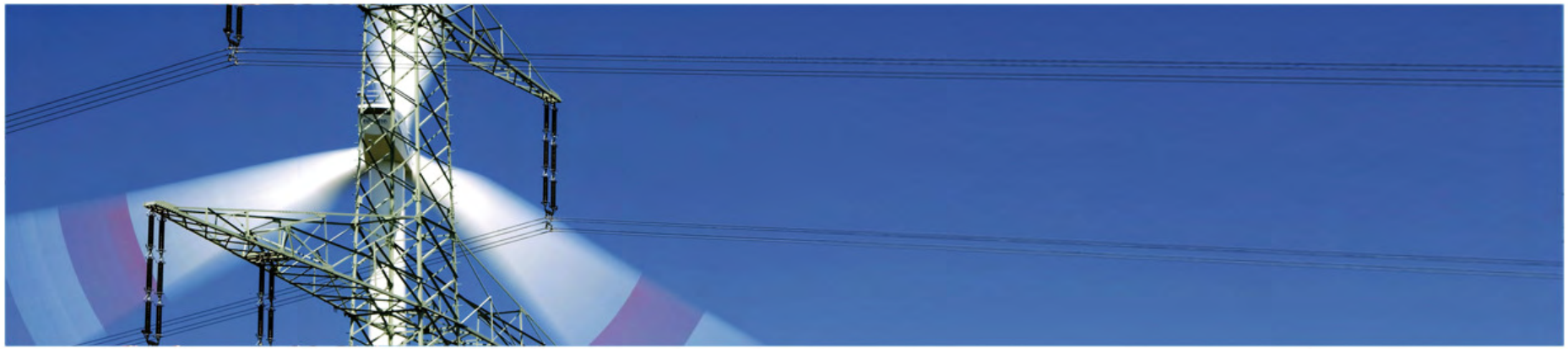


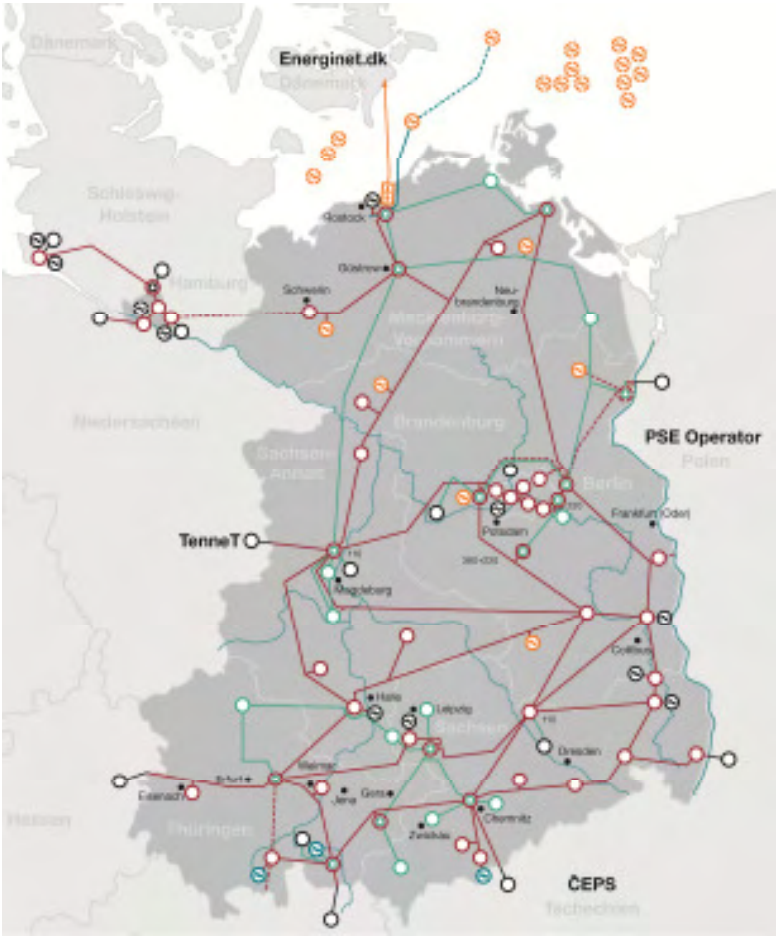
RGI Cable Workshop
Understanding Underground Cables

13 Feb 2013
A workshop kindly hosted by Swissgrid

Wilfried Fischer

50hertz

50Hertz at a glance – Situation at the end of 2012

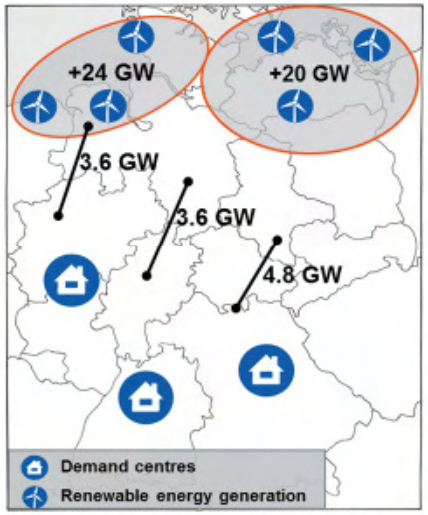


	Value (share of GER)*
Surface	**109.360 km²** (31%)
Total circuit length	**9.980 km** (~28%)
Maximum load	**~ 15 GW** (~18%)
Electricity consumption	**~ 98** TWh** (~20%)
Installed capacity: - thereof RES - thereof wind	**~ 42.700 MW** (~25%) **21.400* MW** (~31%) **12.400* MW** (~41%)
Employees	**760**
Turnover - thereof grid	**€ 6,9 bn** **€ 0,6 bn**

*) As of 1/2013, Source: EEG-Anlagenstammdaten of 50Hertz **) As of 1/2012

Transmission requirements in target year 2022

Transport capacities between north and south



The current north-south routes are already at full capacity in strong wind situations!

44 extra GW generated by 2020
vs.
12 GW new transmission capacity!

Accelerated, more committed grid expansion is required!

Source: 50Hertz Transmission & TenneT GmbH forecasts for 2020

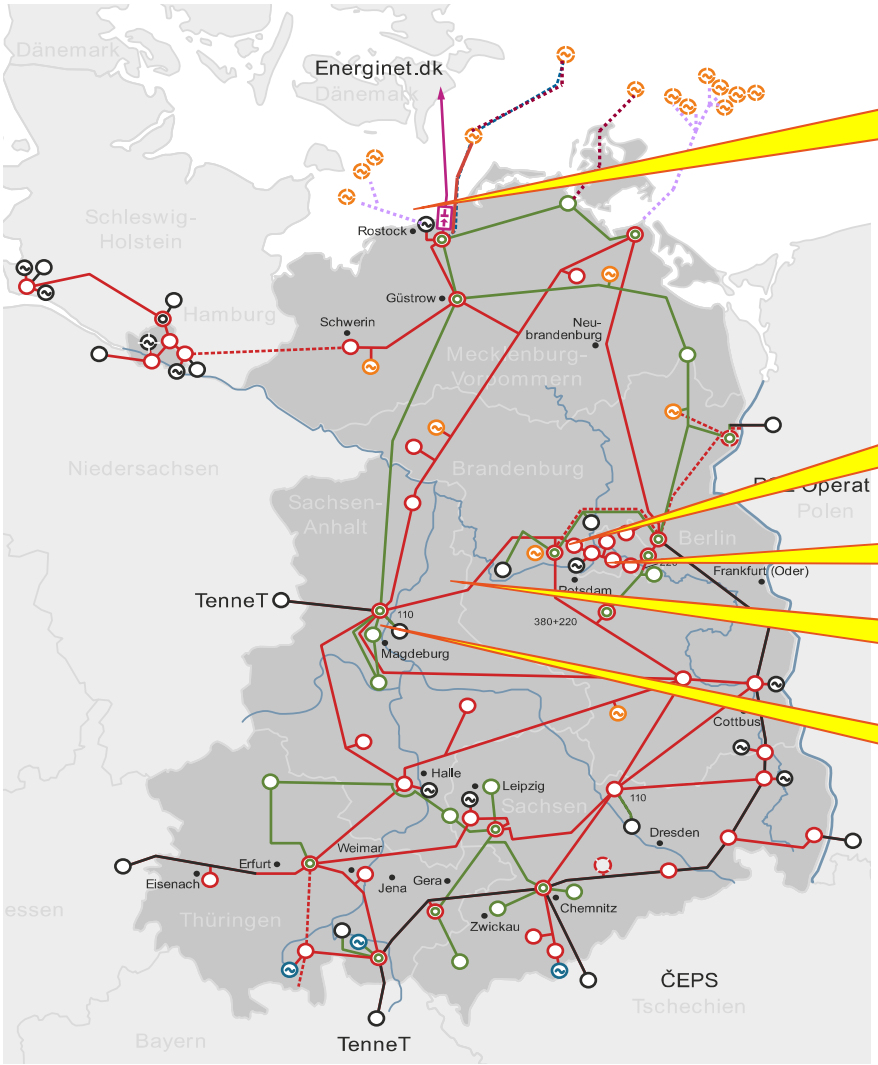
* Line capacities: see document of the German Bundestag 16/10491, statement of reasons for EnLAG

12

LEITSZENARIO B 2022

Source: grid development plan for electricity 2012

50Hertz – cable systems (summary overview)



14 km of 380 kV DC oil-filled cables (underground; 0.6 GW)

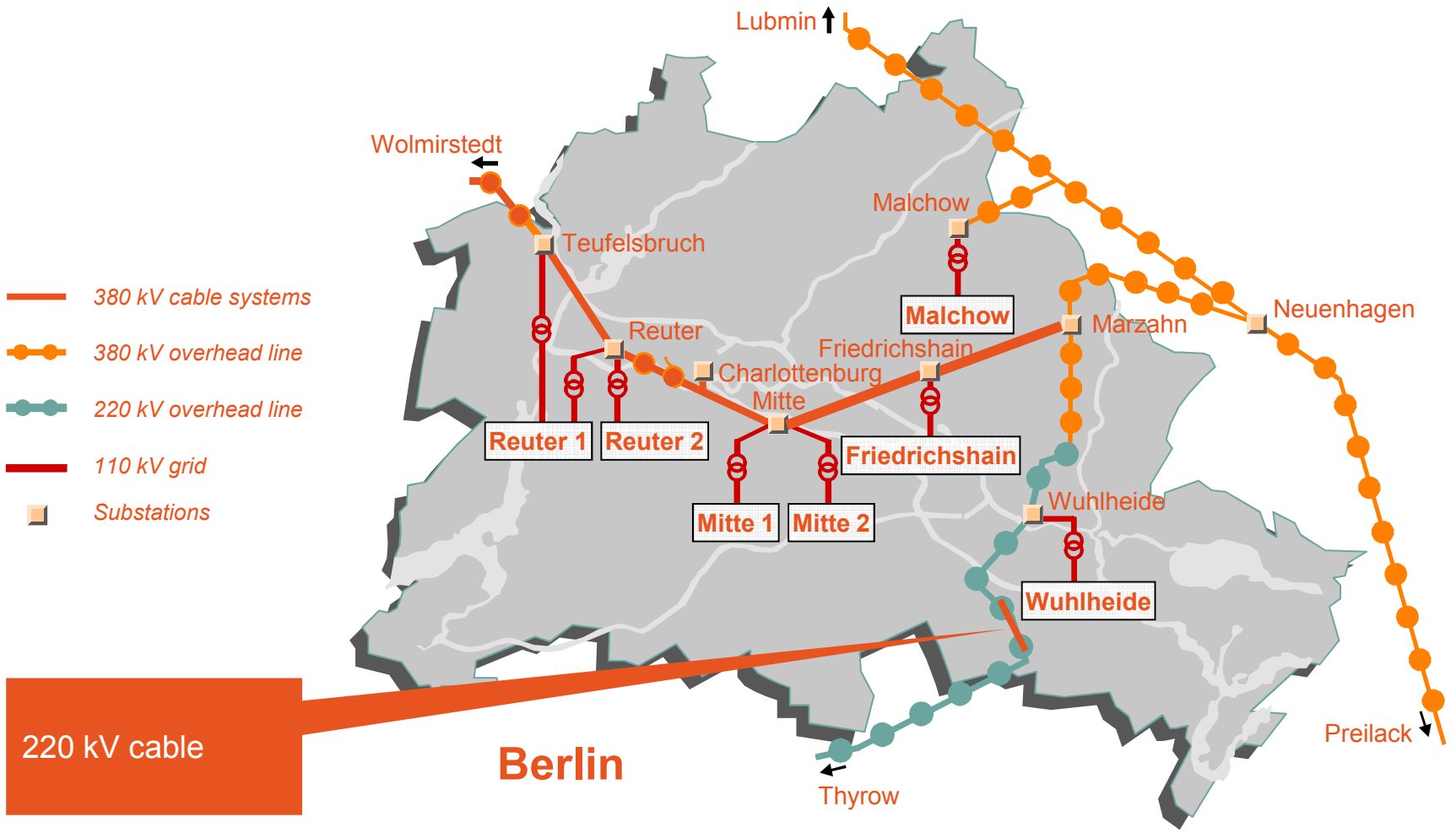
16 km of 380 kV water-cooled oil-filled cables (underground; 1.2 GW)

12 km of 380 kV air-cooled XLPE cables (in tunnel; 1.2 GW)

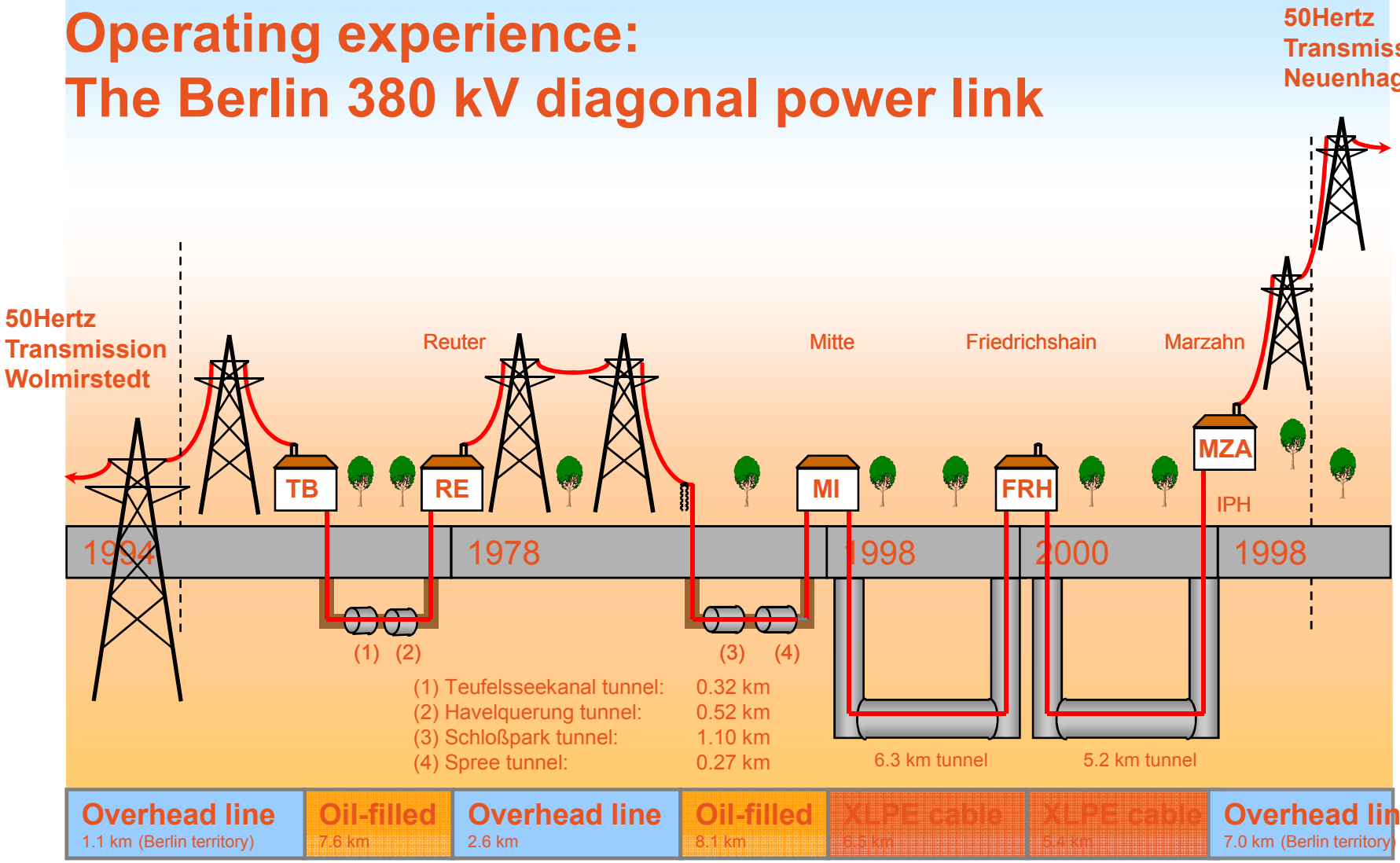
1.8 km of 220 kV XLPE cables (underground; 0.4 GW)

2 km of 110 kV XLPE cables (underground; 0.2 GW) - Elbe Crossing

Power Supply Lines for the city centre of Berlin



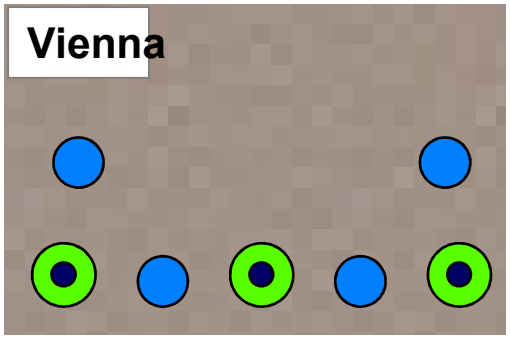
Operating experience:
The Berlin 380 kV diagonal power link



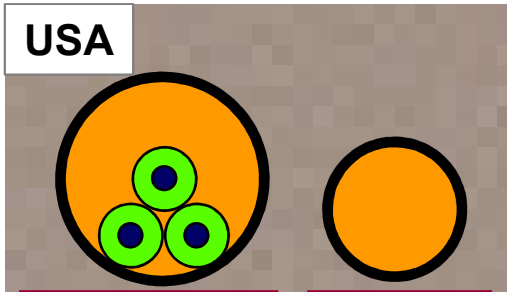
Diagonal power link project

Secured transmission capacity > 1,000 MVA in urban areas using forced draught

indirect water cooling: conductors and cooling pipes in trench

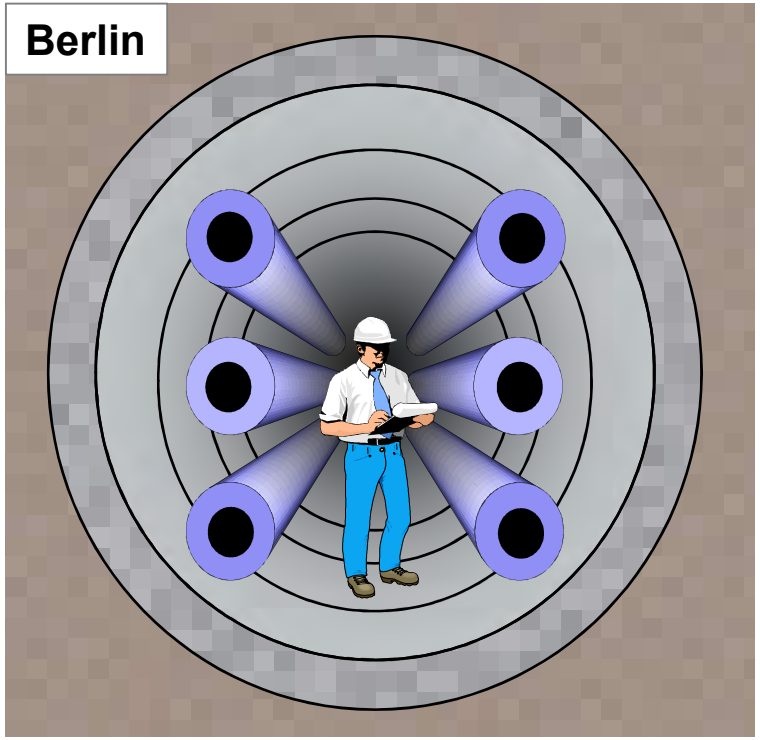


High pressure oil-filled cable, conductors in steel pipe with closed-loop cooling



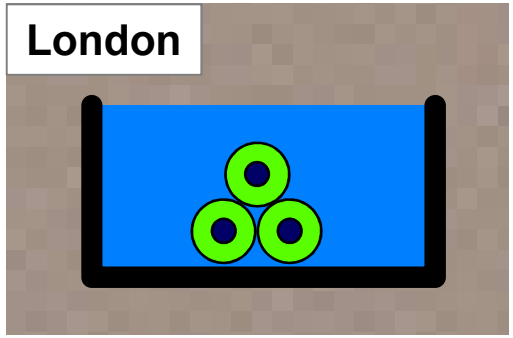
Conductors in steel pipe Overflow pipe

conductors in air-cooled tunnel

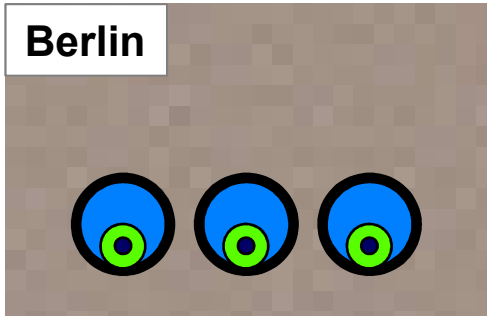


London Madrid

direct water cooling: conductors in water trough



direct water cooling: conductors inside cooling pipes



380 kV diagonal power link

Choice of transmission technology

Oil-filled cable

- over 20 years of very good operating experience

XLPE cable

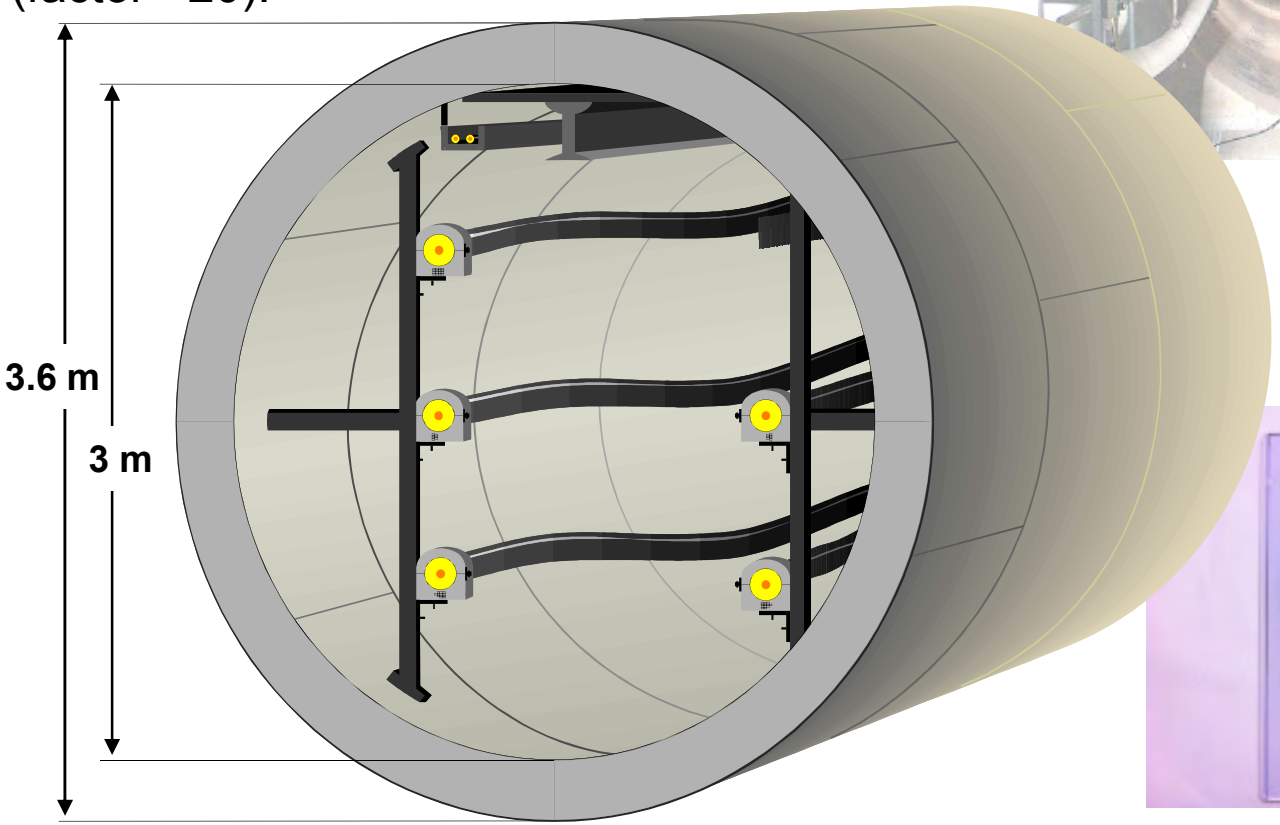
- 380 kV synthetic cable new cable technology for extra high voltage
- Limited operating experience

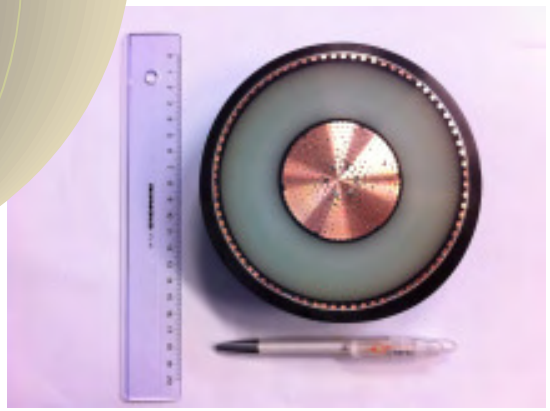
GIL

- SF6 content in insulating gas < 20%
- losses reduced
- lower maintenance costs
- less operating experience

380 kV diagonal power link, cross-section of tunnel

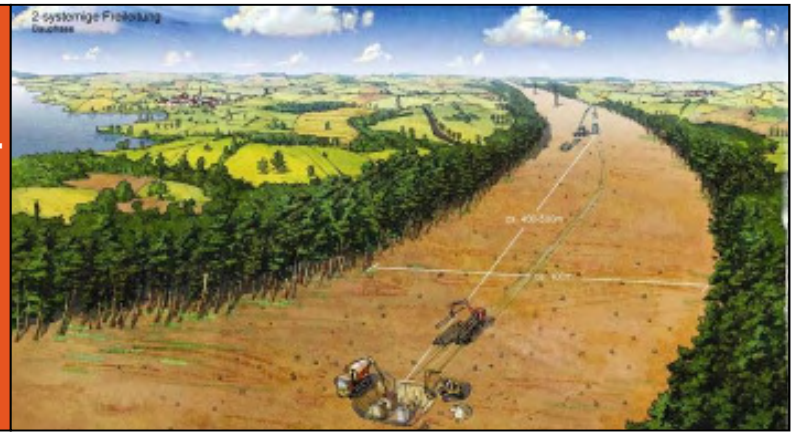
Not cost-efficient under normal circumstances due to significantly higher construction costs (factor >20).





380 kV overhead line (2.4 GW) at different time stages

Construction phase



Completion

After 10 years

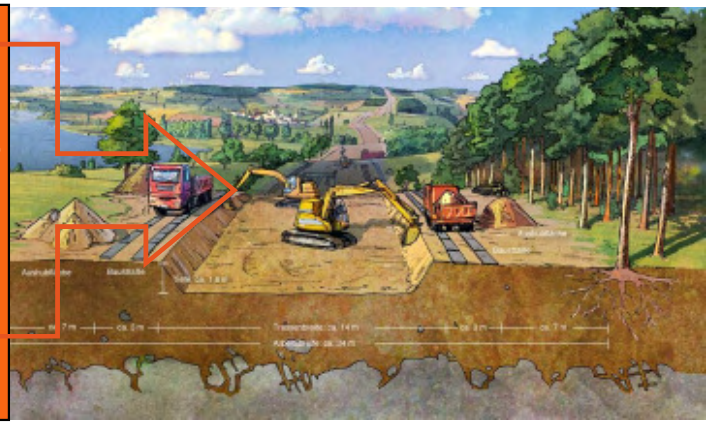
After 20 years

Source: cable study Rennsteig crossing 50Hertz 2009

380 kV underground cable route (2.4 GW) at different time stages

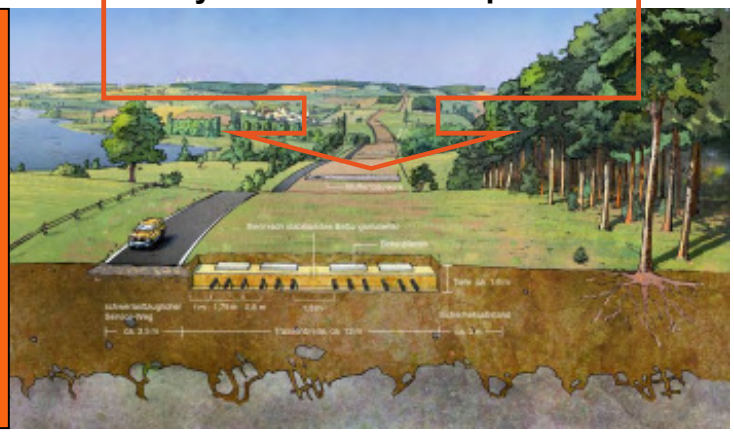
Ground heat exchange (thermal conductivity)

Construction phase



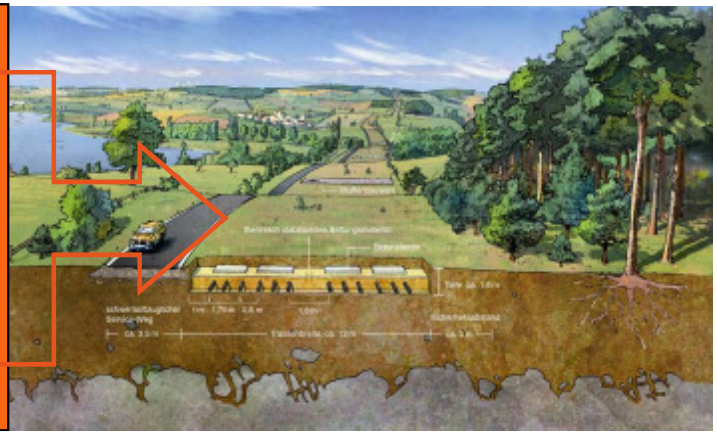
Every 600-800 m: cable pits

Completion



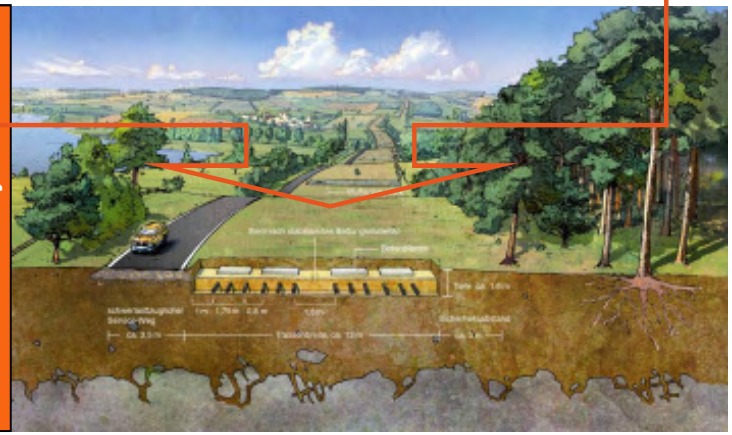
Thermal stabilisation, e.g. using lean concrete slab

After 10 years



Cable route cover: soil, grass

After 20 years



Source: cable study Rennsteig crossing 50Hertz 2009

Transition of a 380 kV overhead line to an underground cable

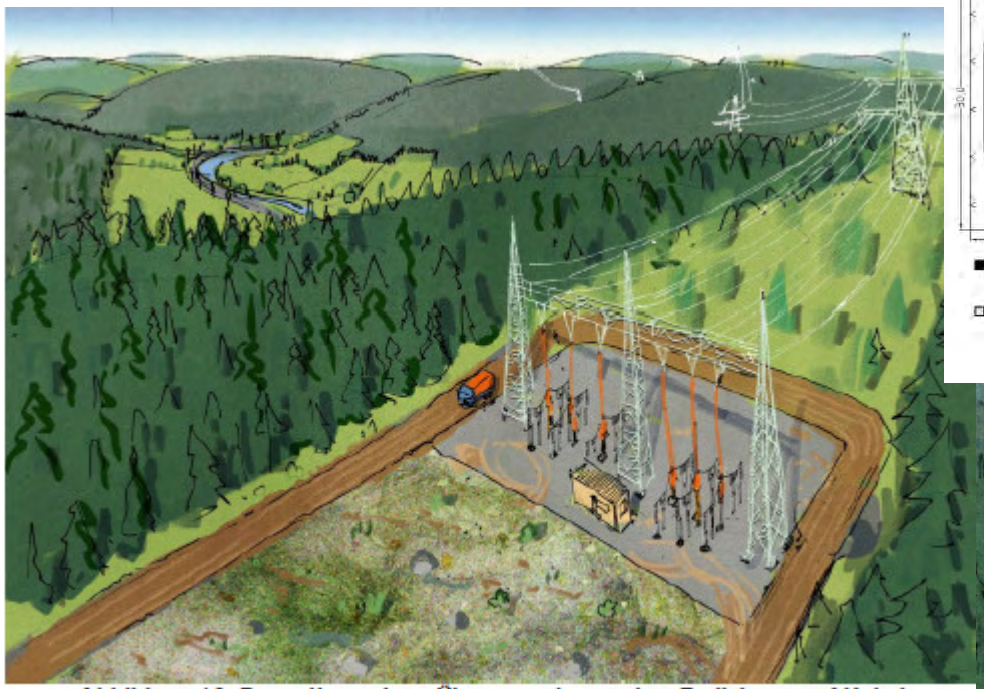


Abbildung 16: Darstellung eines Übergangsbauwerkes Freileitung auf Kabel für eine 2-systemige Übertragungsleitung

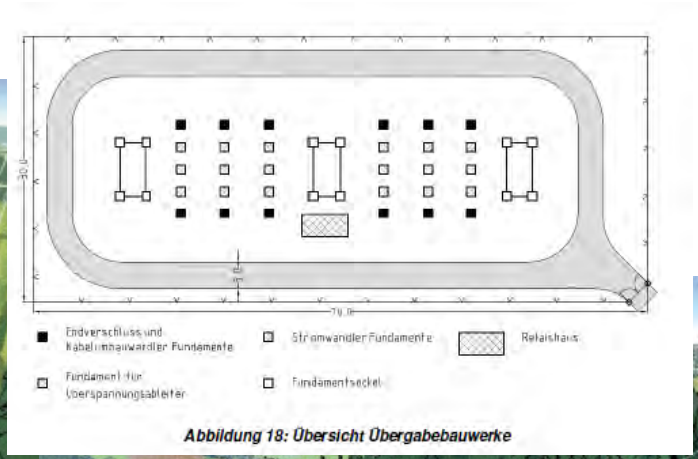


Abbildung 18: Übersicht Übergabebauwerke

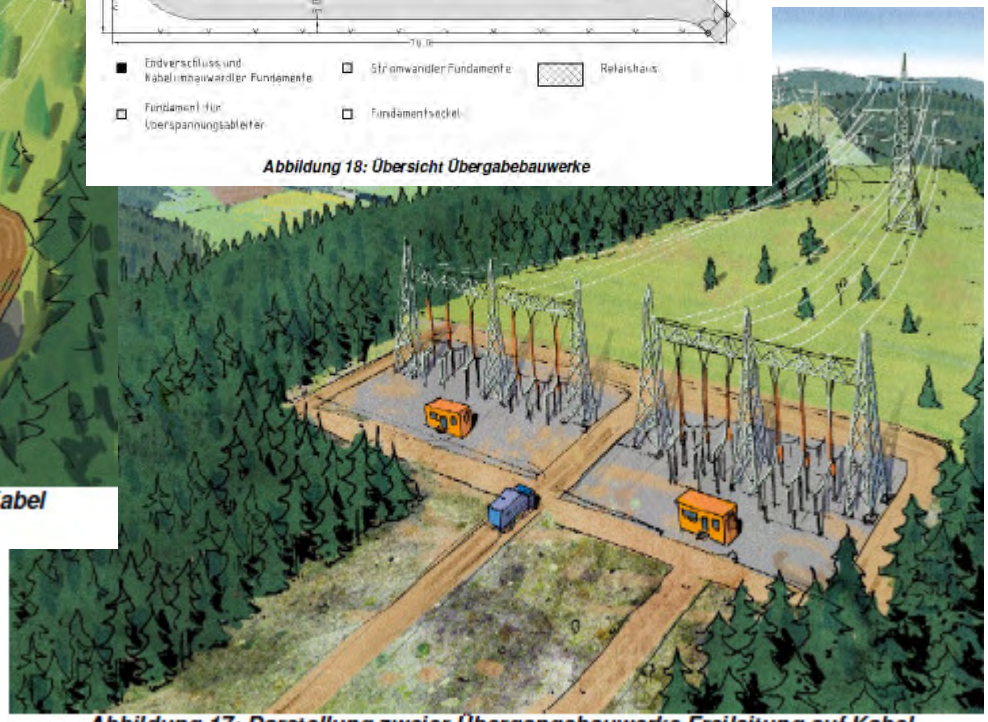
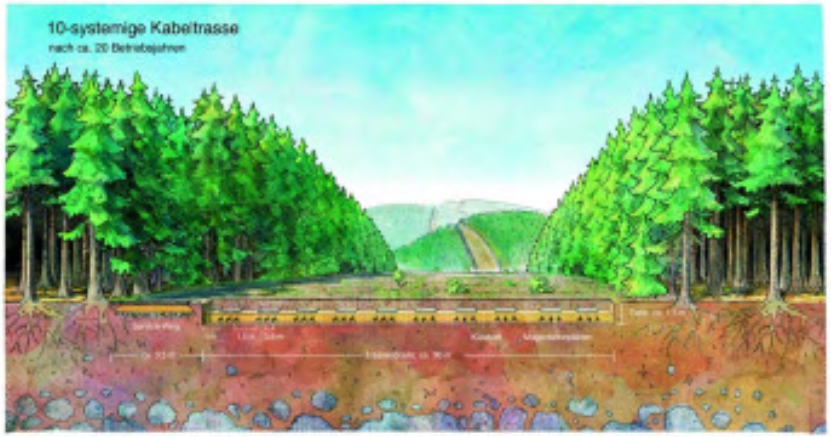


Abbildung 17: Darstellung zweier Übergangsbauwerke Freileitung auf Kabel für eine 4-systemige Übertragungsleitung

Source: cable study Rennsteig crossing 50Hertz 2009

Risks and opportunities of underground cables at 380 kV level

Acceptance



- Expectations: preserving the landscape
- Actual solutions rather disappointing or expensive;
- The problem is the spatial impact:
  - Open aisles cannot be built on or cultivated
  - Only limited plant growth possible due to lean concrete slab (production of an allotment garden; usefulness for agricultural purposes reduced)
- Local acceptance varies substantially before and after presentation of actual plans

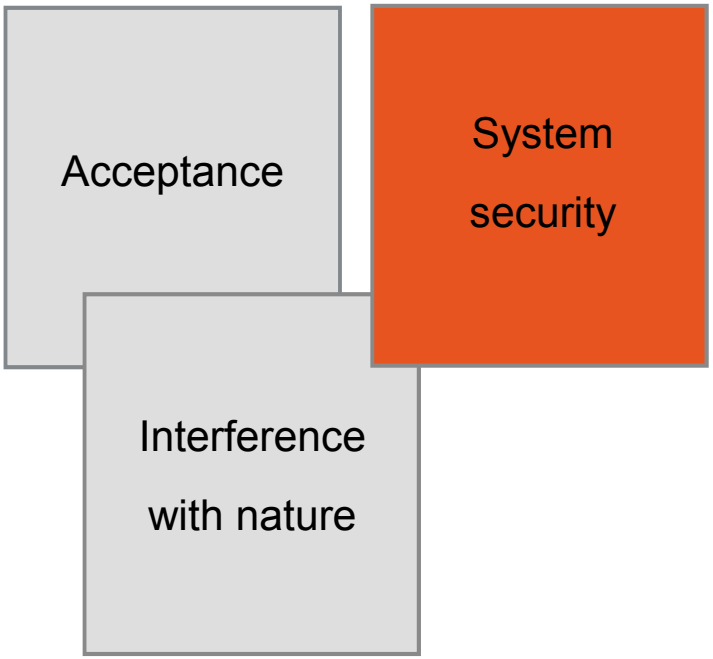
Risks and opportunities of underground cables at 380 kV level

Acceptance

Interference with nature

- Access roads need to be built and maintained (heavy transports)
- Large amounts of soil need to be dug off and replaced (thermal conductivity)
- Planting/cultivation is only possible to a limited degree
- Visual impact: very wide cable aisles and cable pits where necessary
- Conservation of species and nature might be more strongly affected.
- Lower degree of acceptance by authorities and environmental protection associations

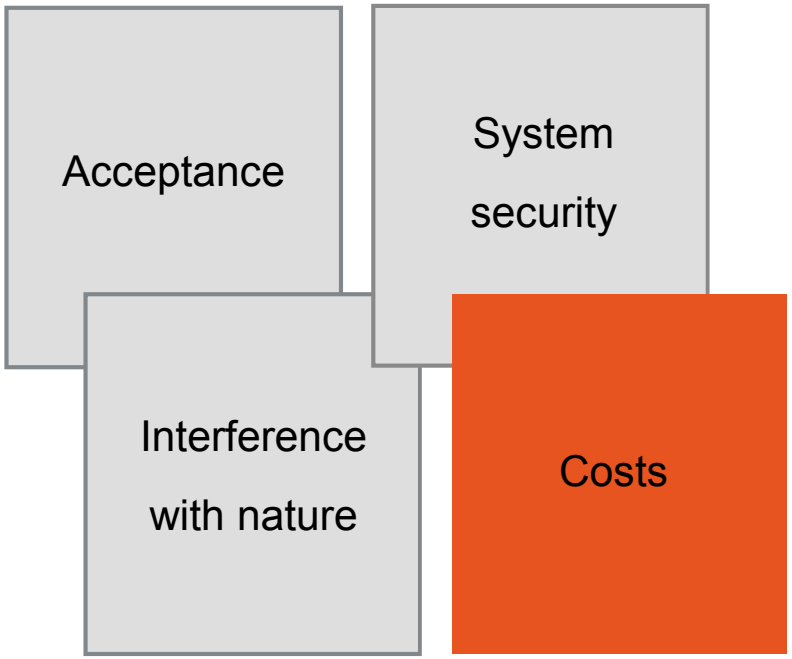
Risks and opportunities of underground cables at 380 kV level



	Underground cable system	Overhead line
Availability	~ 90 %	98 – 99 %
Life span	Pilot phase / 40 years targeted	Approx. 80 years
Vulnerability to natural phenomena	low	higher
Fault analysis	difficult	easy
Downtime (duration)	Experience: up to 18 months	Hours up to days
(n-1) security	Due to downtime, additional measures are required (reserve)	Standard, no additional measures

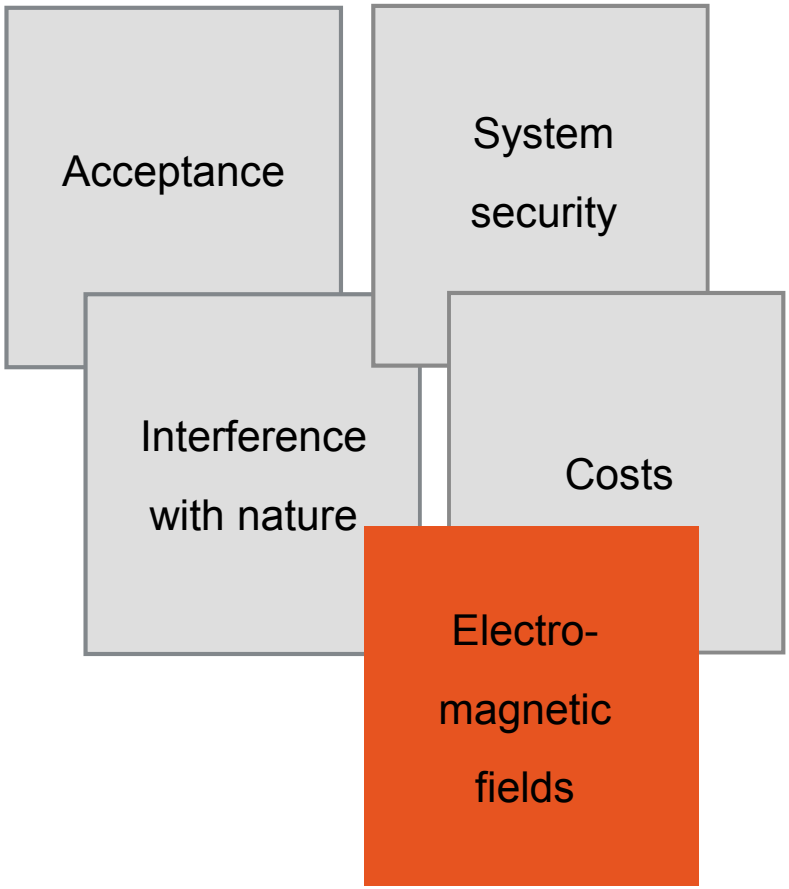
The use of underground cables changes the prevailing security philosophy

Risks and opportunities of underground cables at 380 kV level



- Less energy might be lost
- Investment costs: factor 5-10 for underground cables, 20-30 for tunnel cables
- Until now: shorter system life span
- Additional costs in case of intensified use due to influence on security philosophy

Risks and opportunities of underground cables at 380 kV level



- Electrical field almost 0 kV/m owing to cable shielding and soil
- Magnetic fields are not shielded: in case of horizontal arrangement, approx. 60-90 µT
  → admissible limit in accordance with 26th federal emission control act: 100 µT
- However: the magnetic field is already significantly weaker some metres away from the centre line of the cables

Conclusions from the EnLAG project in Thuringia

Excerpts from the regional planning assessment (30/03/2011)

Official guideline:
No underground cables along the Rennsteig, an underground cable study has however been ordered for more densely populated areas along the line.

- The underground cable solution along the Rennsteig is rejected by the spatial planning authority for reasons of monument protection and species and nature conservation.
- Advantage: better visual effect from a distance
- However, the visual impact remains obvious up close.
- „As regards species conservation, a cable system can be considered significantly less favourable as the overhead line: inconveniencing construction works can take long, the current forest biotope is permanently altered, and no forest growth is possible over a width of some 60 metres.“

50Hertz's experience with 380 kV cable systems

- As opposed to lower voltage levels, 380 kV cable systems are not yet state-of-the-art.

- So far, feasibility studies and approval procedures have not indicated any added value for underground cable solutions in nature reserves. A study on underground cables in more built-up areas seems more suitable to increase acceptance.

- Based on our current experience, the local installation of underground cables does not automatically increase acceptance of a line project.
- An appraisal of the effects on nature, man, costs and system security is necessary in every individual case.
- The decision is up to the stakeholders.

Be renewable and smart at any times !

Now it‘s time for Q&A

What are the possible approaches?

220 kV / 380 kV grid

Optimisation	→	**Enhancement**	→	**Expansion**
Load flow control		Upgrade to higher voltages		Overhead line
Temperature-dependent line operation		High temperature conductors		Cables