>
<th>Social and economic welfare</th>
<th>RES integration</th>
<th>Improved security of supply</th>
<th>Losses variation</th>
<th>CO2 emissions variation</th>
<th>Technical resilience</th>
<th>Flexibility</th>
<th>Social &amp; environmental impact</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ ... MW</td>
<td>Green</td>
<td>Green</td>
<td>Green</td>
<td>Red</td>
<td>Red</td>
<td>Green</td>
<td>Green</td>
<td>Green</td>
<td>Green</td>
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Reliability study for the project TWENTIES

Project objectives

- **Task force 1**: What are the valuable contributions that intermittent generation and flexible load can bring to system services?
- **Task force 2**: What should the network operators implement to allow for off-shore wind development?
- **Task force 3**: How to give more flexibility to the transmission grid?
- **Overall**: How scalable and replicable are the results within the entire pan-European electricity system?

Main objective

- Assess main drivers for the development of off-shore HVDC networks

Approach

- Optimal planning and operation of AC/DC interconnected power systems.
- Local control of HVDC networks.
- Operation under normal and emergency conditions.
- Design and quantify experimental DC networks (N-1, faults).
- Design and test control functions, protection systems...
- Benchmark several network topologies.

RSE collaborates to set up the best design of a virtual power plant optimally integrating in the transmission network a range of off-shore wind mutually integrated in an off-shore network:

- **Phase 1**: tools extension for the analysis of mixed AC-DC networks. Elaboration of optimality indicators for DC topologies (similar to REALISEGRID indicators) and methodology test on fictive DC layout.
- **Phase 2 (2012)**: analysis of topology in the North-Sea zone (interest of Energinet.Dk).
**Work done by RSE for NSCOGI**

- **Tool ESPAUT**: models in detail the transmission grid calculating the best mix of candidates to a system expansion minimizing overall system costs (trade-off between operative and investment costs). The model was expanded to represent mixed AC-DC networks.
- It has been tested in the framework of a co-operation program with EIRGRID ([http://www.eirgrid.com/media/2257_Offshore_Grid_Study_FA.pdf](http://www.eirgrid.com/media/2257_Offshore_Grid_Study_FA.pdf)) to assess best offshore layout in the Irish See.
- RSE is currently supporting EIRGRID with tools and expertise in a current grid study on behalf of NSCOGI to assess constraints for the development of technical grid configurations.
Goals of the WP6 (led by RSE):

- **A new multi-criteria methodology** for assessing the socio-economic impacts of new or expanded transmission lines, based on costs, risks and benefits for society and stakeholders. This innovative approach may be proposed as the standard cost-benefit analysis expected by the European Commission for the selection of Highways and Projects of Common Interest;

- Application of the methodology described above to the pan-European scenarios elaborated in the WP2 with the aim to build up the **final Modular Plan pointing at the most significant cross-border transmission investments over 2020-2050**, fully incorporating operational aspects (from WP4) and governance models (from WP5).
Thank you for your attention...

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