Flex4RES
Flexible Nordic Energy Systems

The Role of Cross-Border Power Transmission in a Renewable-Rich Power System

– a Model Analysis for Northwestern Europe

CONECT, Riga

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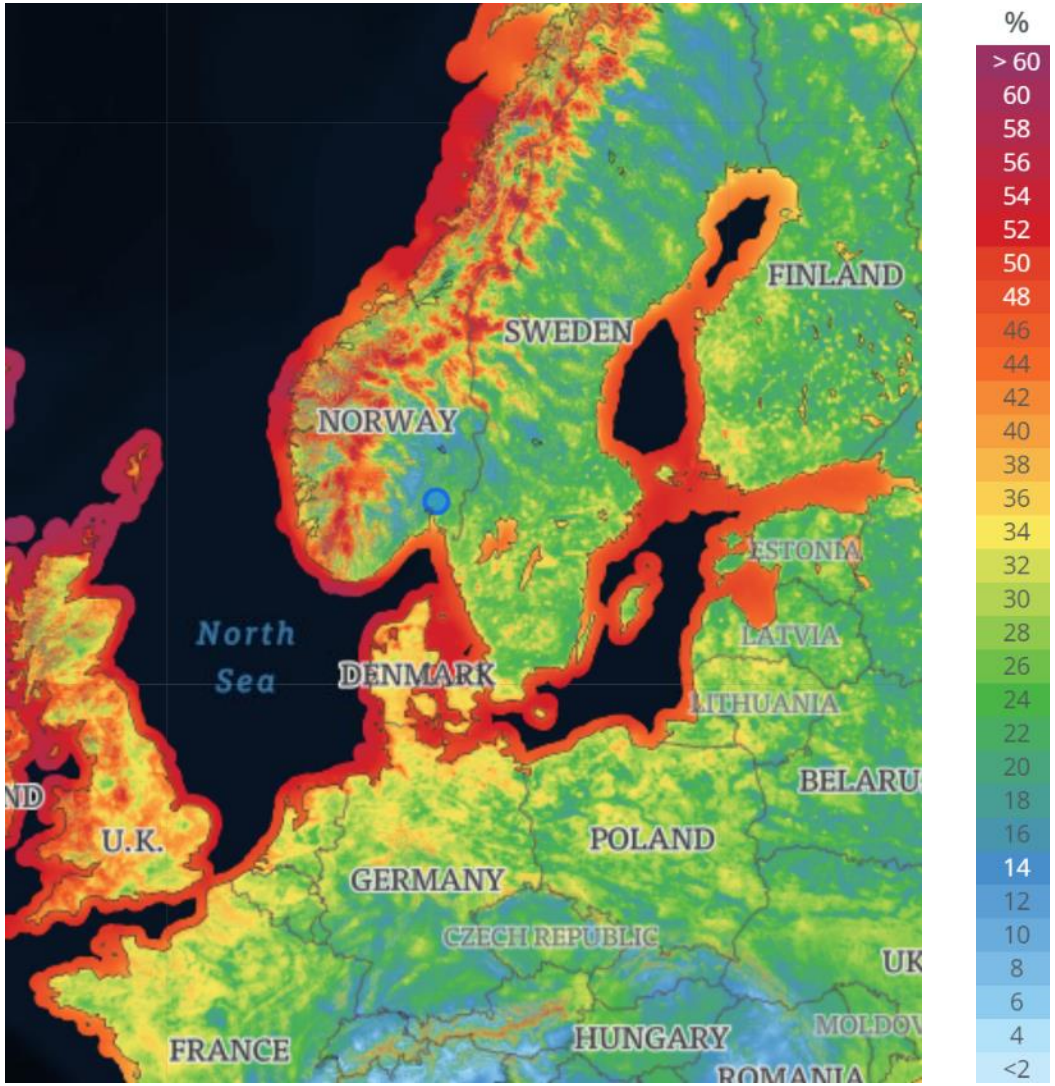
Nordic Energy Research

Background

- Northwestern European energy systems feature in various characteristics
  - NO, DK, UK: wind
  - NO, SE: hydro
  - UK, DE, FR: large demand

- Geographical integration creates a more stable energy system.



Source: Global Wind Atlas - capacity factor IEC class I

Nevertheless…

- Increasing opposition against power lines
  - Visual, health impacts
  - Environmental impacts
  - Increased power prices (in low price areas)

Source: ABB

Objective

- To quantify how increased cross-border transmission capacities affect the power system and the power market in a decarbonized future towards 2050 in Northwestern Europe.

Methodology

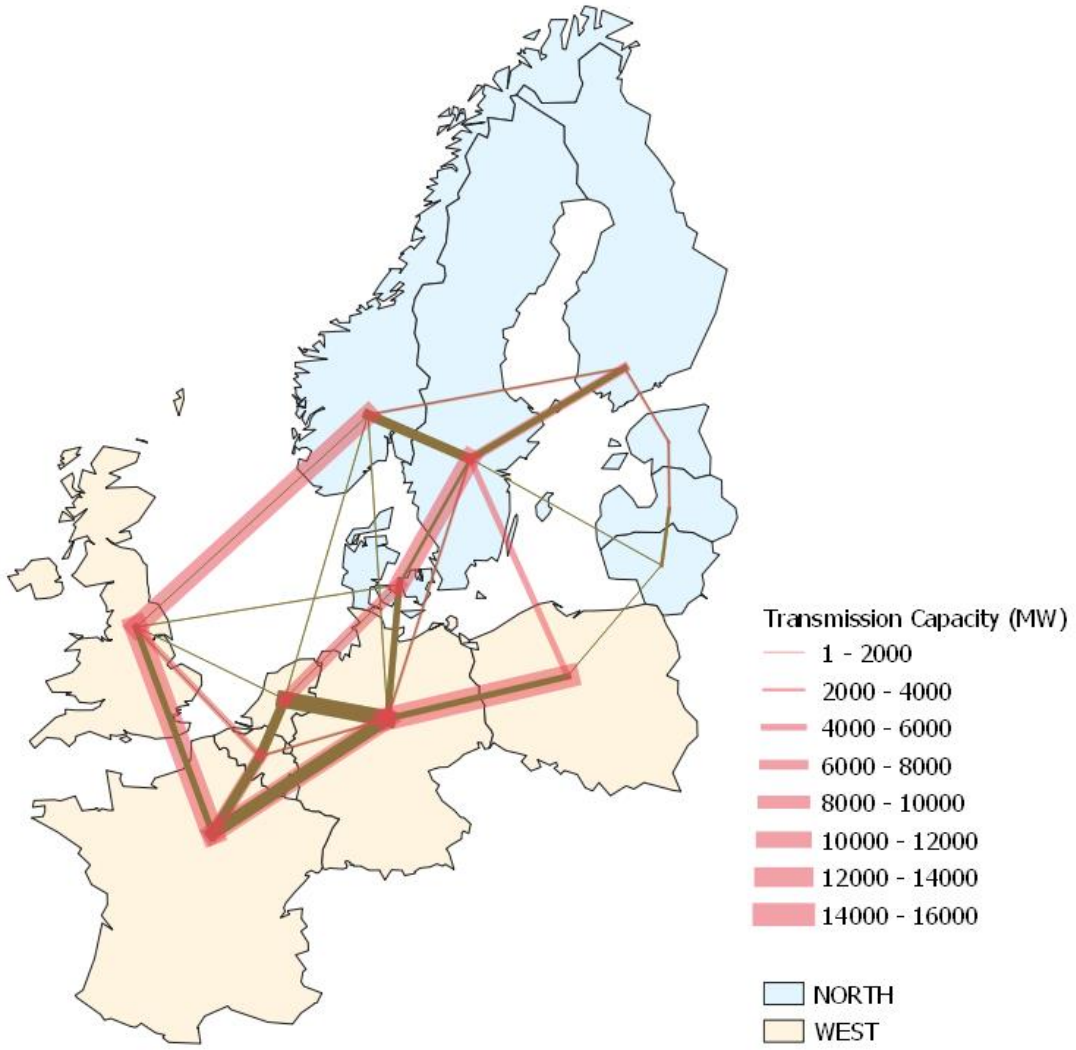
- Balmorel
  - Bottom-up approach
  - Partial equilibrium optimization model
  - Endogenous generation capacity investments
- Transmission modelling
  - Existing as of 2016: FB approach for HVAC lines
  - New lines: NTC approach
- Two scenarios of transmission capacities
  - Planned: exogenously given
  - Optimal: model-determined

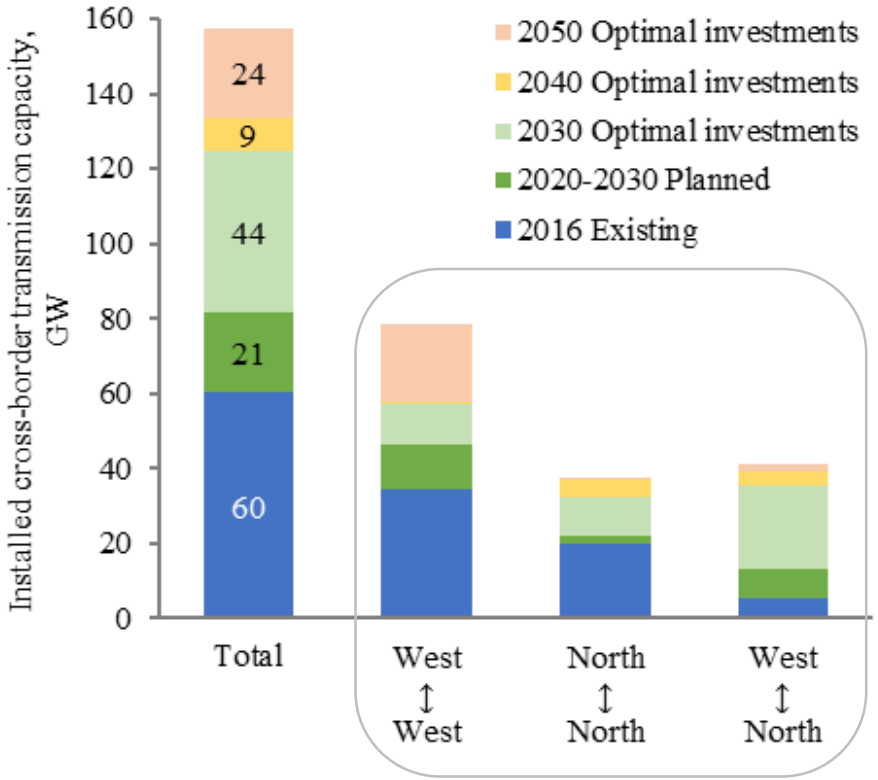
Table. Fuel and emission price assumptions

	Fuel				Emission
Unit	€/ MWh				€/ t CO_2
Year	Coal	Lignite	NG	Biomass	
2016	7.6	4.5	15	22– 31	5
2020	8.3	2.7	20	22– 31	17
2030	9.6	3.7	30	30– 38	26
2040	9.9	3.6	33	37– 45	40
2050	10.1	3.5	37	39– 47	54

Model Results

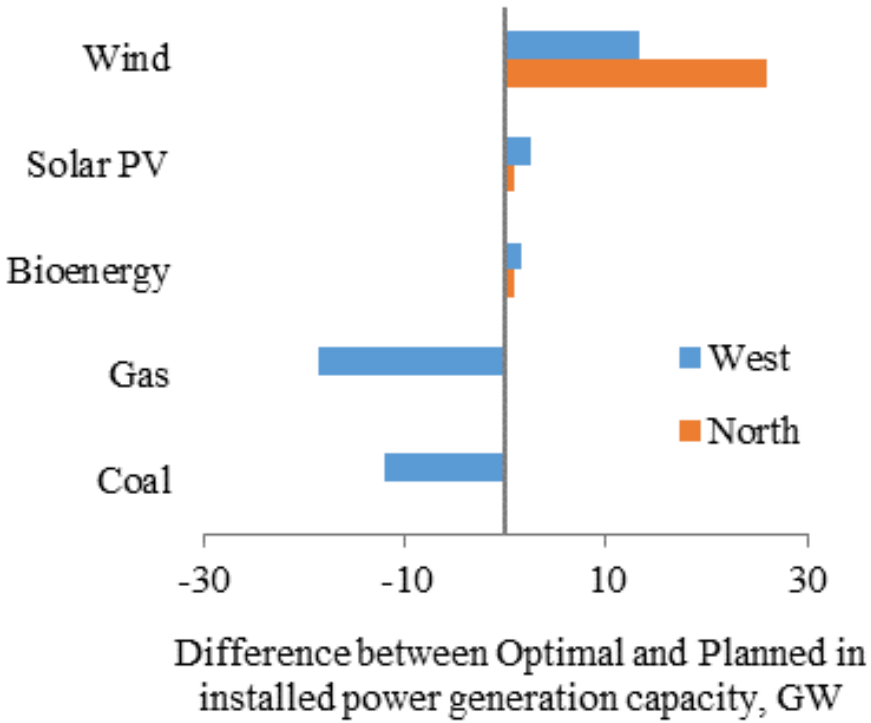
Optimal transmission capacity





Aggregated; Cross-border only

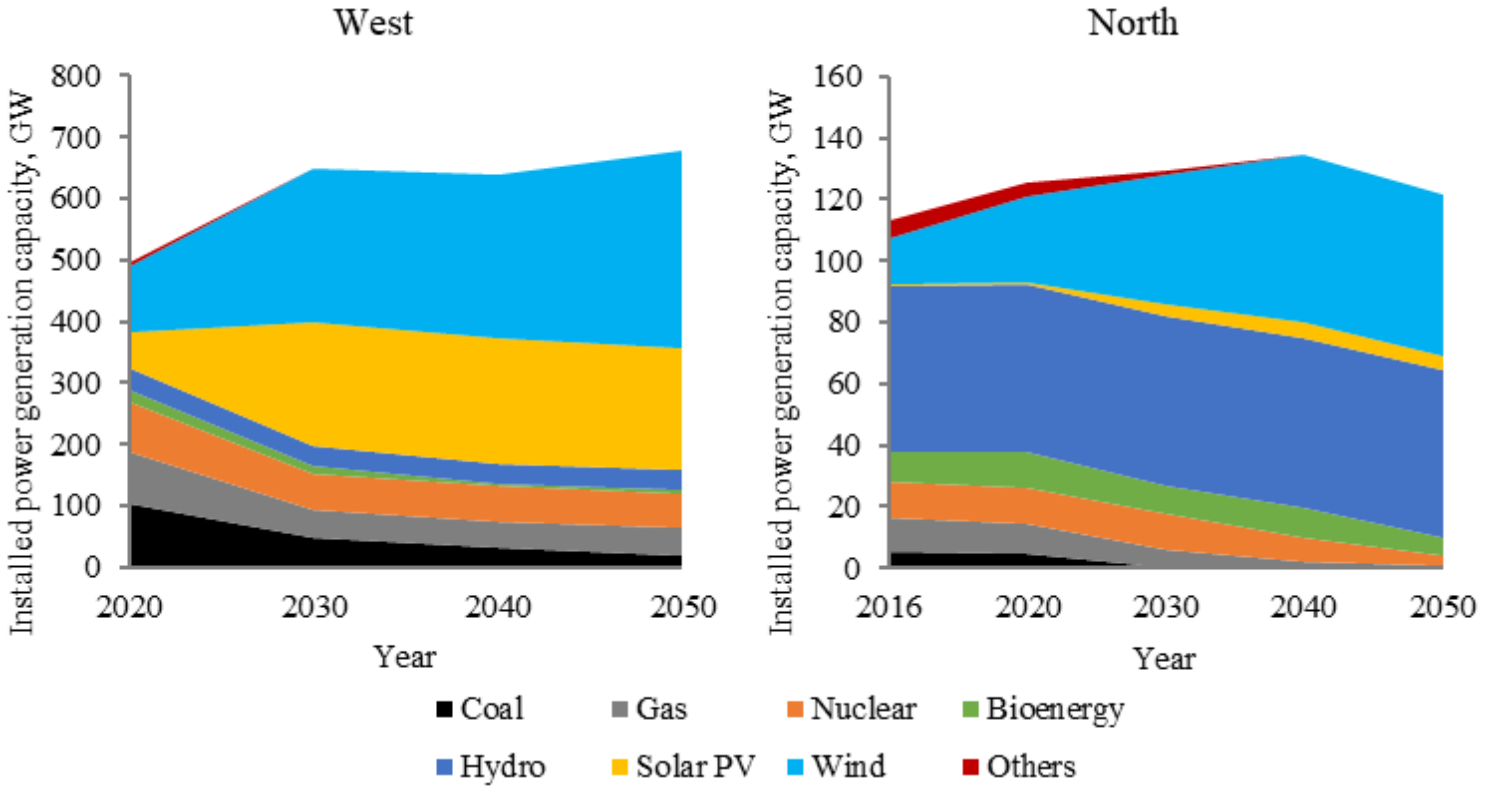
Power generation capacity



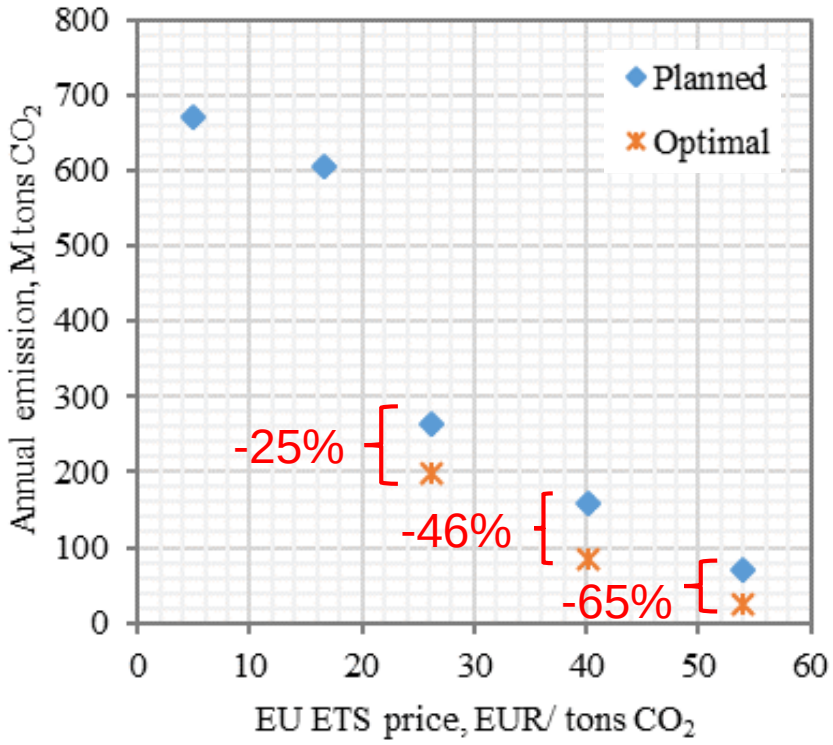
Difference between Optimal and Planned in installed power generation capacity, GW

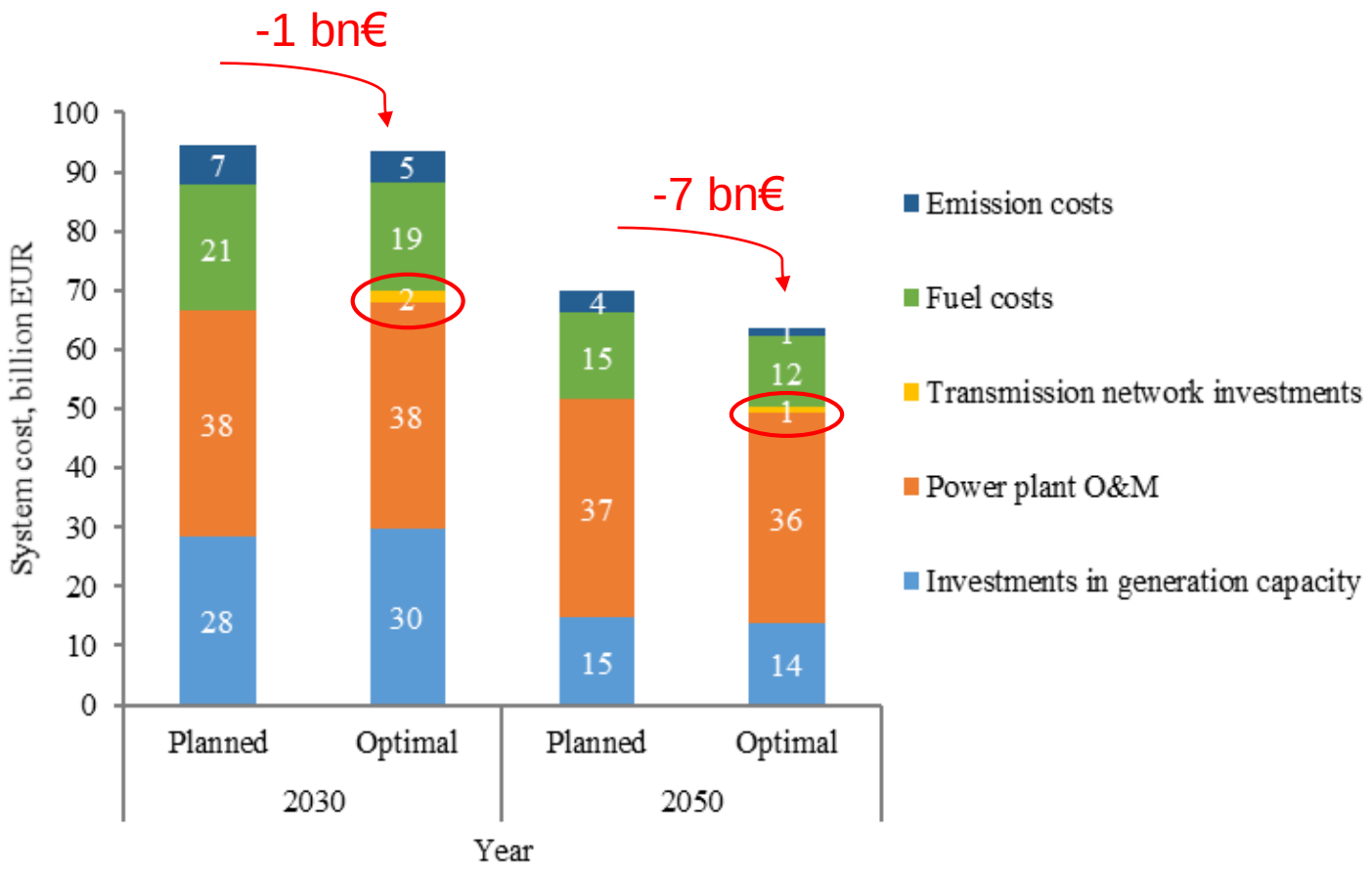
Year 2050

Planned Scenario

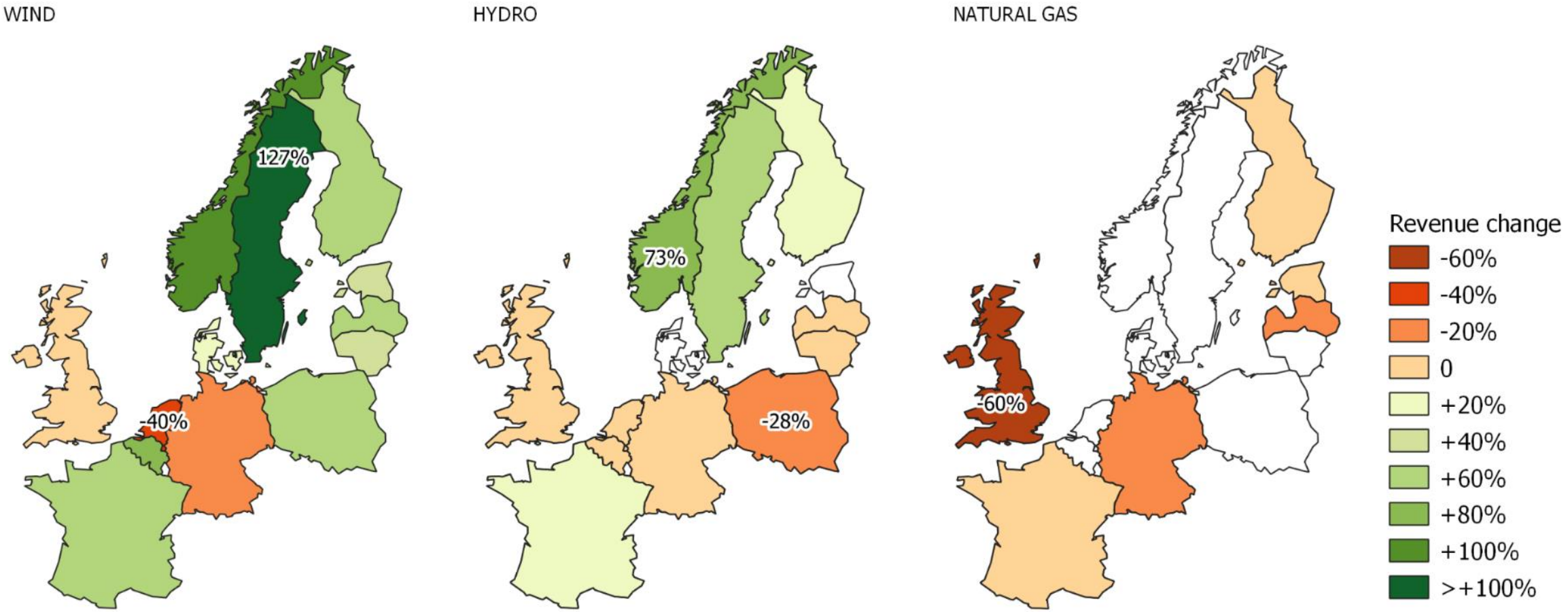


Emission impact and system costs

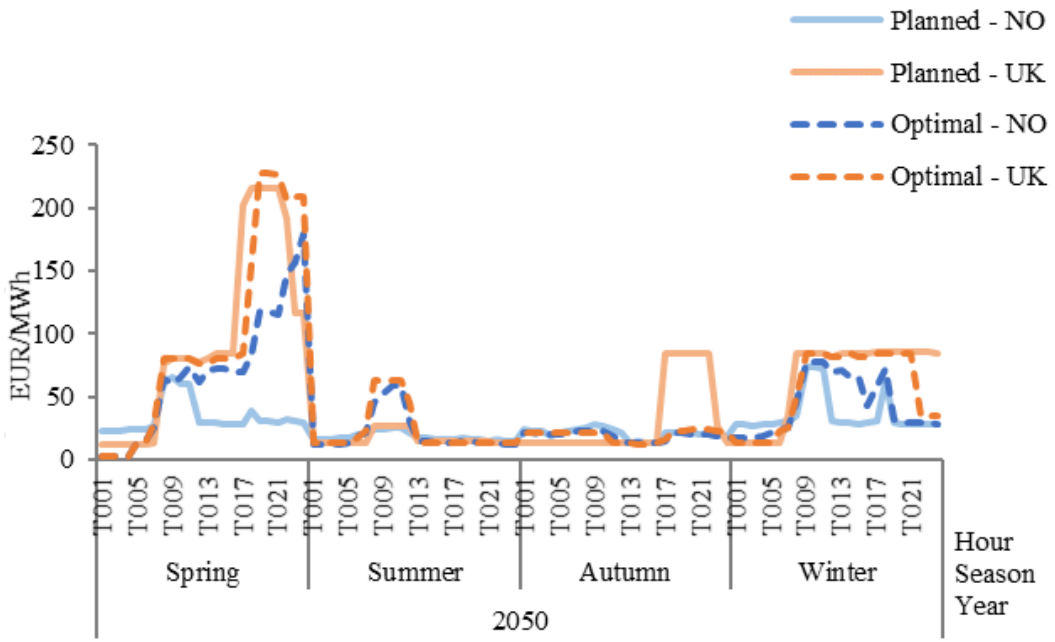




Welfare distribution
- Change in producer revenues (2050)



Welfare distribution
- Change in consumer prices (2050)



Conclusions

- The optimal scenario suggests additional 76 GW of cross-border transmission capacity expansion from 2030 to 2050
- More wind power substitutes fossil fuel based energy
  - Further emission reduction
  - Lower system costs
- Benefits asymmetrically distributed
  - ☺: Northern wind power producers, Northern hydro power producers, Western consumers
  - ☹: Fossil-fuel-based power producers, Northern consumers

➢Barrier and/or opportunity?

Thank you for your attention!

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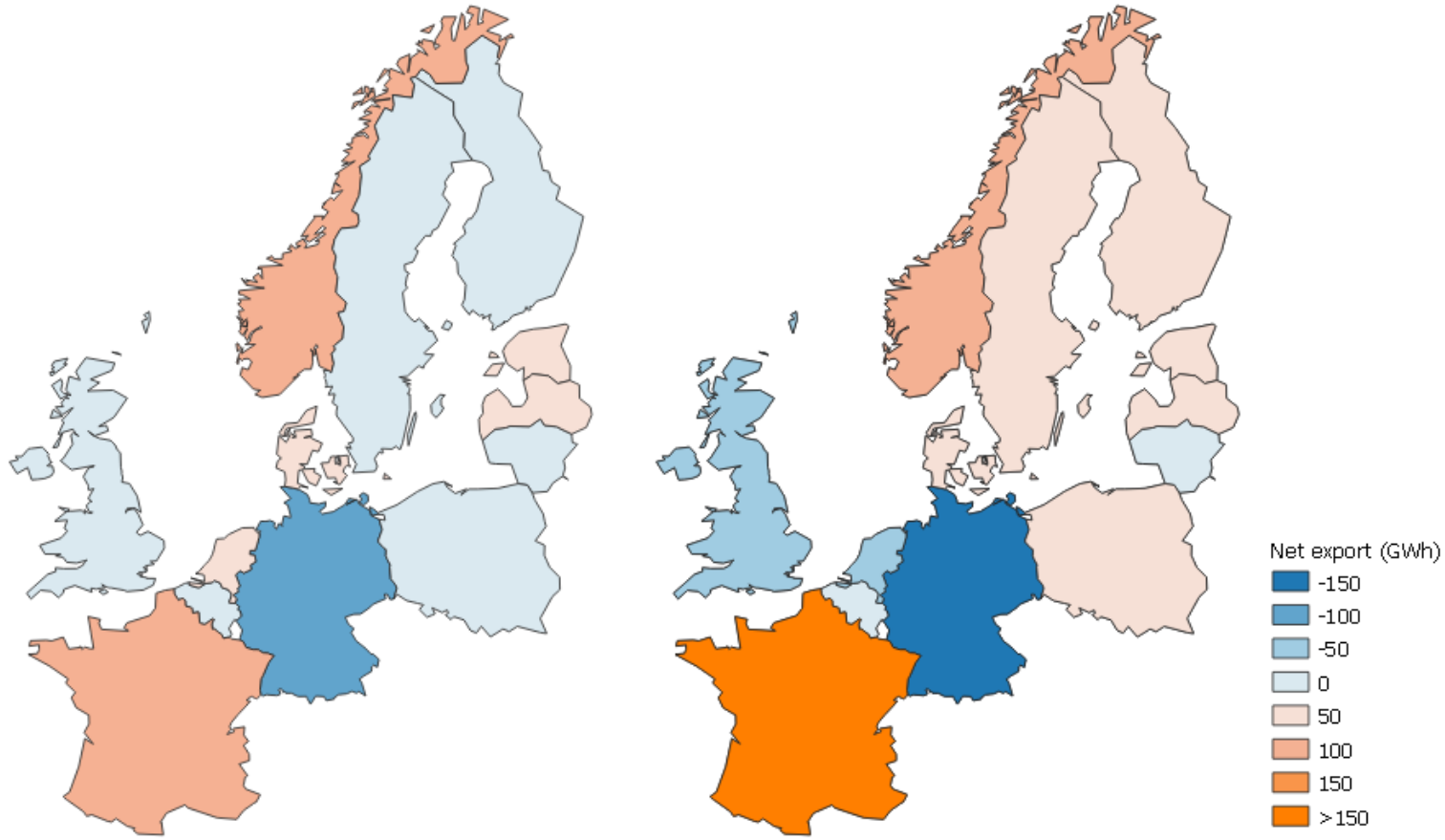
Transmission assumptions

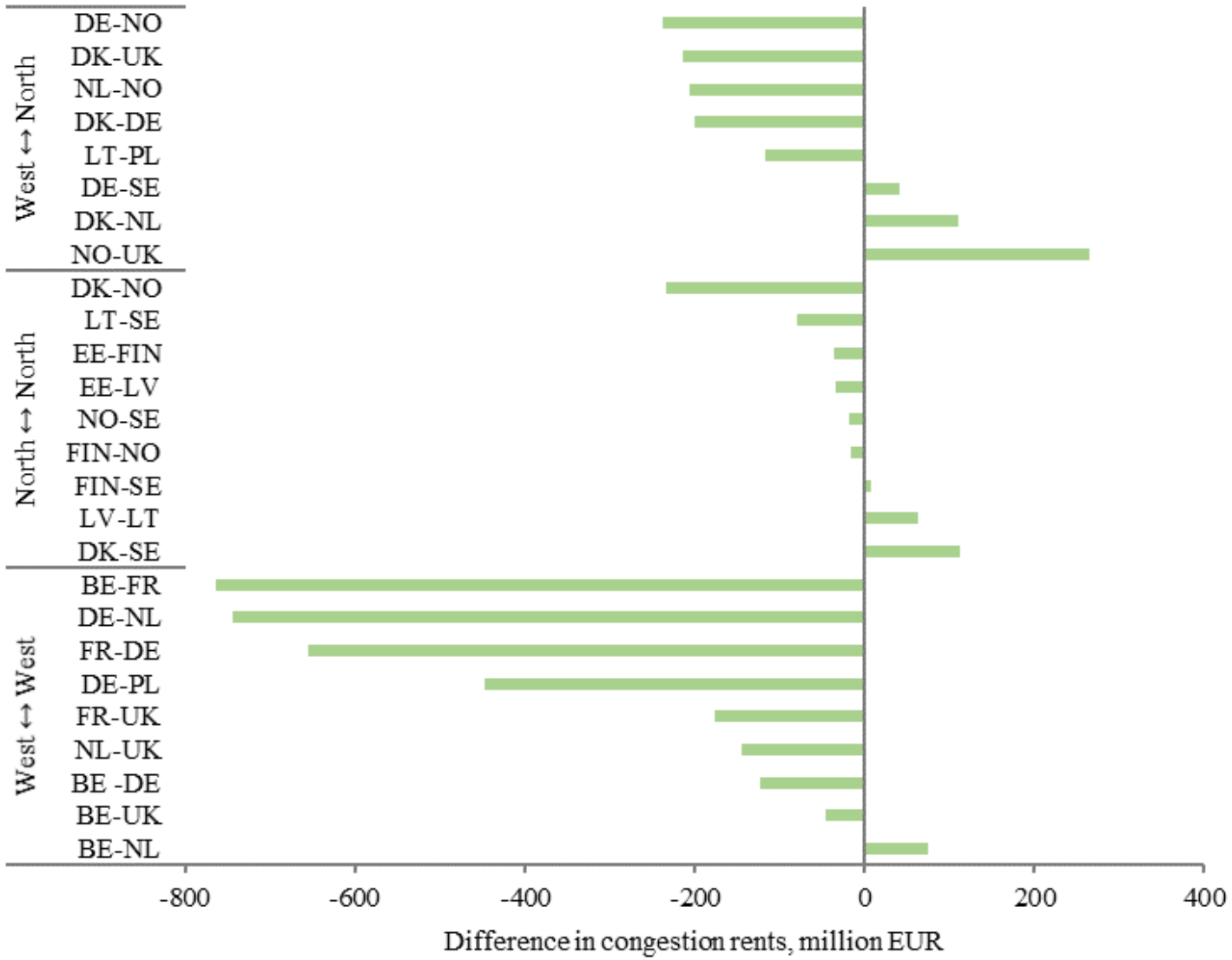
- Investment cost data derived from or estimated by established projects
  - a pay-back period of 40 years with 3.25% discount factor
- O&M cost: 0.1 EUR/MWh
- Efficiency: 95.8%
- Capacity rating: 90%

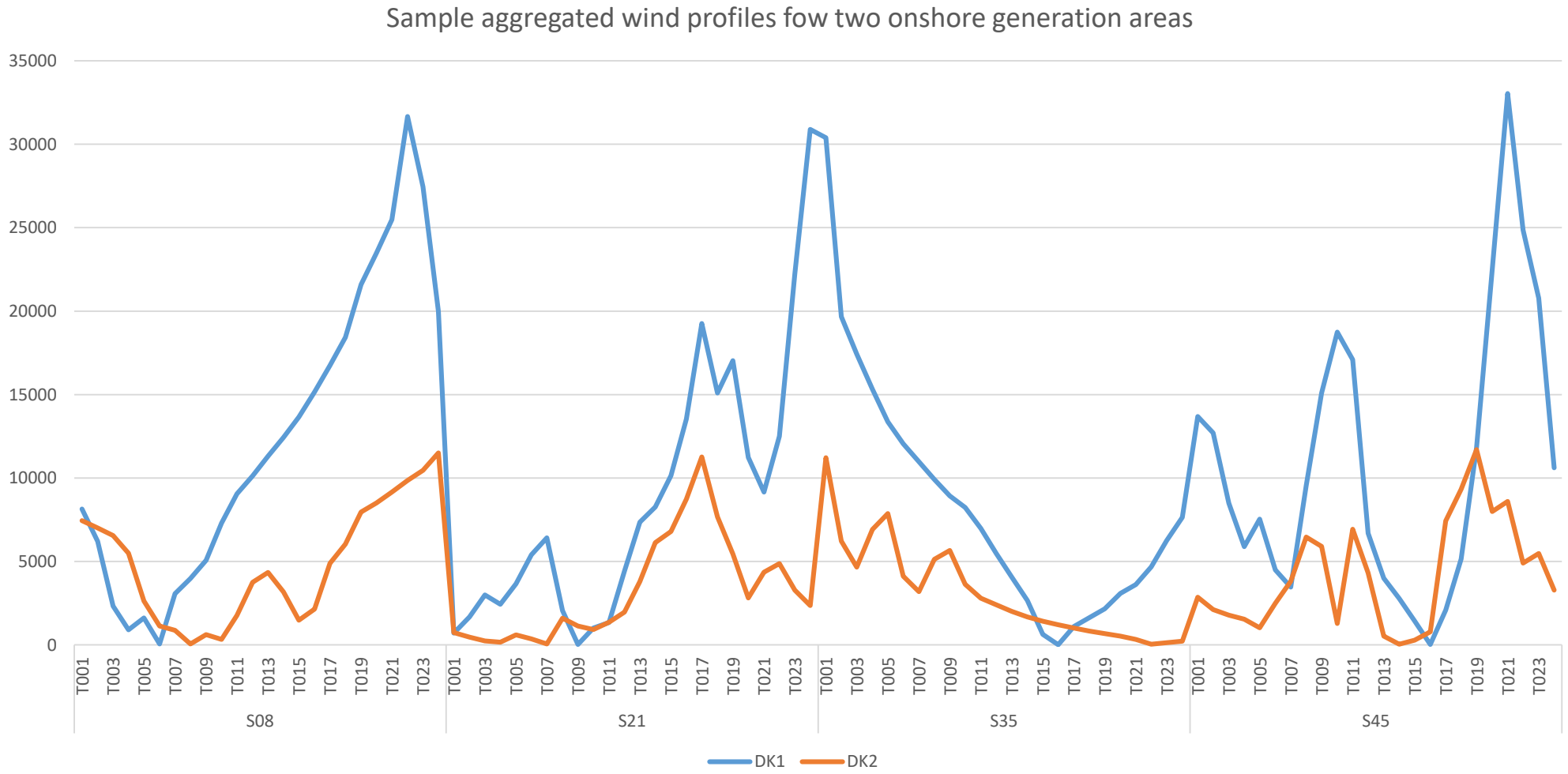
TABLE XINVCOST(YYY,IRRRE,IRRRI) 'Investment cost in new transmission capacity (Money/MW)'

	DK2	DK1	SE1	SE2	SE3	SE4	NO4	NO3	NO5	NO1	NO2	FIN	DE4-S	DE4-E	DE4-N	DE4-W	UK	EE	LV	LT	PL	NL	FR	BE
2016.DK2		509 574				421 379									568 371									
2016.DK1	509 574				774 161						695 800				568 371		1 195 600					842 800		
2016.SE1				568 371			489 975					568 371												
2016.SE2			568 371		568 371		538 973	568 371																
2016.SE3		774 161		568 371		568 371				568 371		793 760						999 600	999 600					
2016.SE4	421 379				568 371										725 163					989 800	862 400			
2016.NO4			489 975	538 973				568 371				568 371												
2016.NO3				568 371			568 371		509 574	568 371														
2016.NO5								509 574		519 374	489 975													
2016.NO1					568 371			568 371	519 374		509 574													
2016.NO2		695 800							489 975	509 574					1 185 800		1 215 200							
2016.FIN			568 371		793 760		568 371											676 200						
2016.DE4-S														568 371		568 371						568 371	568 400	539 000
2016.DE4-E													568 371		568 371	568 371					568 371			
2016.DE4-N	568 371	568 371				725 163					1 185 800			568 371		568 371								
2016.DE4-W													568 371	568 371	568 371									
2016.UK		1 195 600									1 215 200											872 200	735 000	401 800
2016.EE					999 600							676 200							450 800					
2016.LV					999 600													450 800		450 800				
2016.LT						989 800													450 800		568 371			
2016.PL						862 400								568 371						568 371				
2016.NL		842 800											568 371				872 200							450 800
2016.FR													568 400				735 000							568 400
2016.BE													539 000				401 800					450 800	568 400	

Country	Export_P	Import_P	NetE_P	Export_O	Import_O	NetE_O
BELGIUM	29 860	45 017	- 15 157	43 234	56 000	- 12 767
DENMARK	39 457	34 421	5 036	66 265	57 130	9 135
ESTONIA	7 859	5 145	2 714	12 070	7 960	4 110
FINLAND	14 887	16 326	- 1 438	26 579	16 568	10 011
FRANCE	103 727	11 512	92 214	166 450	4 840	161 610
GERMANY	155 686	259 035	- 103 348	183 005	336 647	- 153 642
LATVIA	7 871	7 104	766	12 885	8 506	4 379
LITHUANIA	6 125	13 564	- 7 439	6 266	17 329	- 11 063
NETHERLANDS	60 058	43 489	16 569	30 060	85 467	- 55 407
NORWAY	113 355	62 916	50 439	157 398	96 089	61 309
POLAND	16 865	23 285	- 6 420	52 377	40 101	12 276
SWEDEN	102 217	118 651	- 16 434	191 242	161 541	29 701
UNITED_KINGDOM	20 431	37 933	- 17 502	35 170	94 823	- 59 653




West ↔ North
DE-NO
DK-UK
NL-NO
DK-DE
LT-PL
DE-SE
DK-NL
NO-UK
North ↔ North
DK-NO
LT-SE
EE-FIN
EE-LV
NO-SE
FIN-NO
FIN-SE
LV-LT
DK-SE
West ↔ West
BE-FR
DE-NL
FR-DE
DE-PL
FR-UK
NL-UK
BE -DE
BE-UK
BE-NL
-800
-600
-400
-200
0
200
400
Difference in congestion rents, million EUR


Sample aggregated wind profiles fow two onshore generation areas
35000
30000
25000
20000
15000
10000
5000
0
T001 T003 T005 T007 T009 T011 T013 T015 T017 T019 T021 T023
S08
S21
S35
S45
DK1
DK2