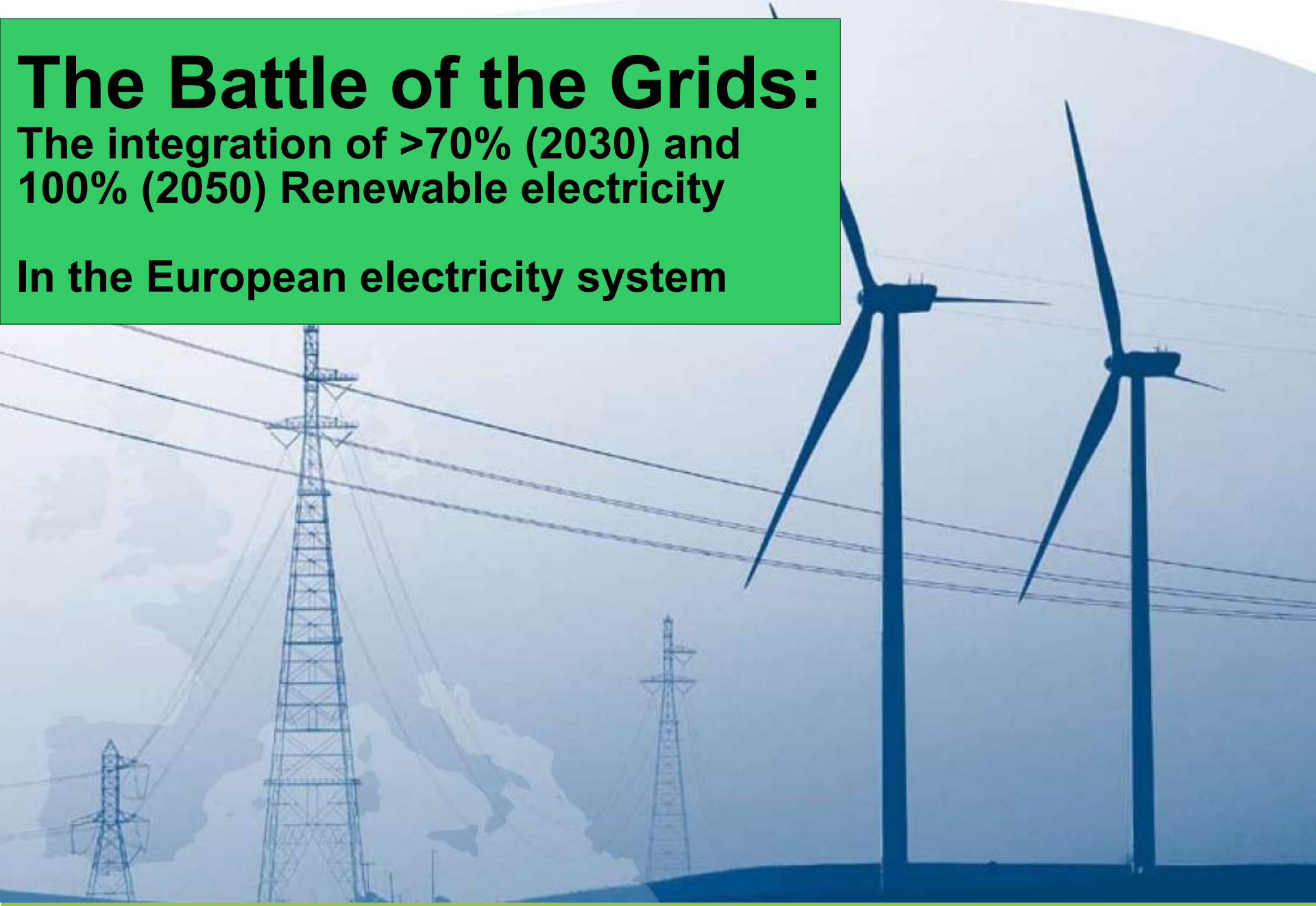
The Battle of the Grids:

The integration of >70% (2030) and 100% (2050) Renewable electricity

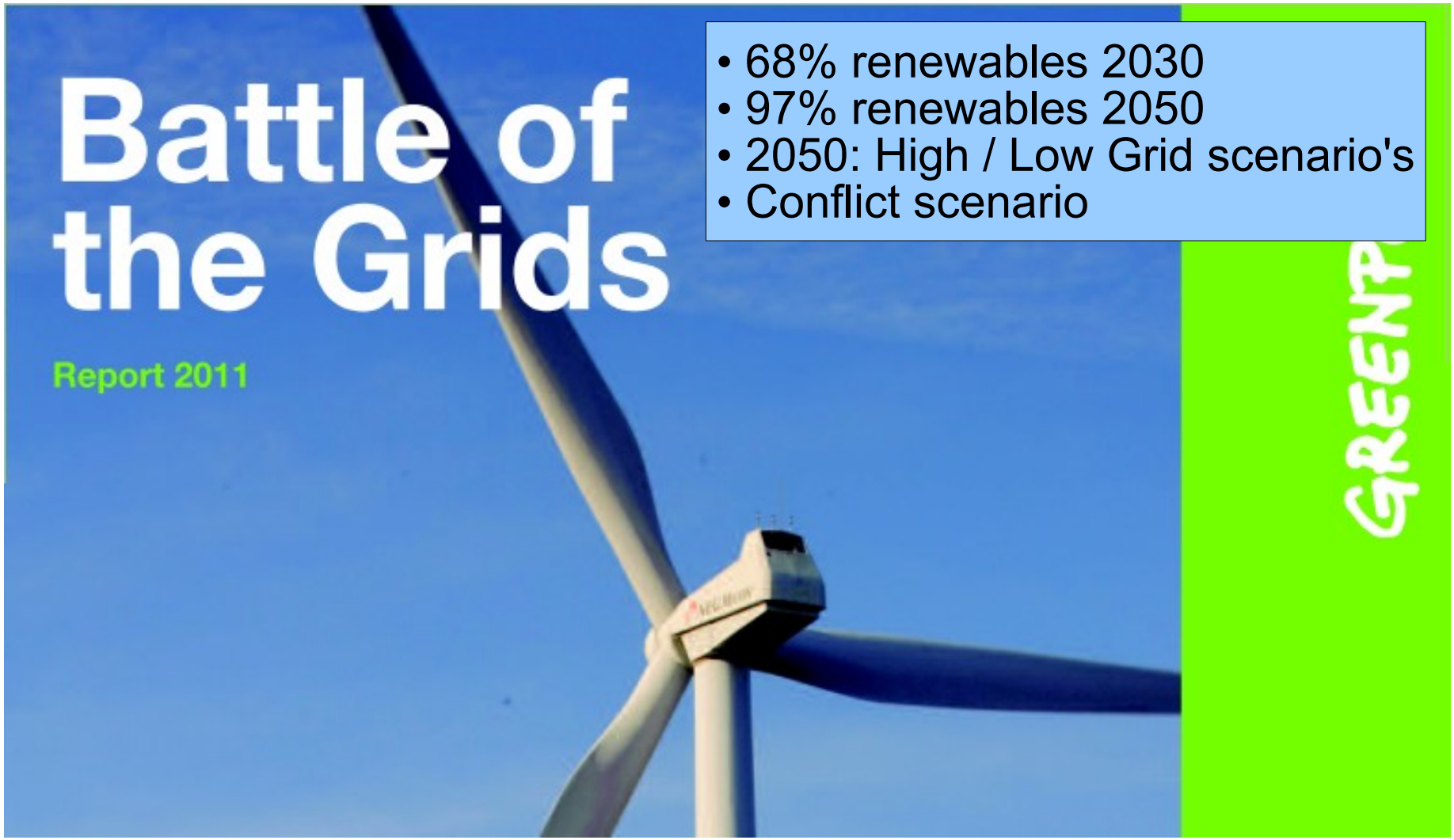
In the European electricity system



GREENPEACE energy [r]evolution

www.greenpeace.org

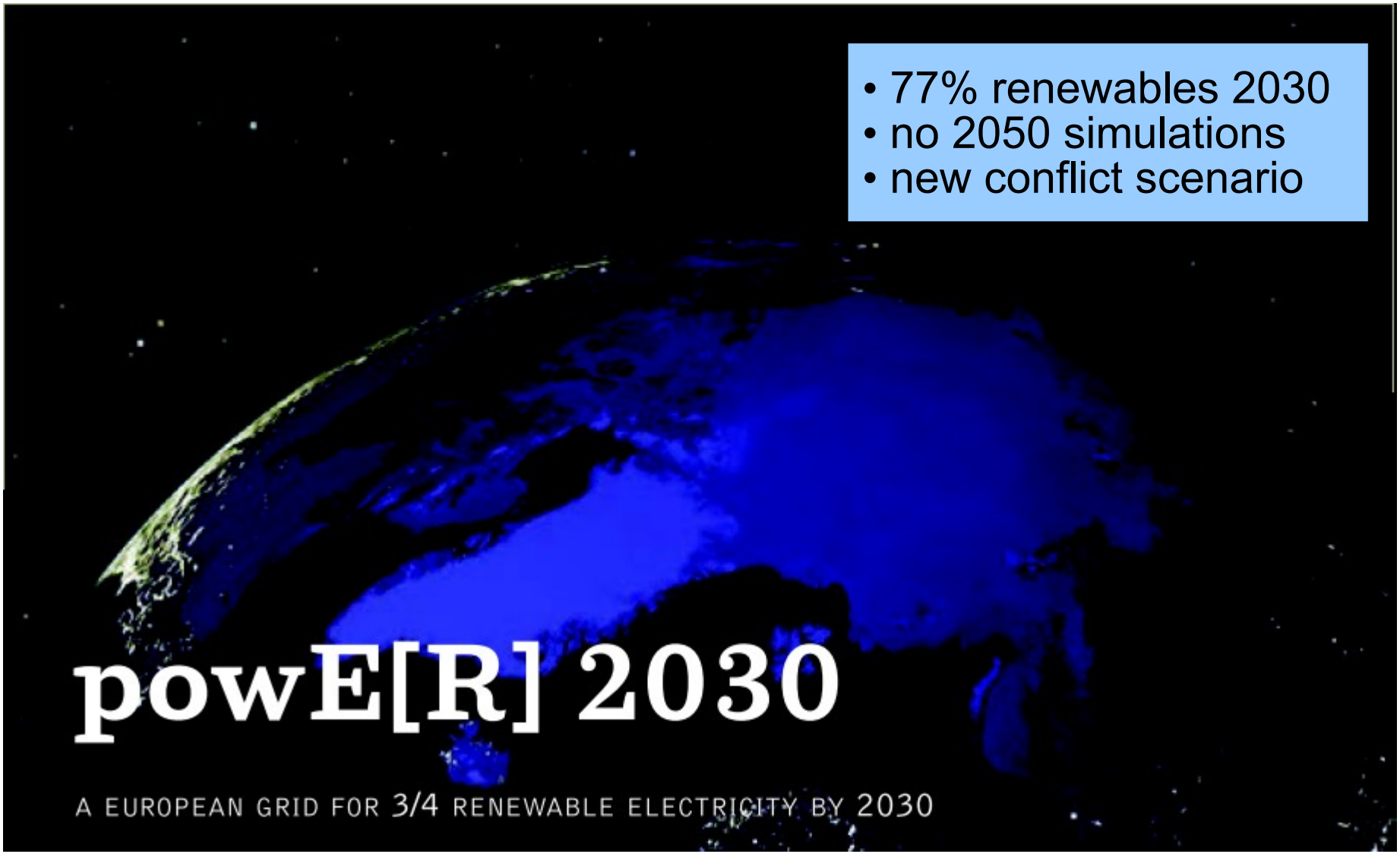
Battle of the Grids (2011)



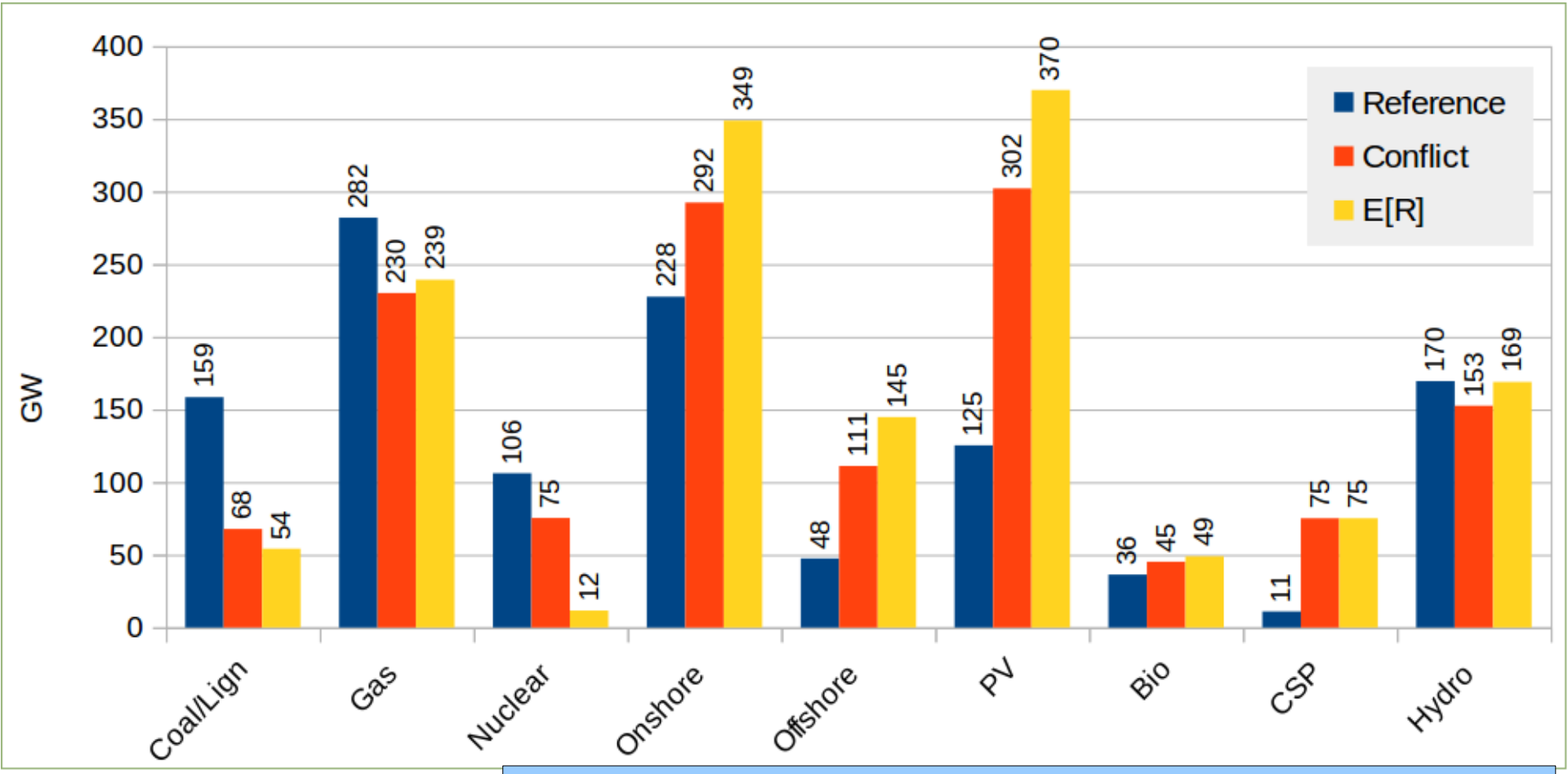
Low-Wind Turbines & consumption-deployment of PV

- More even spread of variable renewables (wind&solar)
- Balance higher cost of renewables / lower cost of grid

powE[R] 2030 (2014)

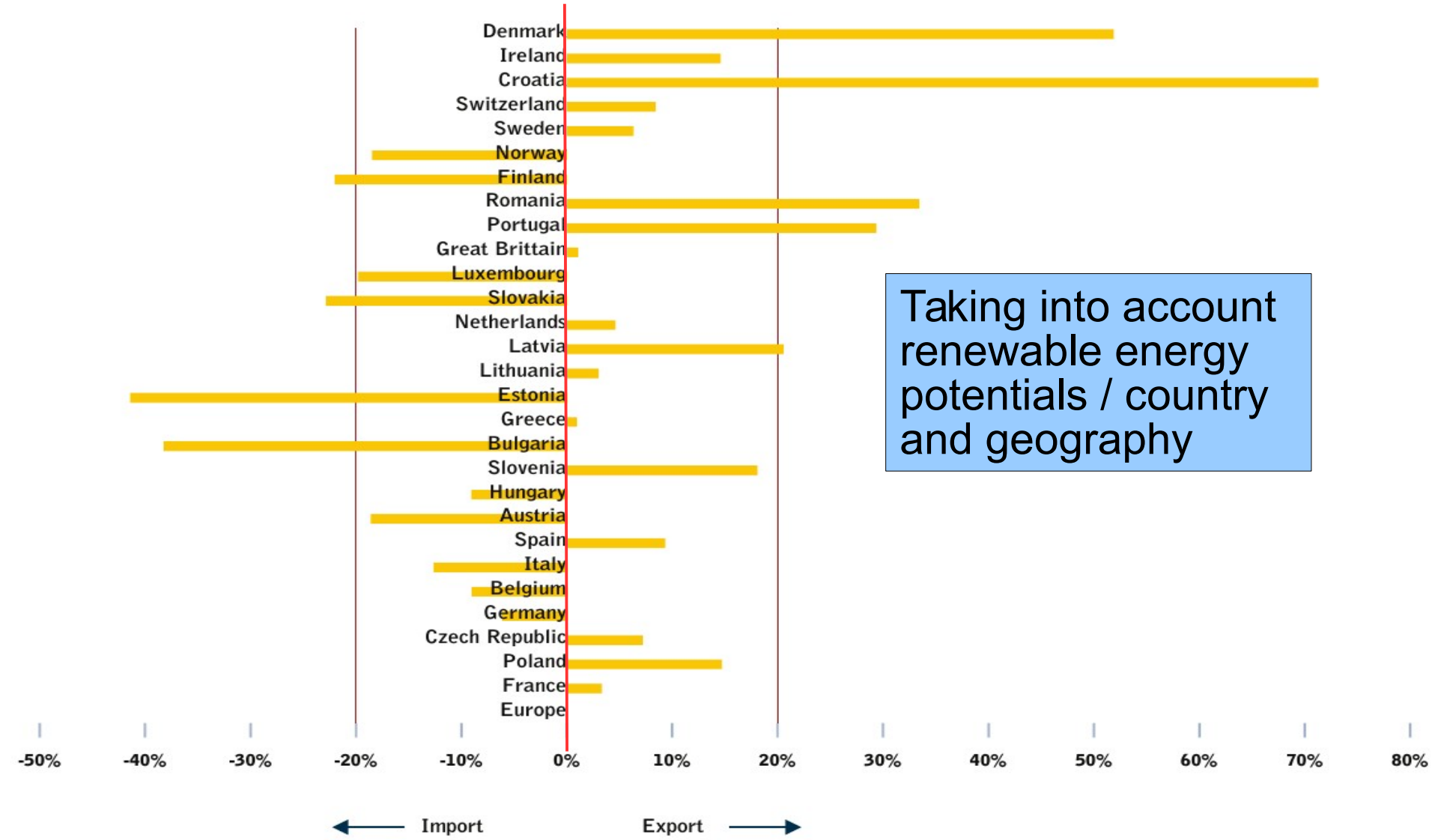


Modelled Generation Capacities 2030 (GW)



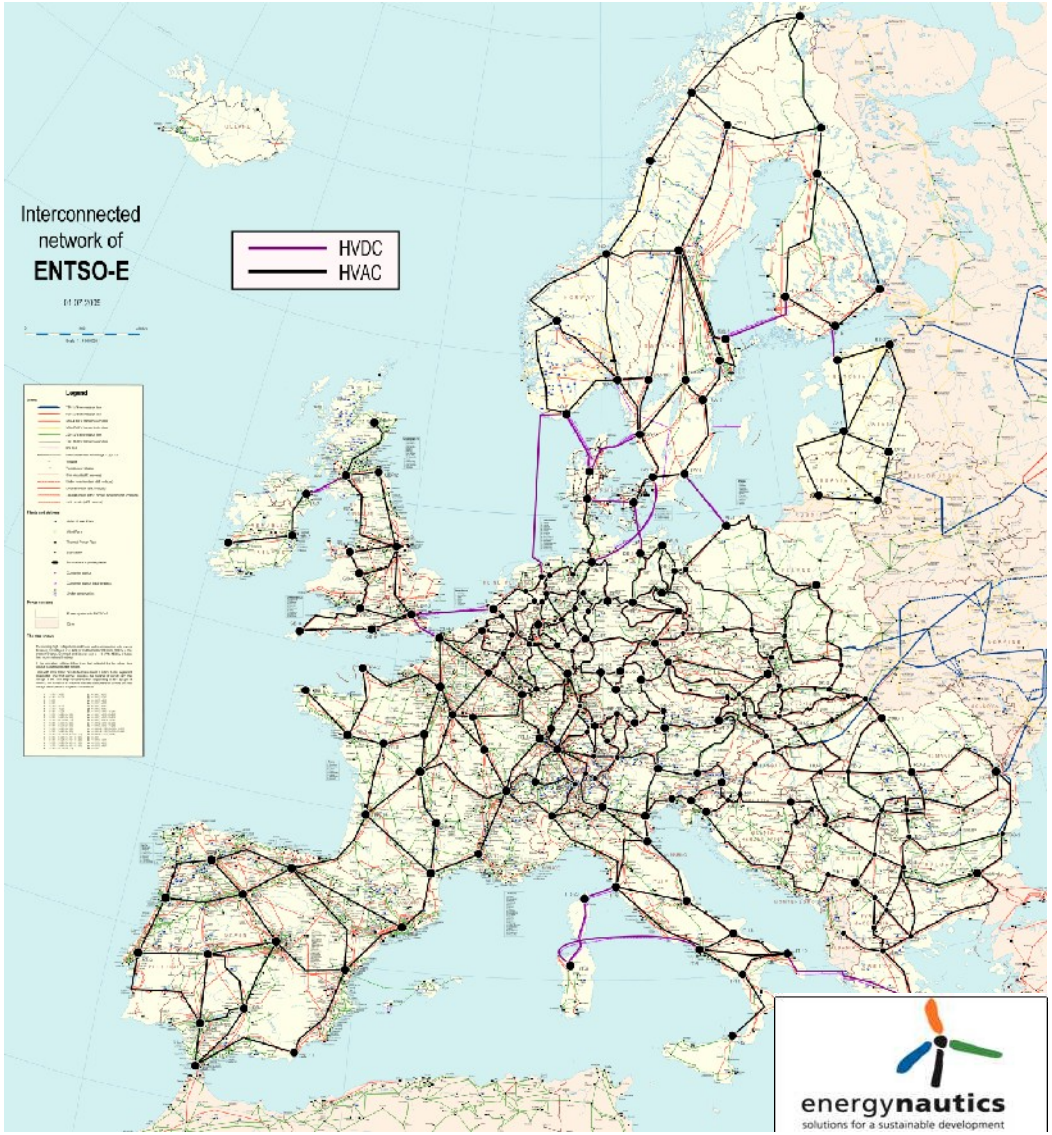
E[R]: 77% Renewable electricity generation

Electricity import/export balance 2030 E[R]



Taking into account renewable energy potentials / country and geography

Grid Model

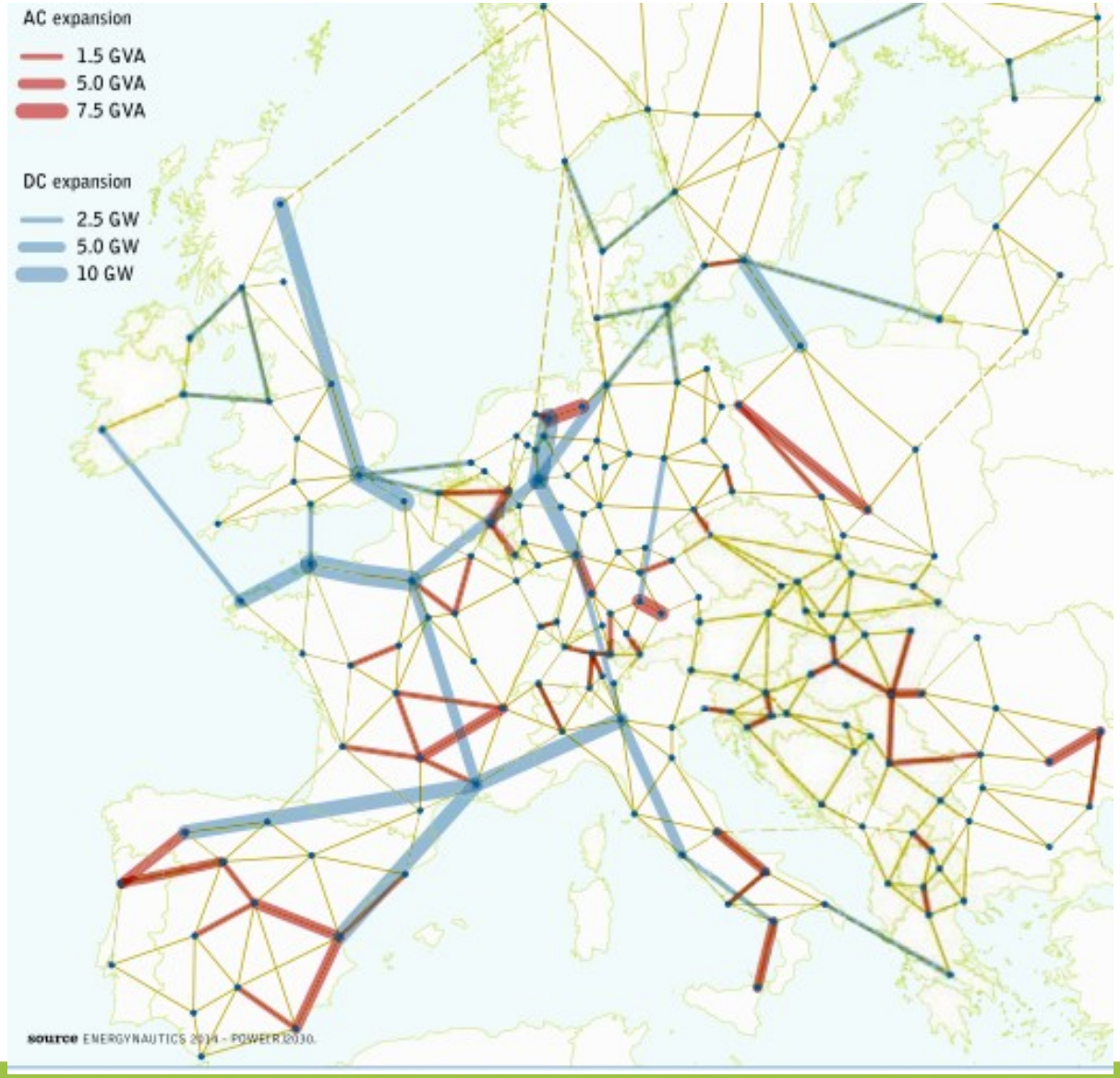


Grid Model:
- 224 nodes
- RES sources allocated to those nodes
- EU-27 + N+ CH + Balkan countries
- DIgSILENT PowerFactory

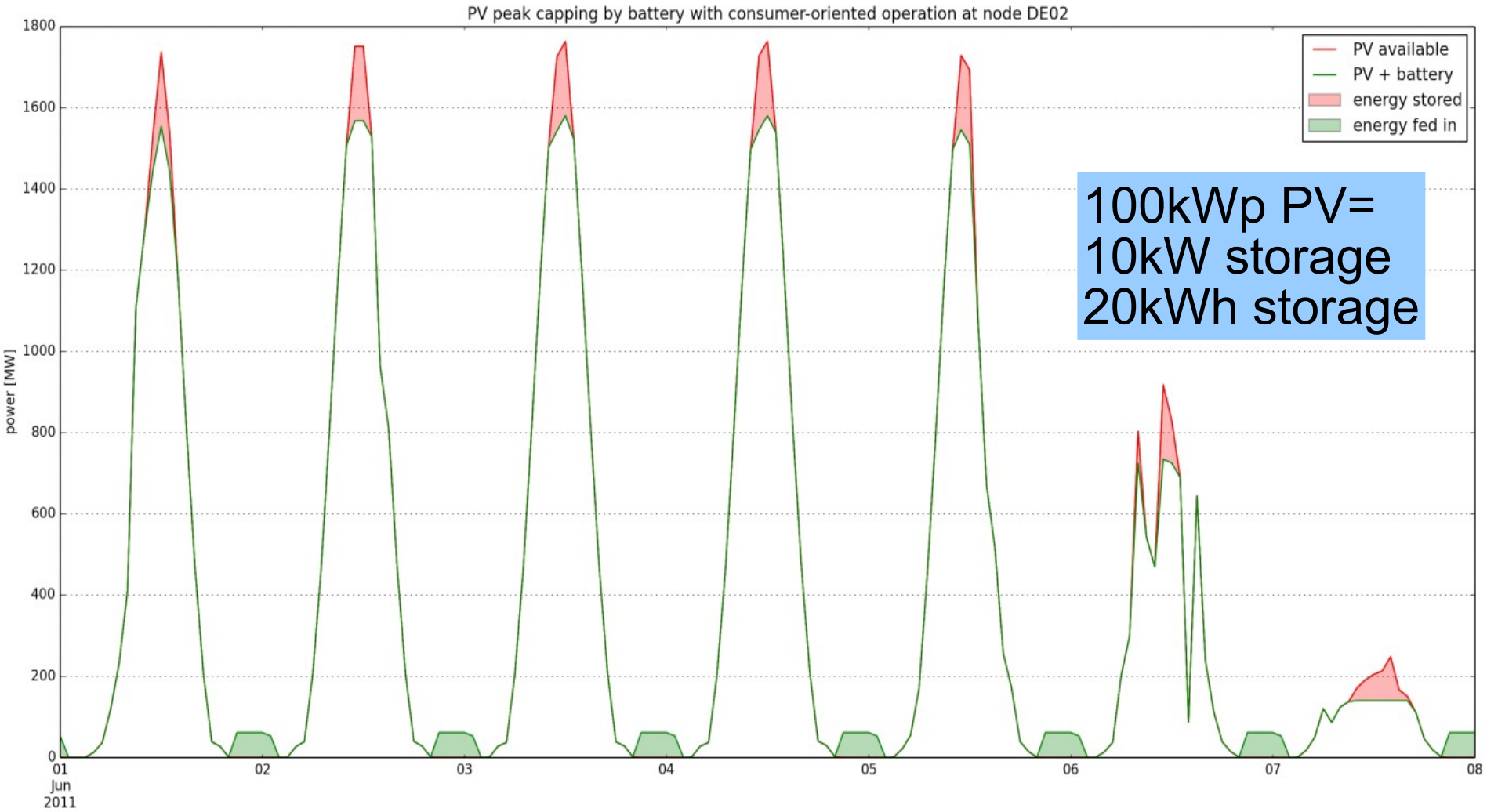
Simulations 2030-50:
1. Full-year (hourly)
2. Extreme events (30y)

Key Results:
1. Grid extensions
2. Load Fact. / curtailment

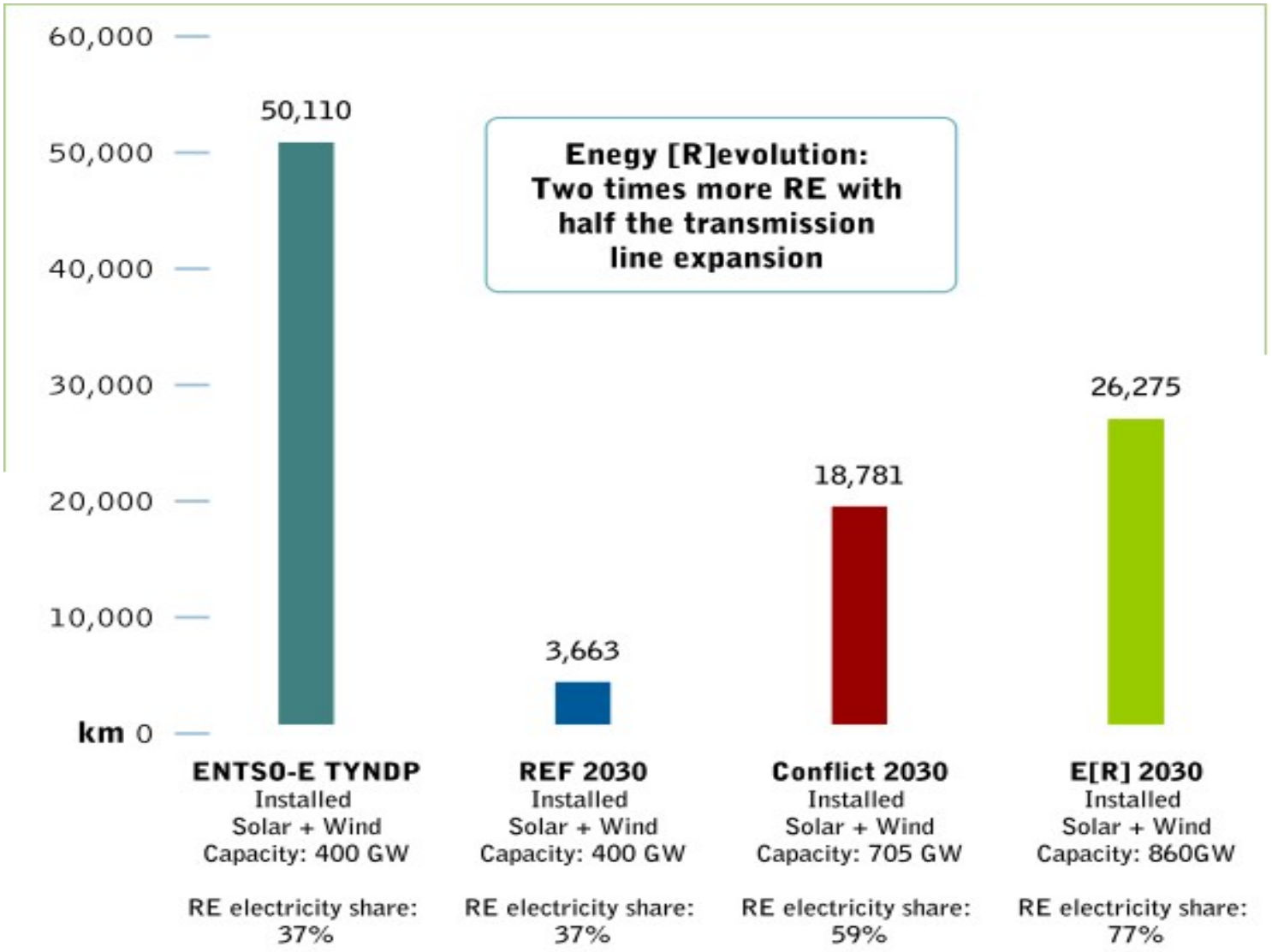
E[r] 2030 case


AC expansion
1.5 GVA
5.0 GVA
7.5 GVA
DC expansion
2.5 GW
5.0 GW
10 GW
source ENERGYNAUTICS 2011 - POWER2030.

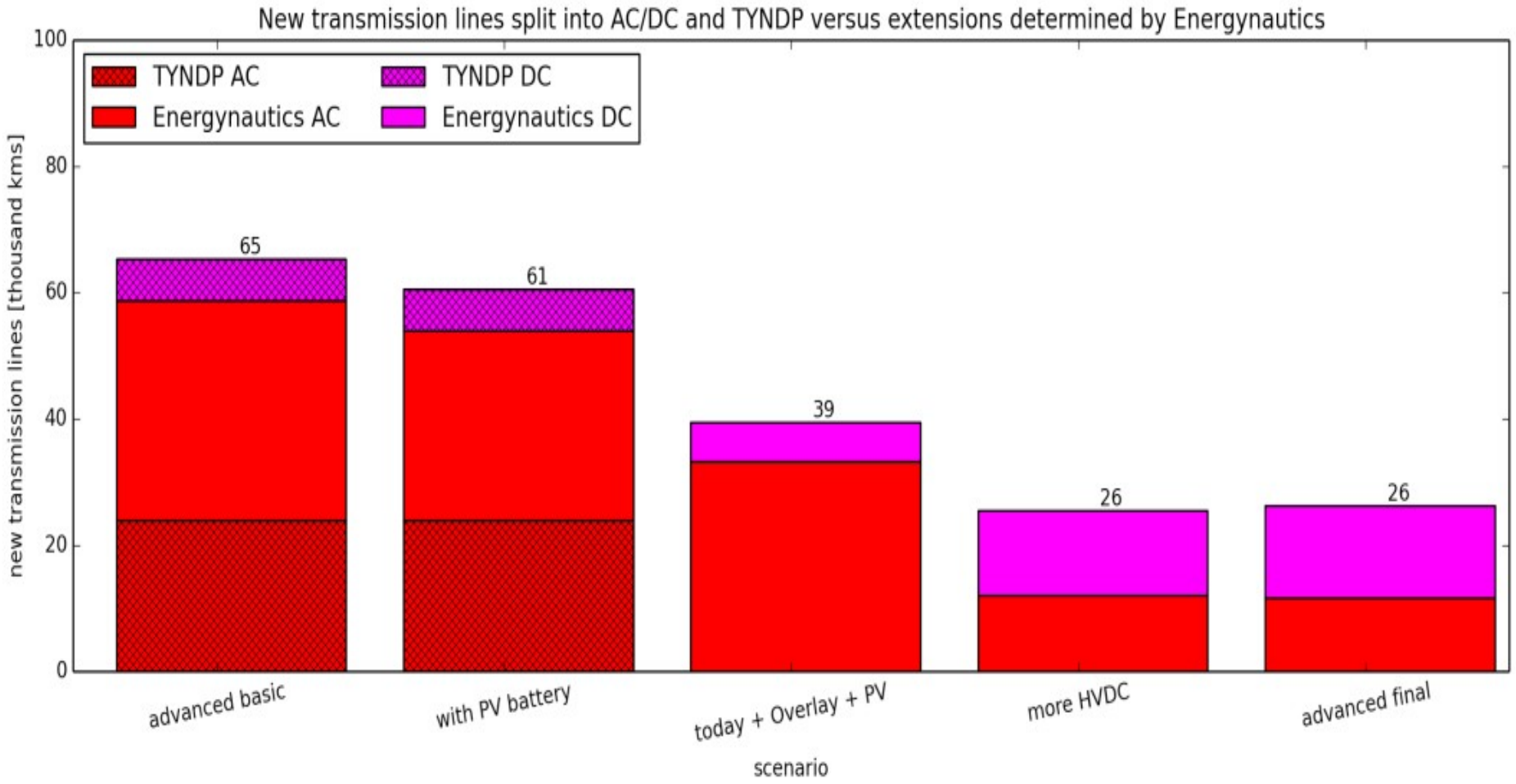
PV battery storage at German node DE02



2014: Grid extensions (km)



E[R] 2030 case (km of lines)



Grid extension 2030 / scenario's

		Length (km)	GVA.km	Cost (€)
Conflict 2030	AC	8224	15189	7
	DC	7055	39111	34
	AC+DC	15279	54299	41
E[R] 2030	AC	22489	22169	10
	DC	10738	52390	51
	AC+DC	22227	74559	61
TYNDP	AC	37520	56280	26
	DC	12590	25180	32
	AC+DC	50110	81460	58

HVDC vs HVAC: cost and capacity

figure 3.3: comparison of AC and DC investment costs using overhead lines. BREAK EVEN POINT IS TYPICALLY BETWEEN 500 TO 1,000 KM.

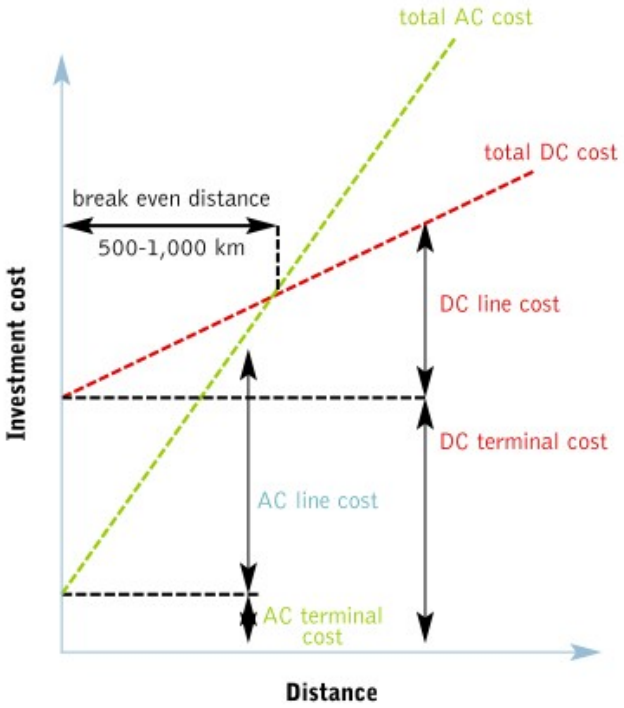
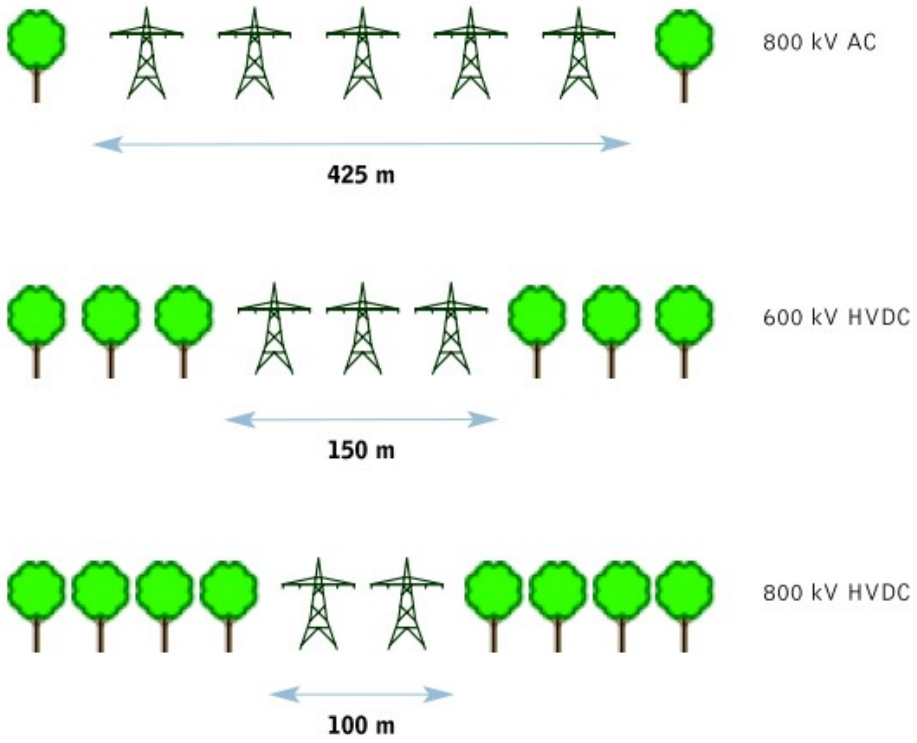
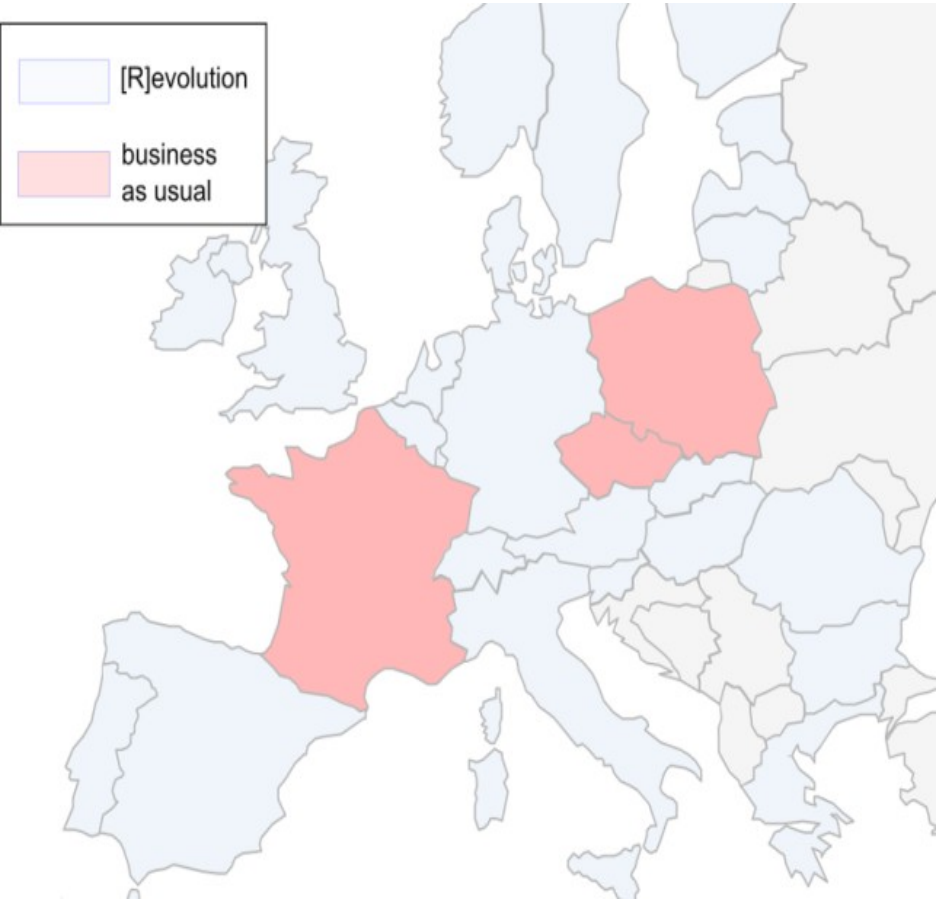
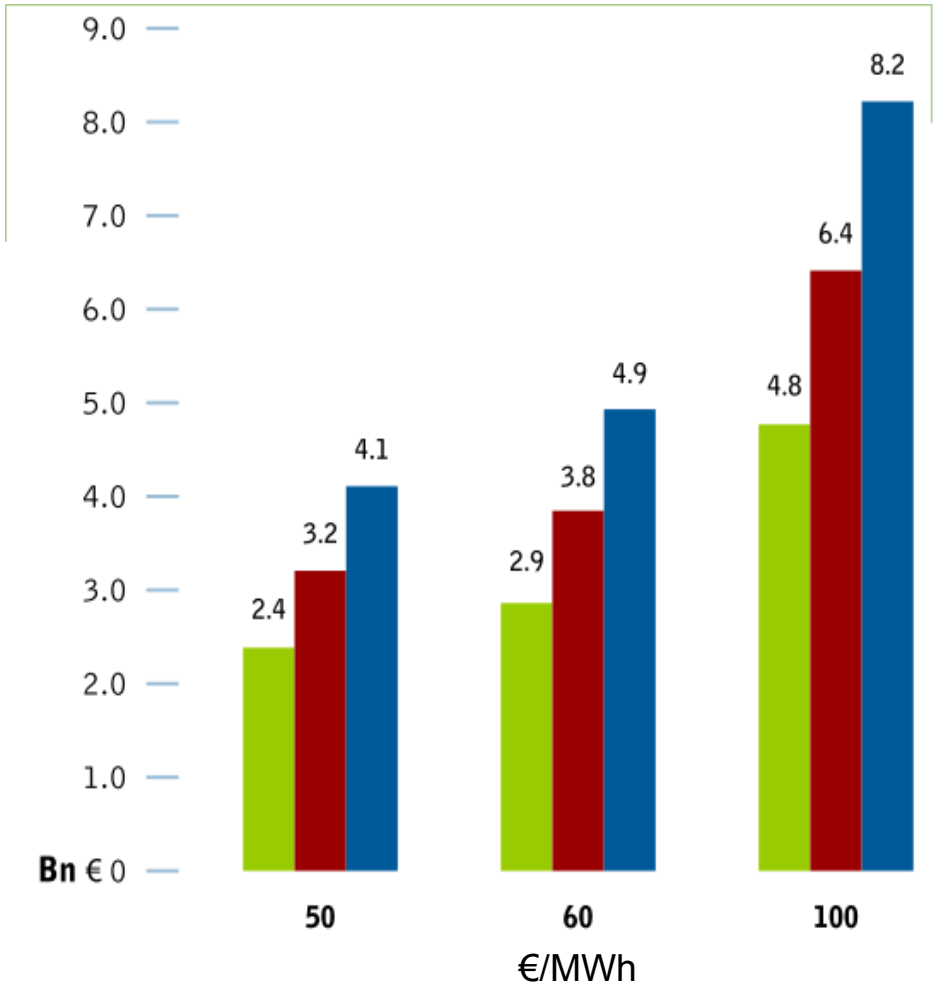


figure 3.4: comparison of the required number of parallel pylons and space to transfer 10 GW of electric capacity

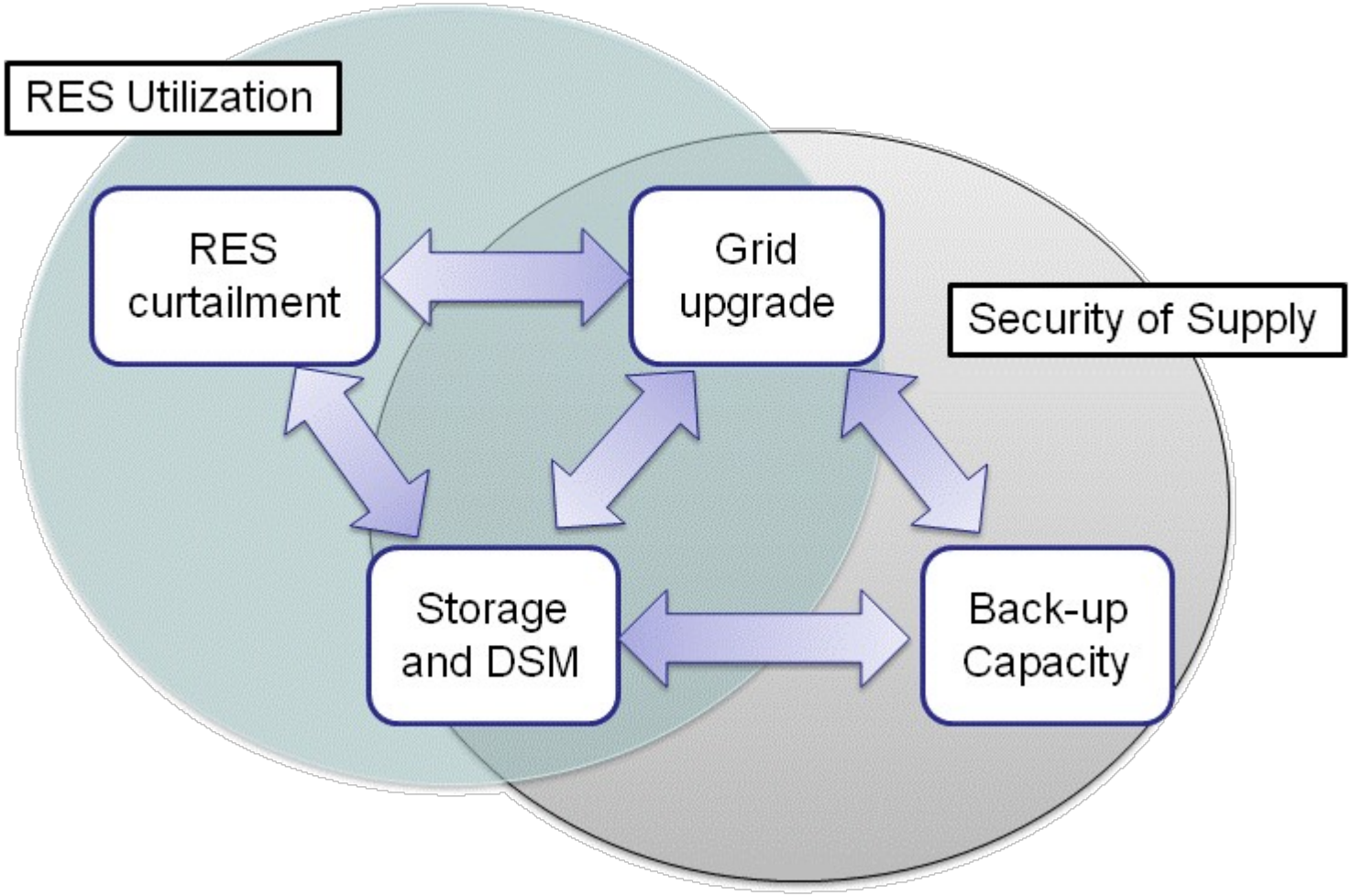


Conflict Case: Curtailment (bn€/y)





Optimisation process



End.

Grid cost assumptions

DC: 6GVA/line
AC: 3 GVA/line

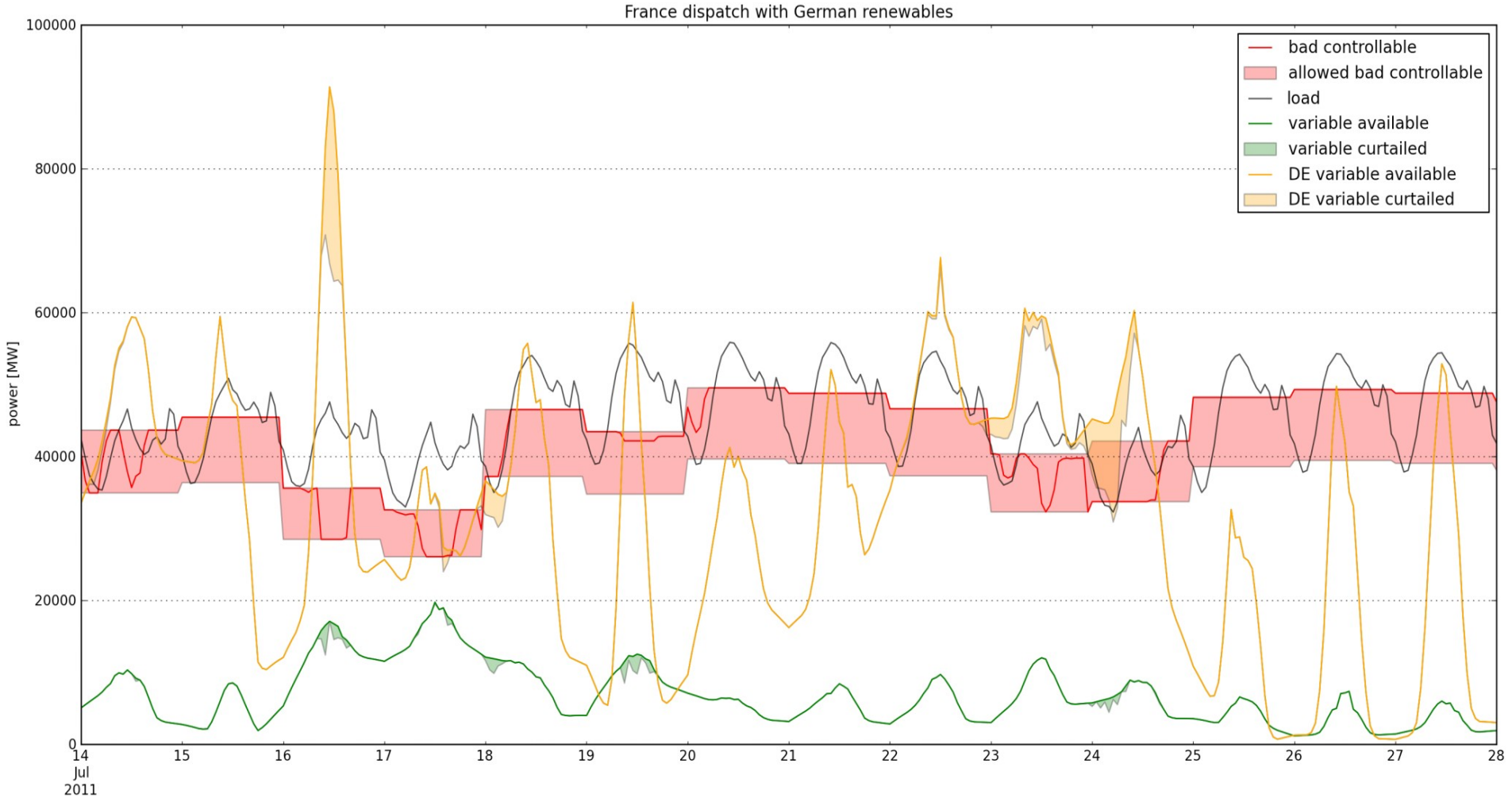
Type	Cost [Euros]	Discrete Unit Size
HVAC (Overhead Line)	400 per MVA per km	1500 MVA
HVAC Reactive power compensation	45 per MVA per km	1500 MVA
HVDC (Overhead Line)	400 per MW per km	1000 MW
HVDC (Underground Cable)	1250 per MW per km	1000 MW
HVDC (Sea Cable)	1100 per MW per km	1000 MW
HVDC VSC Converter Pair	150,000 per MW	1000 MW

a **terrain factor** that adds up to 50% to the line cost according to the difficulty of the terrain

Installed capacities (MW)

Europe	REF 2030	Conflict 2030	E[R] 2030
Coal	113.515	49.106	39.123
Lignite	45.004	18.758	15.119
Gas	282.090	230.163	239.363
Oil + Diesel	25.167	7.815	8.732
Nuclear	106.120	75.424	11.668
Renewables Total	**619.865**	**989.714**	**1.169.515**
Wind - Offshore	47.566	111.195	144.811
Wind - Onshore	227.630	292.409	348.797
Photovoltaic	125.322	302.189	369.878
Geothermal	2.365	10.852	12.896
Bioenergy	36.399	45.222	49.022
CSP	11.011	75.188	75.175
Hydro	169.572	152.659	168.936
Hydro Pump Storage	64.669	64.669	64.669

France-German conflicts (conflict scen)



20% flexibility for nuclear/coal

Cost of Curtailment of Renewables 2030 conflict case for whole of Europe (2011 report)