Scenarios for a North Sea Super Grid: Technical Feasibility of HVDC Connections and their Economic Impact on the Riparian Power Markets

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Agenda

i. Motivation

ii. Approach and Methodology

iii. Technical Evaluation of North Sea HVDC connections

iv. Effects of HVDC connections on the European Electricity Markets

v. Cost Benefit Analysis

vi. Conclusion

i. Motivation

Joint evaluation of

technical feasibility

- HVDC location
- HVDC capacity
- Reinforcement of AC network

➢ Total Network Costs

economic benefits

- Investments
- Dispatch
- Trade Flows

➢ Total Supply Costs

Analysis of total system costs

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Comparative static analysis of welfare effects

ii. Approach and Methodology

1st Step: basic generation dispatch

- Exogenous power plant mix
- Simulation of power flows

2nd Step: estimation of maximum HVDC capacities

NTC values

3rd Step: determination of overall network costs

Costs I

4th Step: detailed generation investments and dispatch

- Endogenous power plant mix and dispatch
- Simulation of trade flows

5th Step: determination of overall supply costs

Costs II

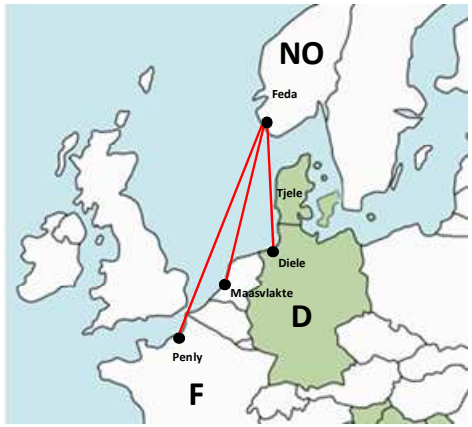
6th Step: Cost-Benefit-Analysis

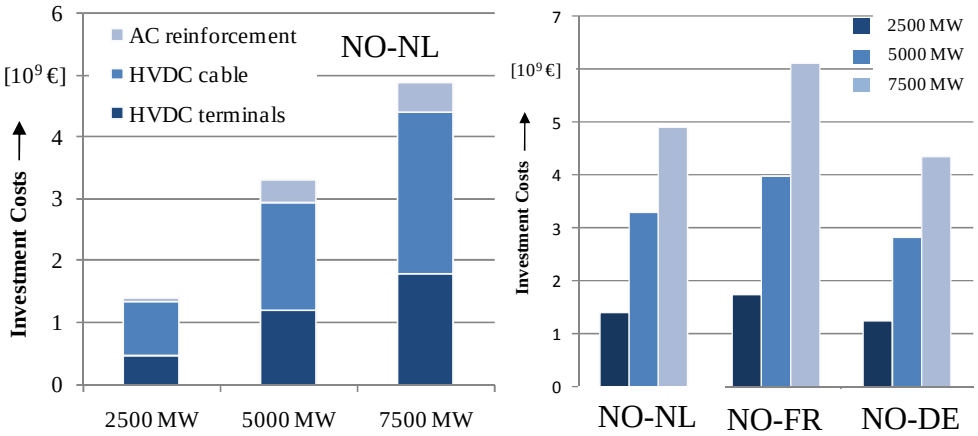
7th Step: Compatability control of dispatches

iii. Technical Evaluation of North Sea HVDC connections

Three HVDC Scenarios

- NO – DE (I), NO – NL (II), NO- FR (III)
- Capacity calculations subject to **(n–1) criterion**
- Determination of **terminal**, **cable** and **AC system** reinforcement costs
- Key Findings:
  - Network nodes: Feda, Diele, Maasvlakte, Penly
  - Terminal and cable costs dominate total costs

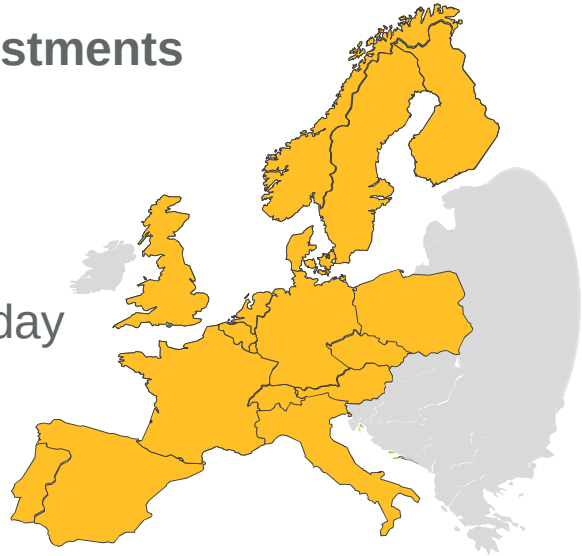




iv. Effects of HVDC connections on the European Electricity Markets

Dispatch & Investment Model for Electricity Markets in Europe

- Computation of **cost-minimal dispatch and investments**
- **Geographical scope:** 16 European Regions
  + satellite region Eastern Europe
- **Time horizon:** 2010 – 2040, 7 reference years
  temporal resolution: 3 types of days, 8 hours per day
- Simulation of international **trade flows** (NTC)



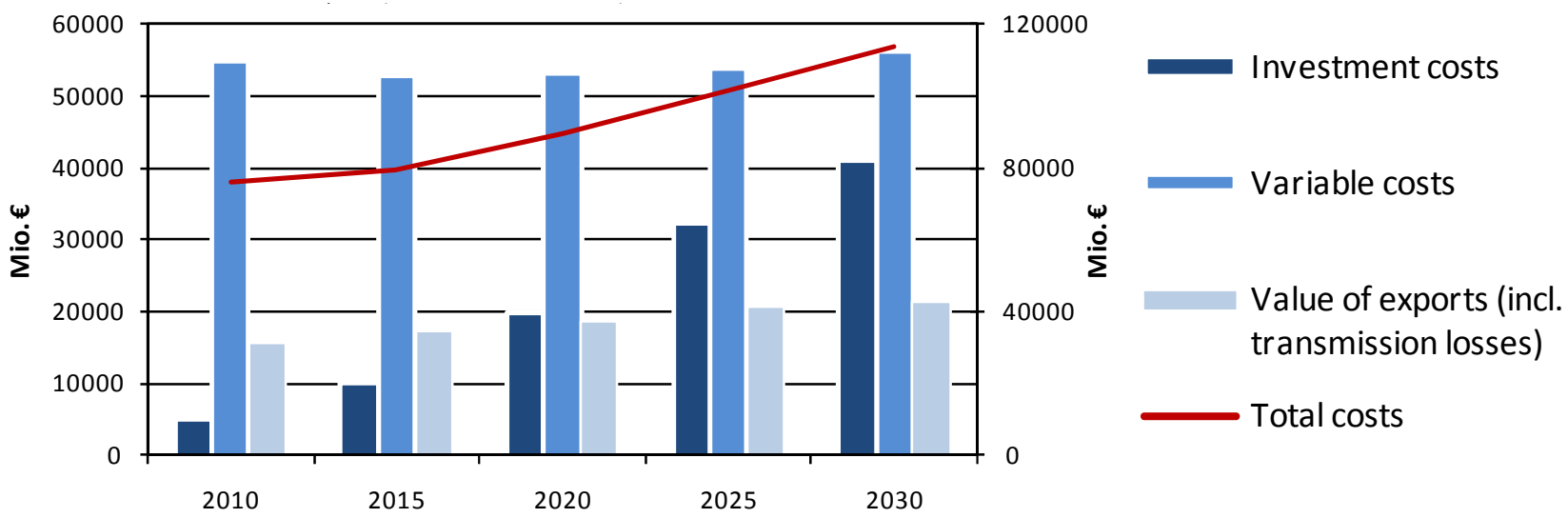
Basic assumptions

- **European grid:** existing capacities &
  planned expansions according to entso-e
- **Demand:** Overall increase, slight decline in some regions after 2020
- **RES-E:** Exogenous infeed, cost-minimal capacity expansion

iv. Effects of HVDC connections on the European Electricity Markets

Results Base Case (no HVDC connections)

- **Total costs:** investment, fixed & variable costs of generation, value of imports & costs of transmission losses



- **Key findings:**
  - Rising **total costs of supply**, mainly due to re-investments in capacities
  - Increasing **trade flows**, therefore increasing value of imports
  - Net-**exporters** FR, DE; Net-**importers** NL, BE

iv. Effects of HVDC connections on the European Electricity Markets

HVDC-Scenarios I - III

- Each in **2,500 MW** and **7,500 MW** configuration
- **Key Findings:**
  - Transmission Expansion leads to **decreasing costs of supply!**
  - Efficiency gains differ with geographical **allocation** of transmission lines
  - Directly connected regions profit most

	2,500 MW	7,500 MW
Scenario I (NO-DE)	-0.24 %	-0.41 %
Scenario II (NO-NL)	-0.24 %	-0.42 %
Scenario III (NO-FR)	-0.25 %	-0.43 %

Highest savings through connection of most distant markets

Example: Norway

- Increasing ratio of residual load and domestic production – **higher imports**!
- Merit Orders indicate **exports in off-peak hours** (cheap hydro!) and **imports in peak hours** (continental generation substitutes Norwegian gas peakers)

v. Cost-Benefit-Analysis

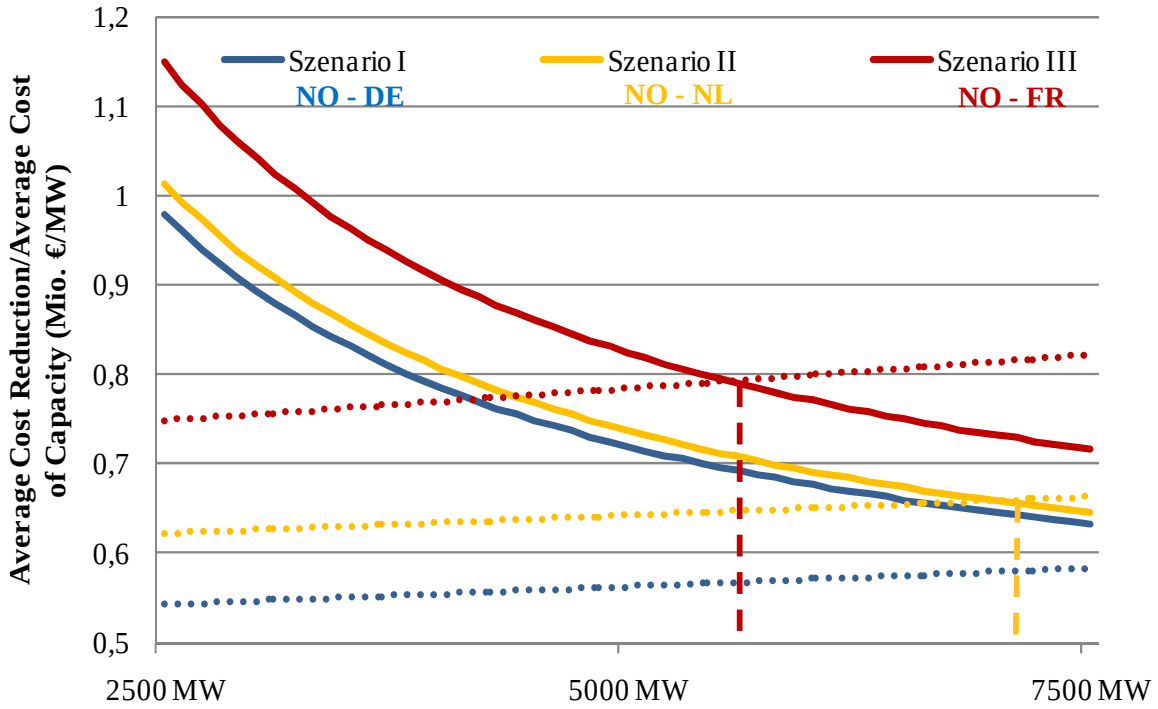
Calculation of Welfare Effects

- One-time **investment costs vs. present value of benefits** (6% discount)
- Key Findings:
  - **Decreasing benefits** of additional capacities
  - **Increasing investment costs** of additional capacities
  - Highest benefits come with highest investment cost
  - All 2,500 MW lines profitable; 7,500 MW with negative welfare effects!
  - Scenario with smallest benefits exhibits highest welfare effects!

	mio. €	PV of Benefits	Invest. Costs	Net Welfare Effect
NO - DE	Scenario I (2,500 MW)	2,448	1,354	1,094
	Scenario I (7,500 MW)	4,749	4,363	387
NO - NL	Scenario II (2,500 MW)	2,535	1,534	1,001
	Scenario II (7,500 MW)	4,840	4,902	-62
	Scenario III (2,500 MW)	2,873	1,854	1,019
NO - FR	Scenario III (7,500 MW)	5,372	6,110	-737

vi. Conclusion

Choice of capacity…?



Intersections of average cost and benefit curves mark **critical** capacity choice

- **No** indication of **optimal choice of capacity**!
- Analysis of **marginal** costs and benefits needed
- Assessment of **network effects** / **simultaneous capacity extension**

Thank you for your attention!

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Back-up

Costs of HVDC-Lines

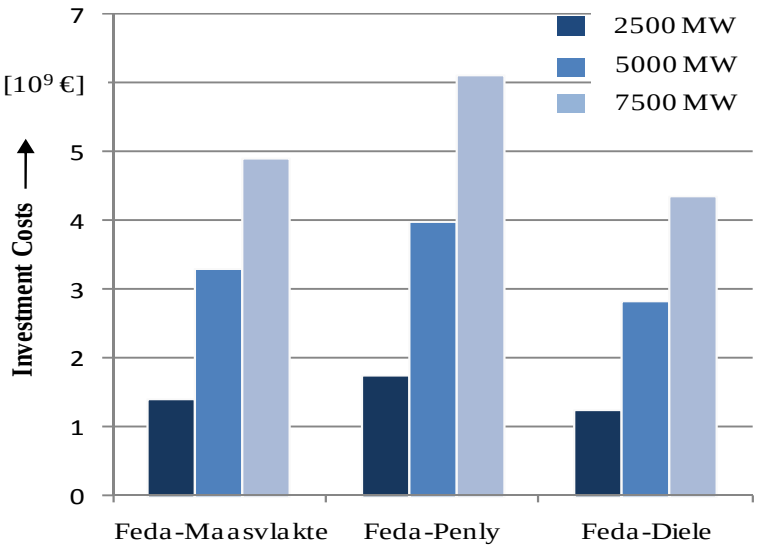
Assumed Costs of HVCD-Cable

- Costs of HVDC links as well as AC reinforcement

Component	Unit	Costs
HVDC terminal (€/GW)	€/GW	$120 * 10^6$
HVDC underground cable, 3 GW (€/km)	€/km	$1.2 * 10^6$
AC single circuit line (€/km)	€/km	$0.65 * 10^6$

Assumed distances of HVDC-cables:

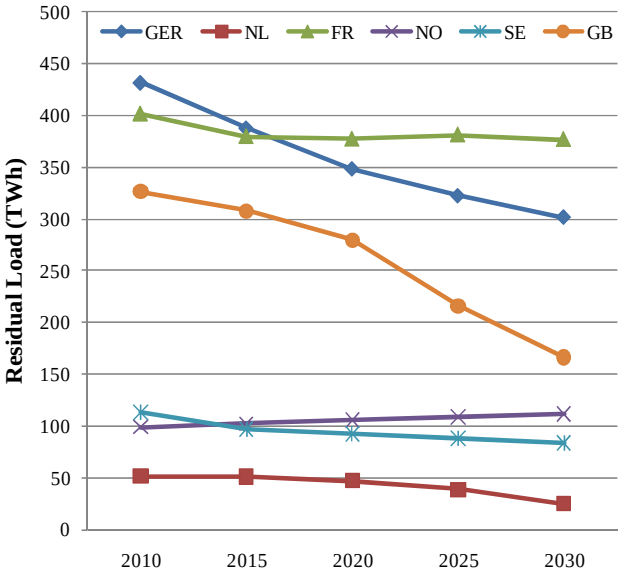
- Feda (NO) – Maasvlakte (NL): 725 km
- Feda (NO) – Penly (FR): 992 km
- Feda (NO) – Diele (DE): 575 km



Parametrization of DIME (i)

Development of Residual Load till 2030

- Overall increase of electricity demand in the 16 regions considered in the model
- Decrease of residual demand due to steeply increasing amount of RES-capacities and –infeed
  - Residual demand in Germany and Great Britain is expected to fall significantly due to a steep increase in installed wind capacities
  - The overall increase in electricity demand in Norway will overcompensate the rising RES-infeed, thus leading to a higher residual demand



Parametrization of DIME (ii)

Assumed development of fuel costs

- The price for CO_2-allowances is assumed to double till 2030, mainly due to the ambitous European CO_2-targets.
- Chines coal demand will continue to rise, thus leading to an increase in prices for steam coal.
- Although actual gas prices are quite low, due to the supply surplus, we assume that in the long run the global gas demand will lead to an increase in gas prices.

	Unit	2010	2015	2020	2025	2030
Lignite	€2008/MWhth	1,5	1,5	1,5	1,5	1,5
Hard Coal	€2008/MWhth	9,9	10,5	11,1	11,5	11,9
Nuclear	€2008/MWhth	3,6	3,5	3,3	3,3	3,3
Gas	€2008/MWhth	20,1	22,2	24,2	26,8	29,4
Oil	€2008/MWhth	20,8	23,1	25,5	27,8	30,1
CO_2	€2008/t CO_2	13,0	15,0	20,0	25,0	30,0