


Some socio-economic aspects of long-distance energy transport by superconducting power lines with a focus on MgB_2

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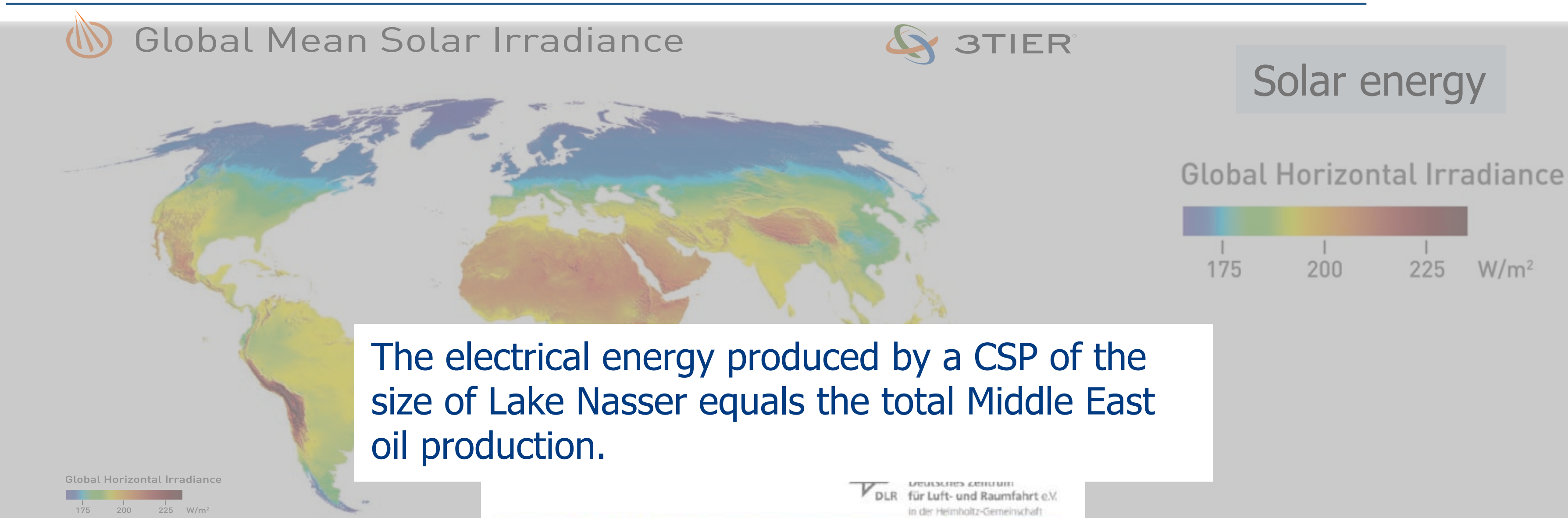
Table of contents

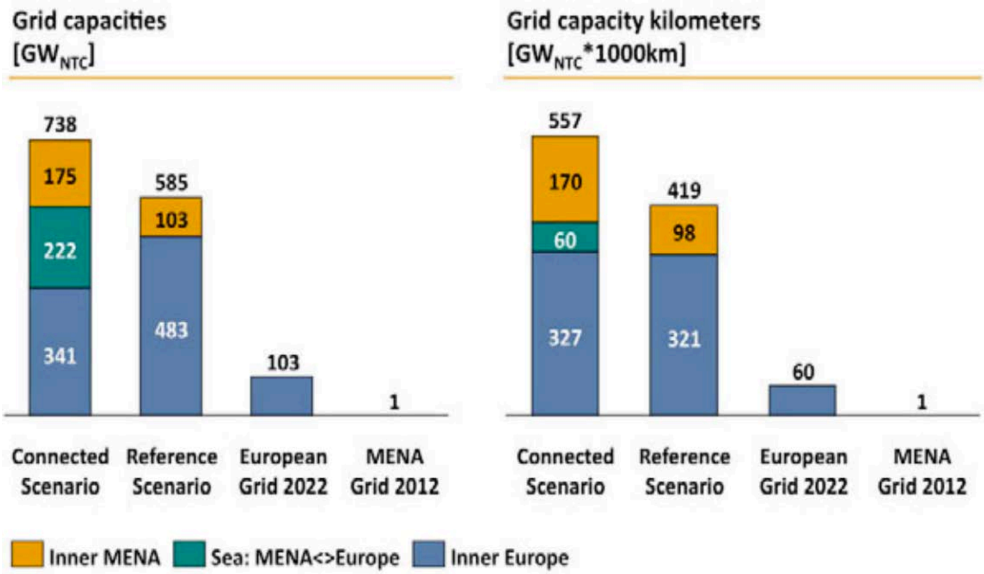
Access to remote renewable energy sources - e.g. solar energy

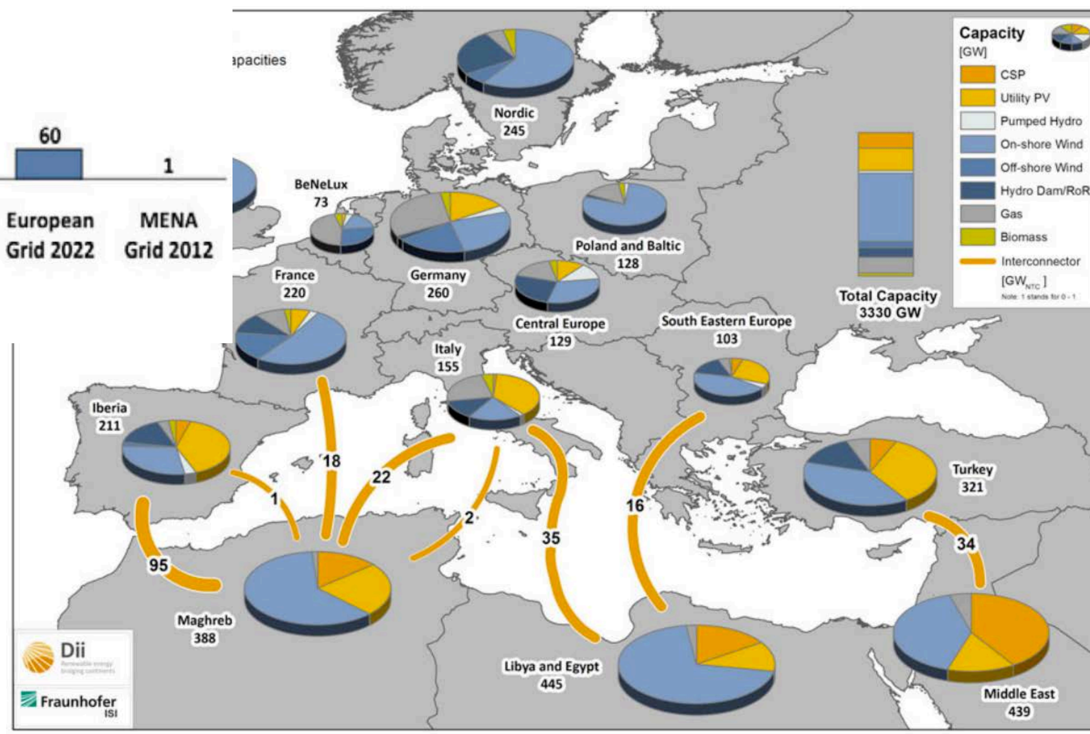


The electrical energy produced by a CSP of the size of Lake Nasser equals the total Middle East oil production.

Potential – EUMENA

222 GW / 60’000 GW*km transmission capacities in 2050 for MENA – Europe
175 GW / 170’000 GW*km transmission capacities in 2050 for inner MENA

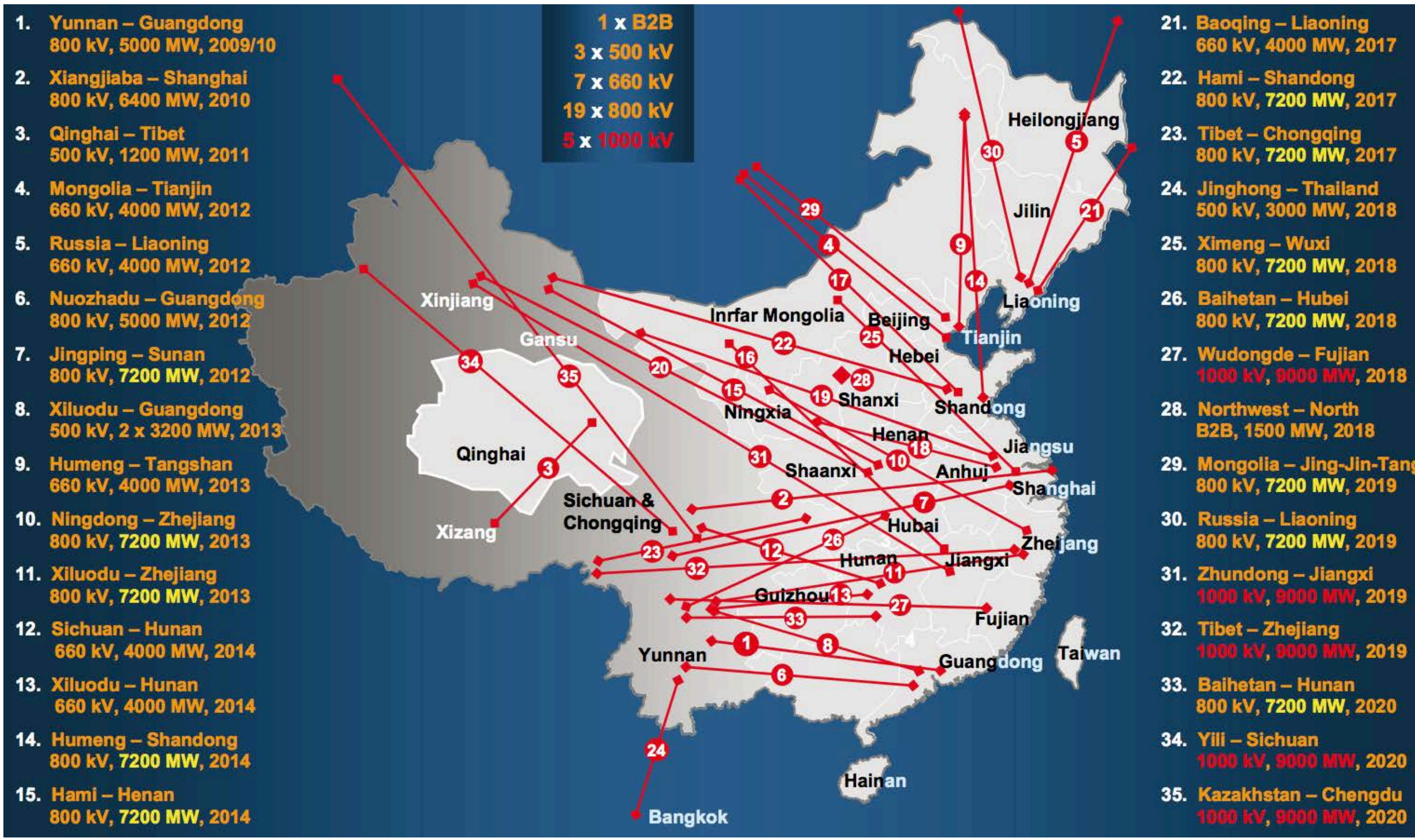




Source: Desert2050, Dii (2012)

Potential – China

217 GW / 400’000 GW*km additional HVDC transmission capacities until 2020

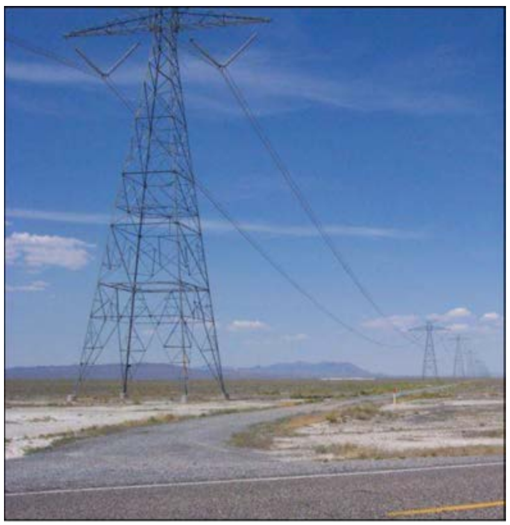


Source: Siemens AG, Energy Sector, Power Transmission Division, Germany (2011)

Energy transmission options

±800kV HVDC OHL

Aluminium
(reinforced with steel)



P < 6.4 GW

Losses: 2 % / 1000 km

±320kV HVDC cable

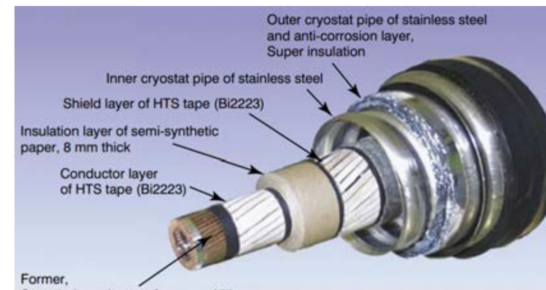
Copper, Aluminium

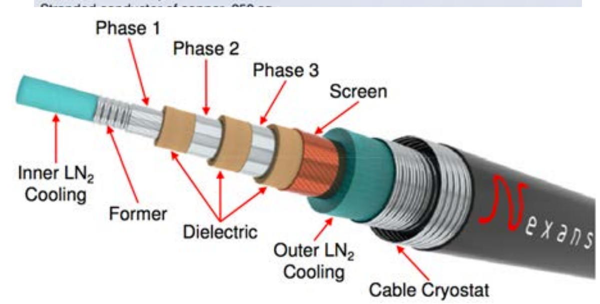
P = 600 – 1200 MW

Losses: 6 % / 1000 km

High temperature SC (HTS)

BSCCO// (RE)BCO – YBCO



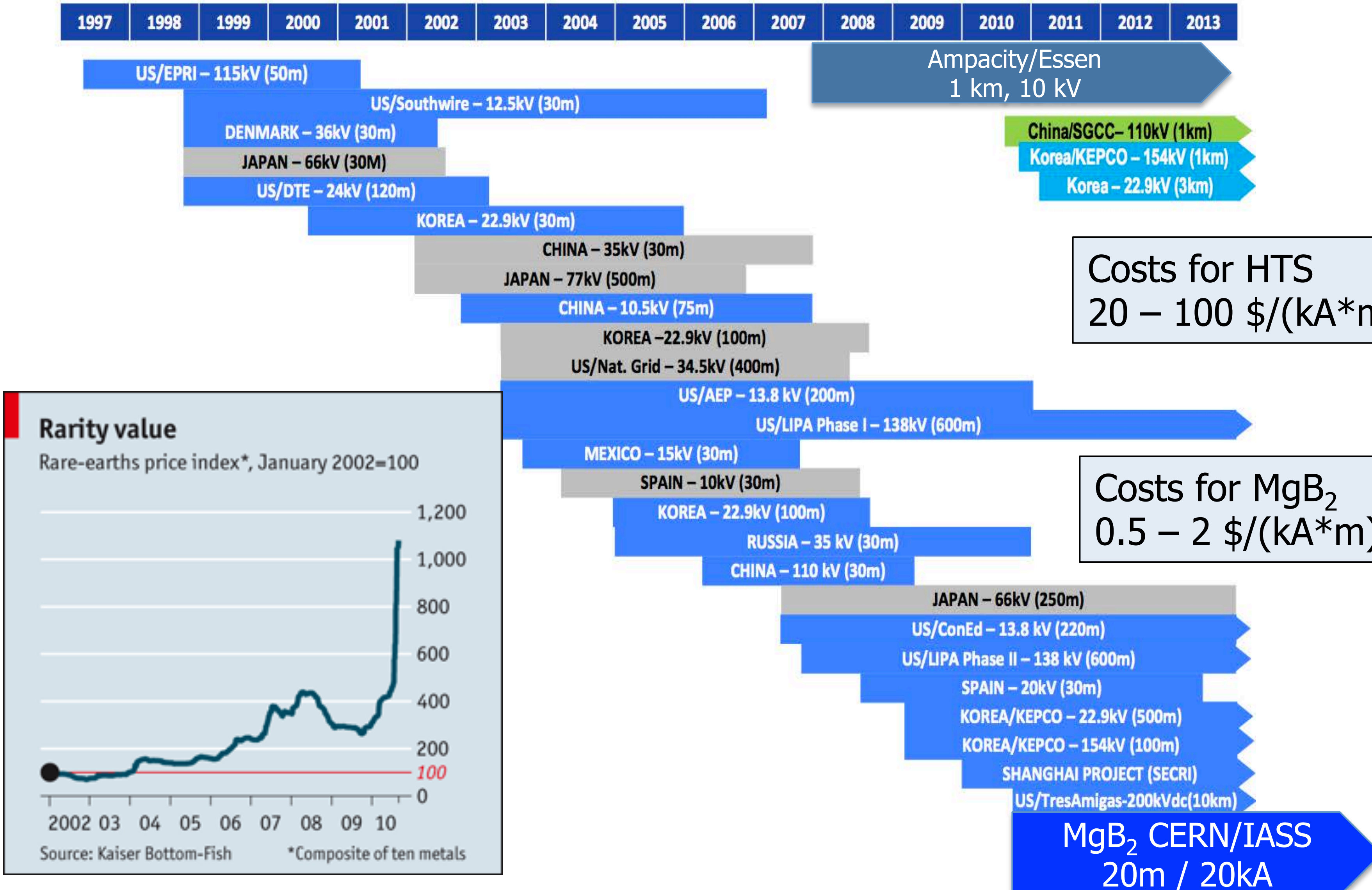


P_{max} = 574 MW (LIPA I)

Project under study

SC losses: < 0.1%/1000 km

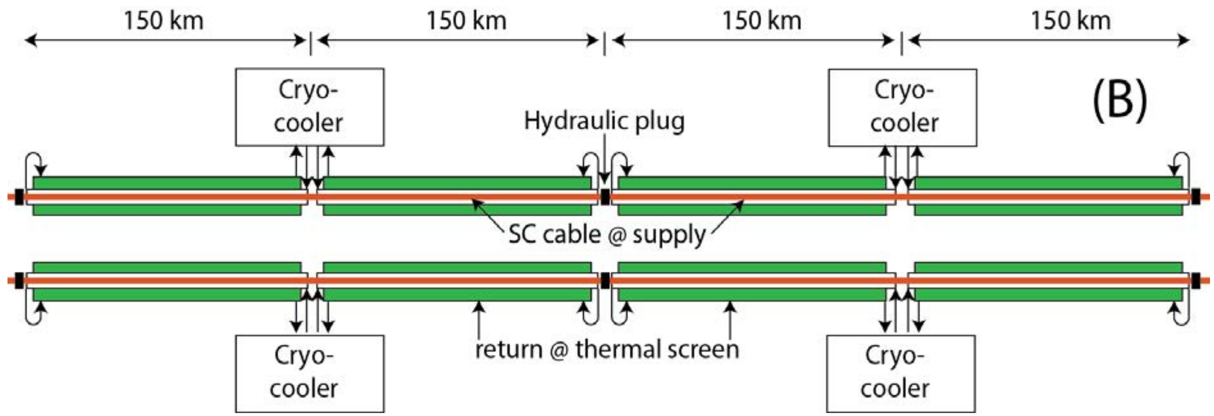
Feasibility – HTS projects around the world



Costs for HTS
20 – 100 \$/(kA*m)

Costs for MgB$_2$
0.5 – 2 \$/(kA*m)

Superconducting transmission lines based on MgB_2 – LH_2 option



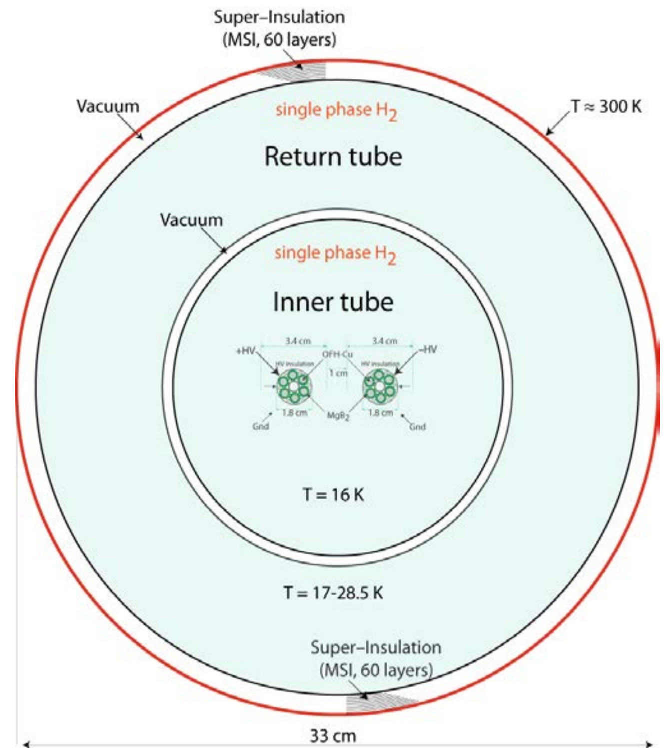
P = 10 GW
E_{max} [1y] = 87.9 TWh
= 15.8 % el. energy consumption GER

Power losses: < 0.1 - 0.38 % (1000 km)

Outer diameter = 33 cm

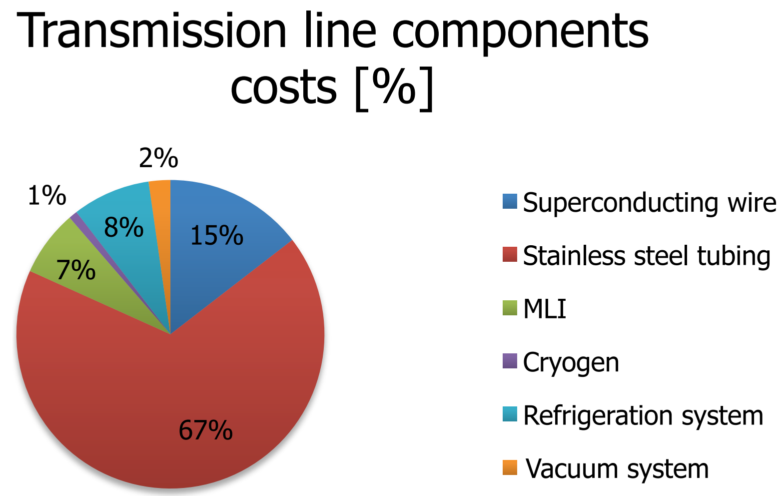
I = 40 kA
U = ± 125 kV

Cost superconductor/MgB_2 wire: 0.5 - 2 $/(kA m)



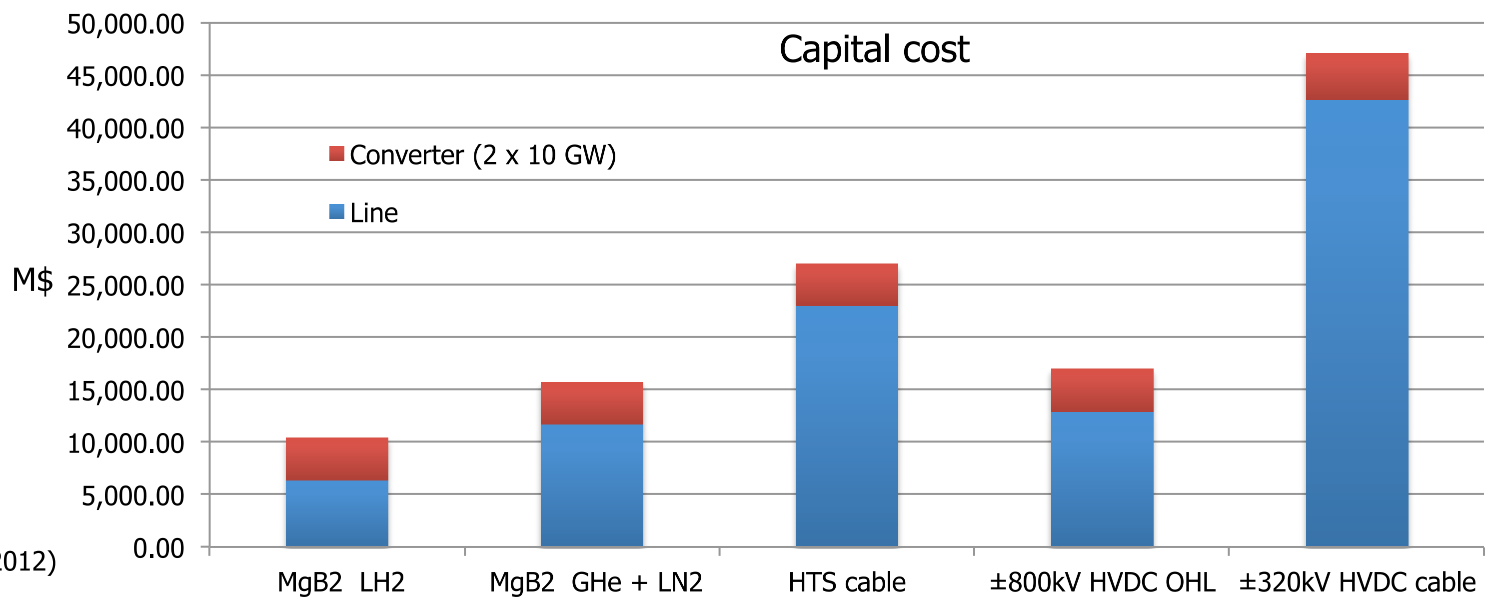
Indicative Costs – 10 GW, 3000 km MgB_2 transmission line cooled by LH_2

Component
Transmission line components
Superconducting wire
Stainless steel tubing
MLI
Cryogen
Refrigeration system
Vacuum system
Total
Total TLC + 50 % contingency



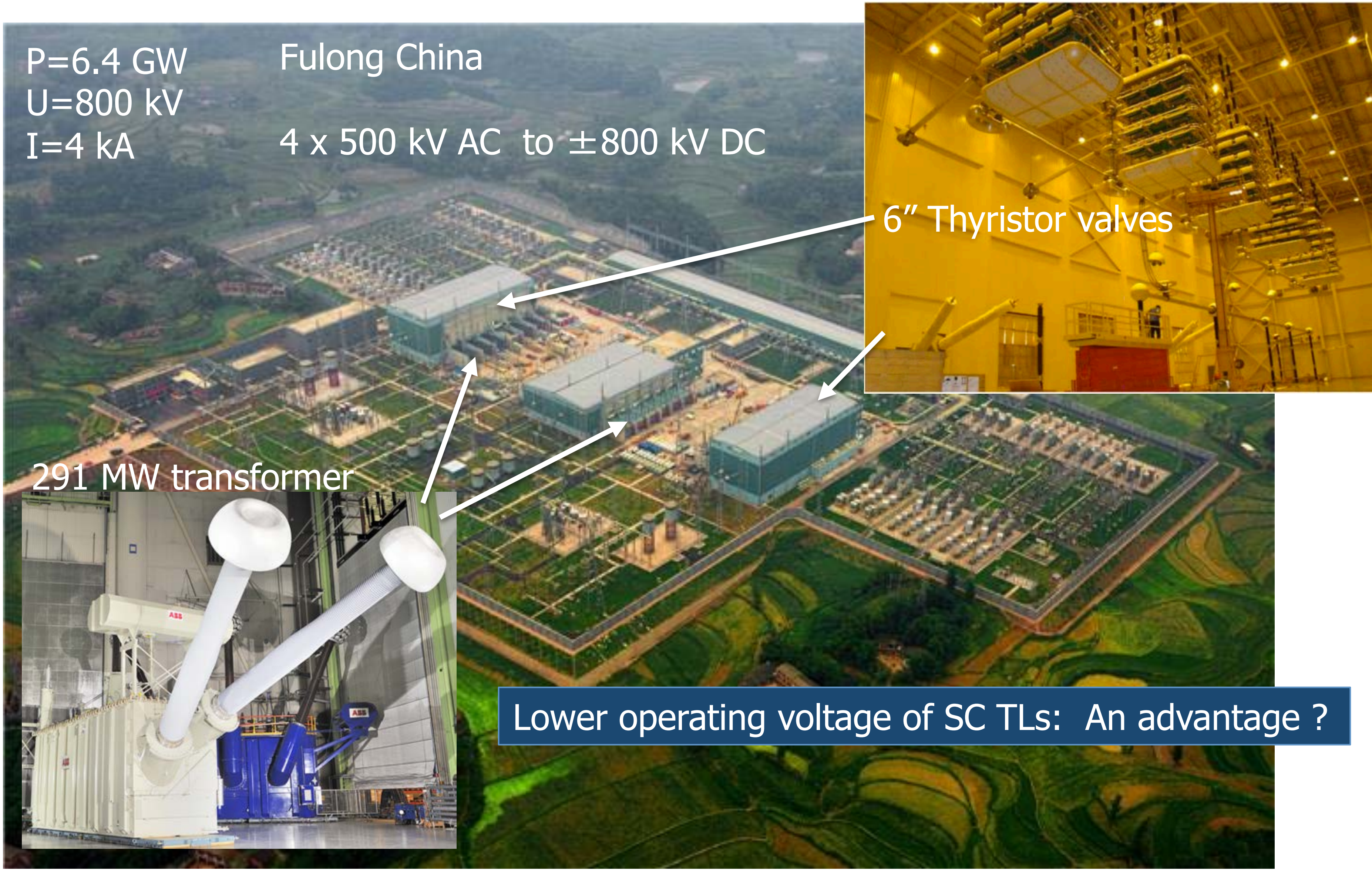
Indicative costs – Comparison of 3000 km energy transmission options

Capital costs	MgB_2 LH2	MgB_2 GHe + LN2	HTS cable	±800kV HVDC OHL	±320kV HVDC Cable
Net capacity of transmission [GW]	10.00	10.00	10.00	10.00	10.00
Installed capacity [GW]	10.11	10.04	10.03	10.64	12.20
Transmission line, [M$/(10 GW x km)]	2.10	3.89	7.64[1]	4.04[2]	11.66[3]
Transmission line costs	6,373	11,700	22,992	12,892	42,662
Converter	4,022	4,007	4,005	4,127	4,439
Total capital costs (COC) [M$]	**~10,000**	**~16,000**	**~27,000**	**~17,000**	**~47,000**



[1] EPRI (2009)
[2] Bahrmann, ABB (2009)
[3] BMU-Study HVDC-cables (2012)

AC-DC Converter

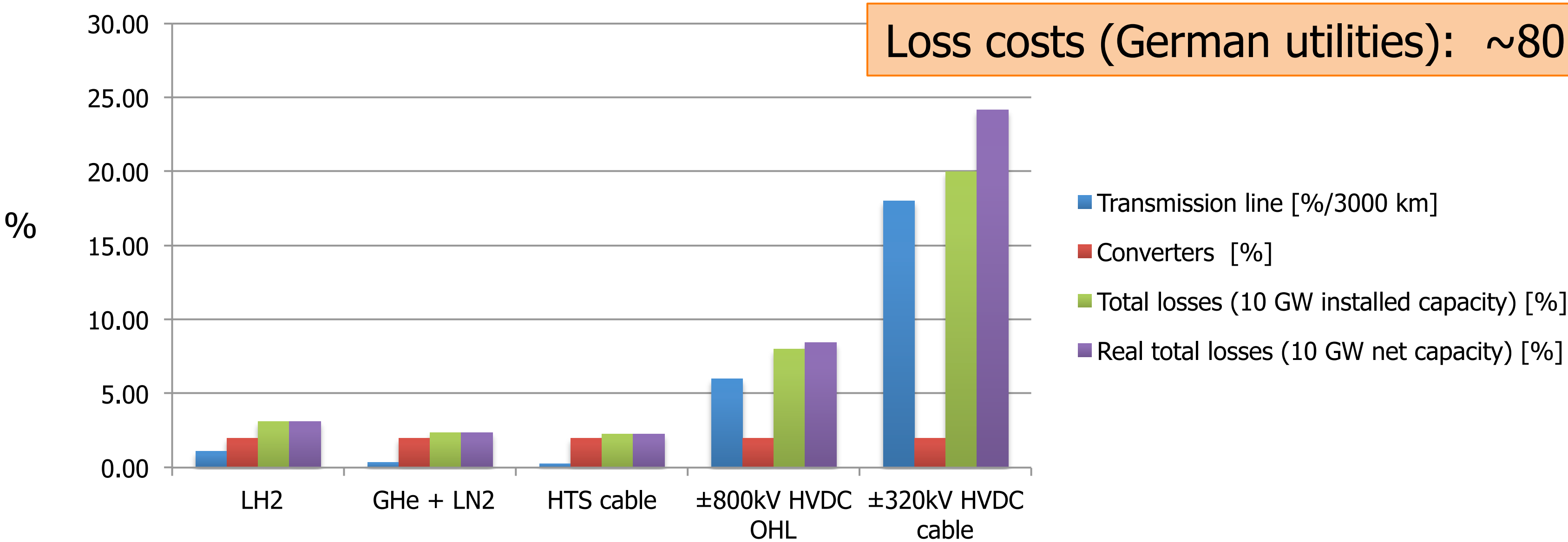


Lower operating voltage of SC TLs: An advantage ?

Indicative costs due to electrical/transmission losses

	MgB_2 LH2	MgB_2 GHe + LN2	HTS cable	±800kV HVDC OHL	±320kV HVDC Cable
Transmission line [%/3000 km]	1.10	0.35	0.27	6.00	18.00
Converters [%]	2.00	2.00	2.00	2.00	2.00
Total losses [%]	3.10	2.35	2.27	8.00	20.00
Real total losses (10 GW net capacity) [%]	3.12	2.35	2.27	8.45	24.17
Total losses [MWh]	2,745,000	2,069,000	1,998,000	7,425,000	21,246,000

Loss costs (German utilities): ~80 $/MWh



Public acceptance

- Visual impact
- Destruction or alteration of the natural landscape
- Possible impact on health
- Environmental impact
- Economic impact and benefits
- Projects of common interest

RETA CA – 500 KV OHL, 75m high towers

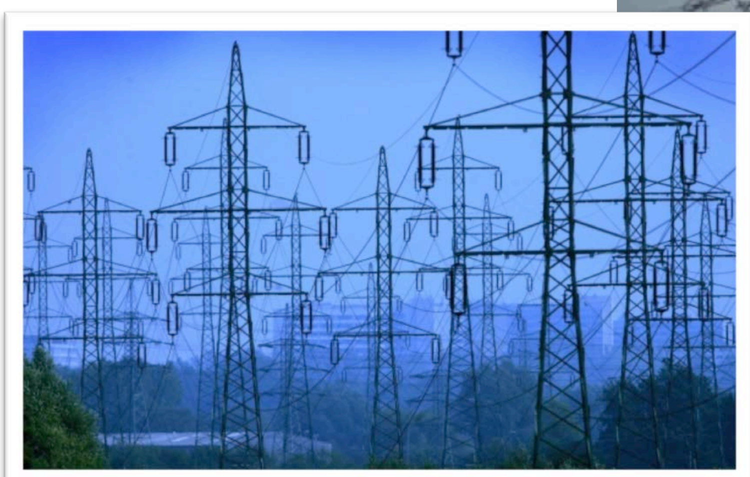
Advantage of superconducting transmission lines relevant to public acceptance:

- Size advantage (~1 m width compared to 25 m for 10 GW standard cables)
- Land use is much smaller
- Low electrical losses (less costs, less CO_2 equivalent emission)

Visual impact

138 KV AC, 574 MW HTS(1G) based
(Long Island Power Authority, Nexans)

±800 KV HVDC, 6.4 GW
Yunnan-Guangdong (Siemens)



380 KV AC, P < 1 GW

Environmental aspects

- Alteration of landscape
- Wetlands
- Woodlands
- Protection of natural habitats
- Electro-magnetic fields
- CO_2 – emission
- Contamination
- …

"Hey Wayne — where's them big b——s suddenly spring up from?"

Cartoon first published 21/7/2011 in Eastern Daily Press. Reproduced by kind permission of the Editor, EDP and Tony Hall

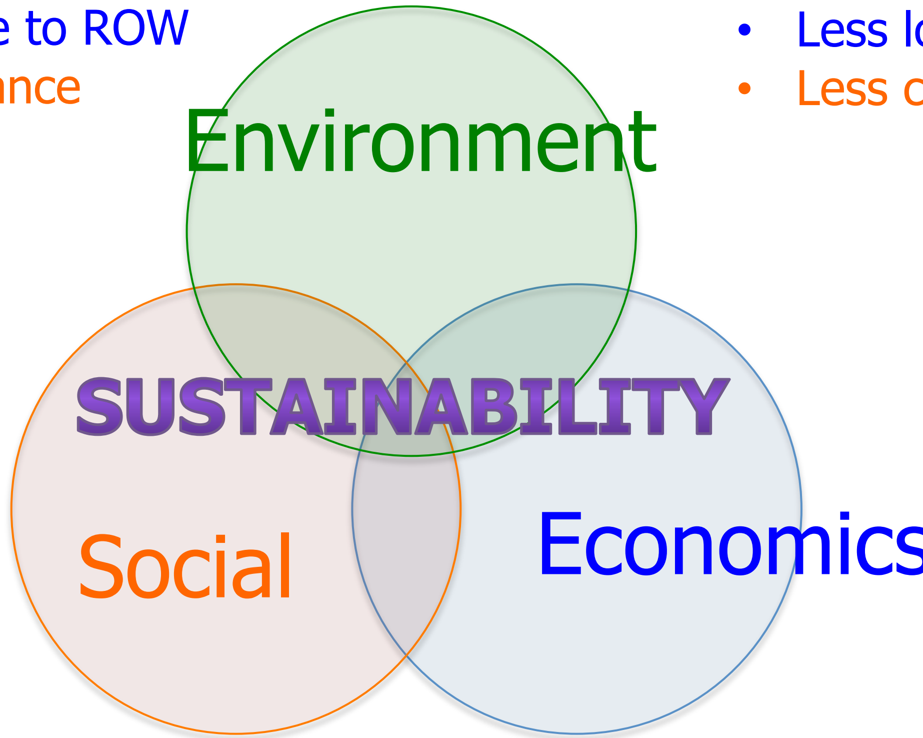
Sustainability

Small size:

- Less impact on environment
- Less costs/delays due to ROW
- Higher public acceptance

Very low electrical losses:

- Less eq. CO_2 emission
- Less loss costs
- Less costs for transmission



Competitive capital and total costs:

- Less costs
- Less extra costs for transmission

It might be the only option:

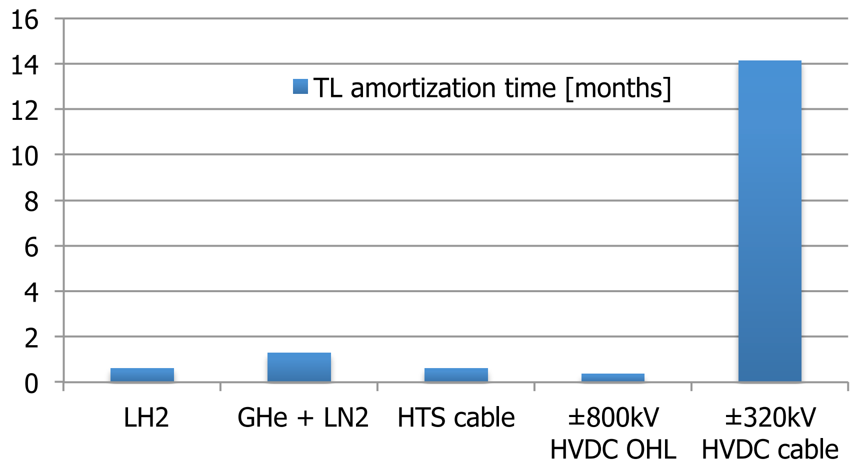
- Size
- Technical design

Energetic amortization time of transmission lines

When does the transferred energy equal the energy consumed to construct the TL ?

$$EAT[a] = \frac{KEA_C}{\frac{E_{net}}{g} - KEA_0}$$

		MgB$_2$ LH2	MgB$_2$ GHe + LN2	HTS cable	±800kV HVDC OHL	±320kV HVDC cable
Total energy needed for construction [GJ]	KEA_C	15,710,809	33,323,860	15,537,990	8,733,754	282,746,195
Energy consumption due to TL losses [GJ/a]	KEA_0	9,883,827	7,451,553	7,194,270	26,729,829	76,488,005
Energy transferred [GJ/a]	E_{net}	316,448,861	316,448,861	316,448,861	316,448,861	316,448,861
TL amortization time [months]		0.615	1.294	0.603	0.362	14.140



Outlook: Next steps

Economic aspects:

- Evaluating lifetime costs
- Impact on electricity price (consumer + industry)
- Cable manufacturing costs

Social aspects:

- Public acceptance (delays due to NIMBY, …)

Environmental aspects:

- CO_2-balance of transmission lines

Others:

- Regulatory framework, EU energy policies
- Include RE power plants (CO_2, energy efficiency, costs, availability)
- Standards (electrical grid,…)