Die Berater der Energie- und Wasserwirtschaft

Overhead Lines and Underground Cables – Potential Benefits of partial undergrounding

Unterzeile

Dr. Michael Ritzau

RGI Cable Workshop "Understanding Underground Cables", Zurich, February 13th, 2013

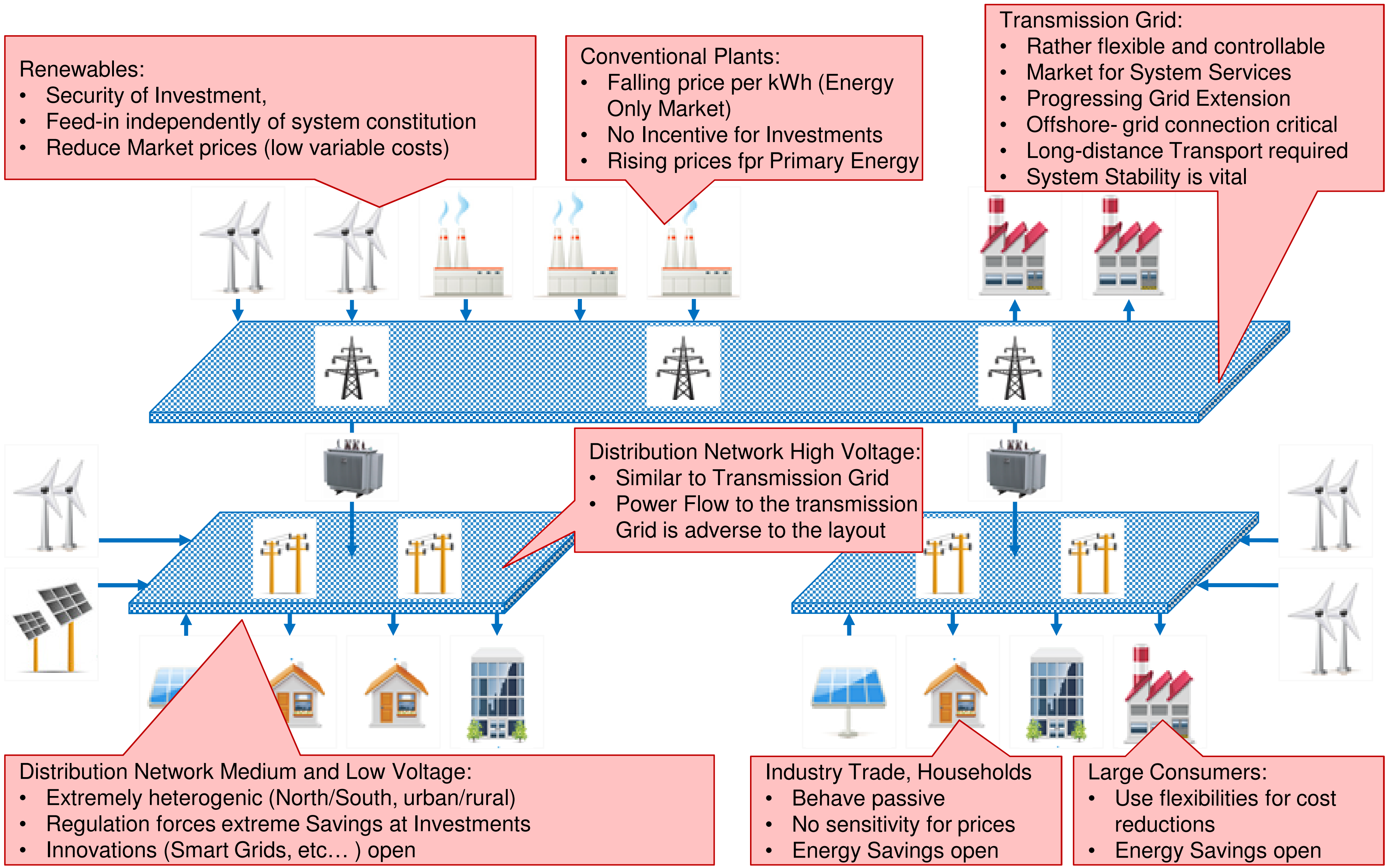
About me

Dr.-Ing. Michael Ritzau

- Born in 1956
- Graduated in electrical engineering at the RWTH Aachen
- Doctorate in engineering (1989) at the Institute for Electrical Plant and Power Industry
- 1988 co-founder and managing director of BET-Büro für Energiewirtschaft und Technische Planung GmbH in Aachen
- Fields of expertise:
  - Energy markets
  - Economic and technical feasibility of power plant projects (fossil fuels and renewables)
  - Net access for power plants & electrical grids
  - Councelling in strategic, energy-related matters for decision makers
- Member of the panel for energy policy in the German Wirtschaftsrat (economic counsel)
- Member of the Fuel & Water Commitee in the VIK

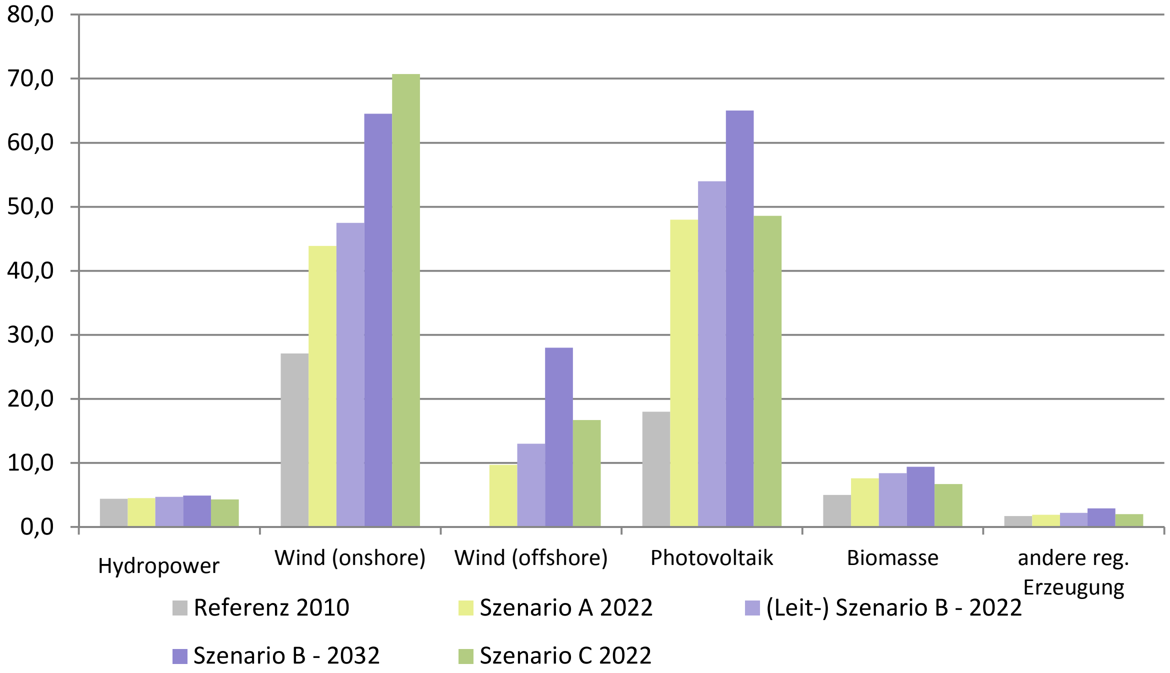
Content

Tasks in an Overview



2011 -2012: National Transmission Development Plan 2012
(Netzentwicklungsplan 2012)

Installed Capacity of Renewables [GW]



Scenario A: moderate

Scenario B: medium

Scenario C: strong

Share of Renewables :

Scenario A	44 %
Scenario B	50 %
Scenario B – 2032	69 %
Scenario C	58 %

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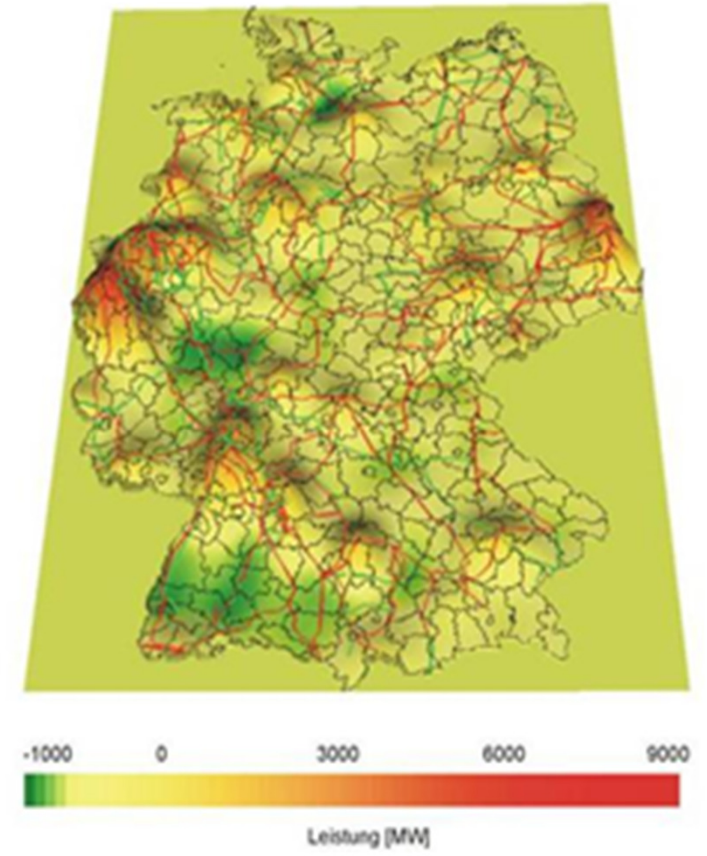
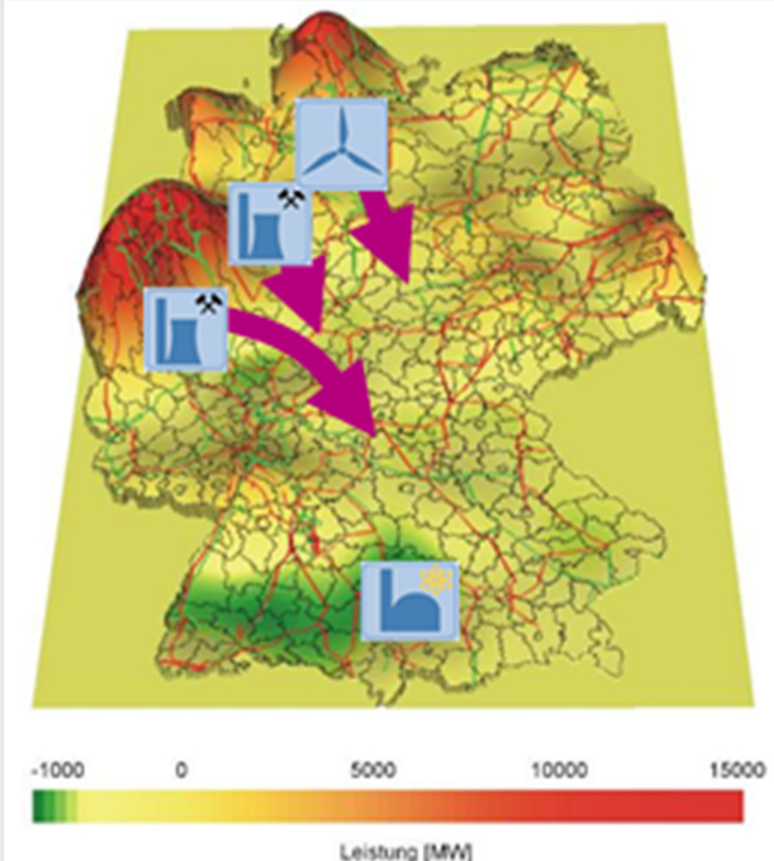
Huge increase of load flows driven by wind in the north and nucelar shut downs in the south



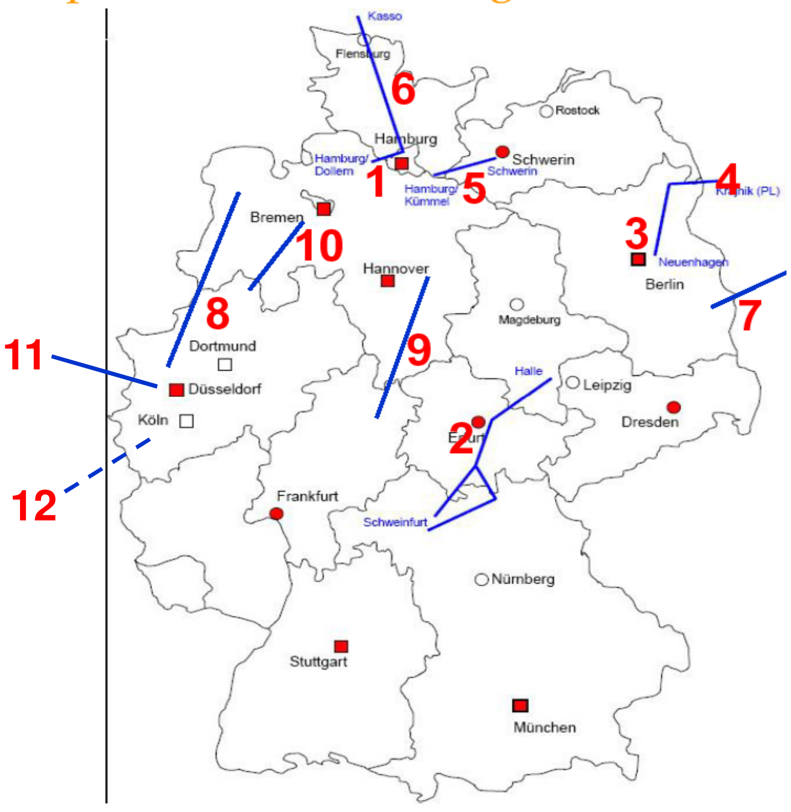


Source: Amprion

Bottlenecks lead to nearly daily redispatcg requirements !

2003 – 2005 : DENA Grid Study 1

Geplanter Netzausbau gemäß Vorrangiger Verbundplan und dena-Netzstudie I.



Quelle: BNetzA 2008 und dena 2005

Priority Network Plan (2013) and DENA Grid Study (2015)

1. Hamburg/Nord-Dollern 45 km
2. Halle-Schweinfurt 220 km
3. Neuenhagen-Bertikow/Vierraden 110 km

Only Priority Grid Plan

4. Bertikow/Vierraden-Krjnik (PL) 15 km
5. Hamburg/Krümmel-Schwerin 90 km
6. Kasso (DK)-Hamburg/Nord 170 km
7. Preilack (DE)-Bczyna (PL) 65 km

Only DENA Grid Study I

8. Diele-Niederrhein 200 km
9. Wahle-Mecklar 190 km
10. Ganderkesee-Wehrendorf 80 km

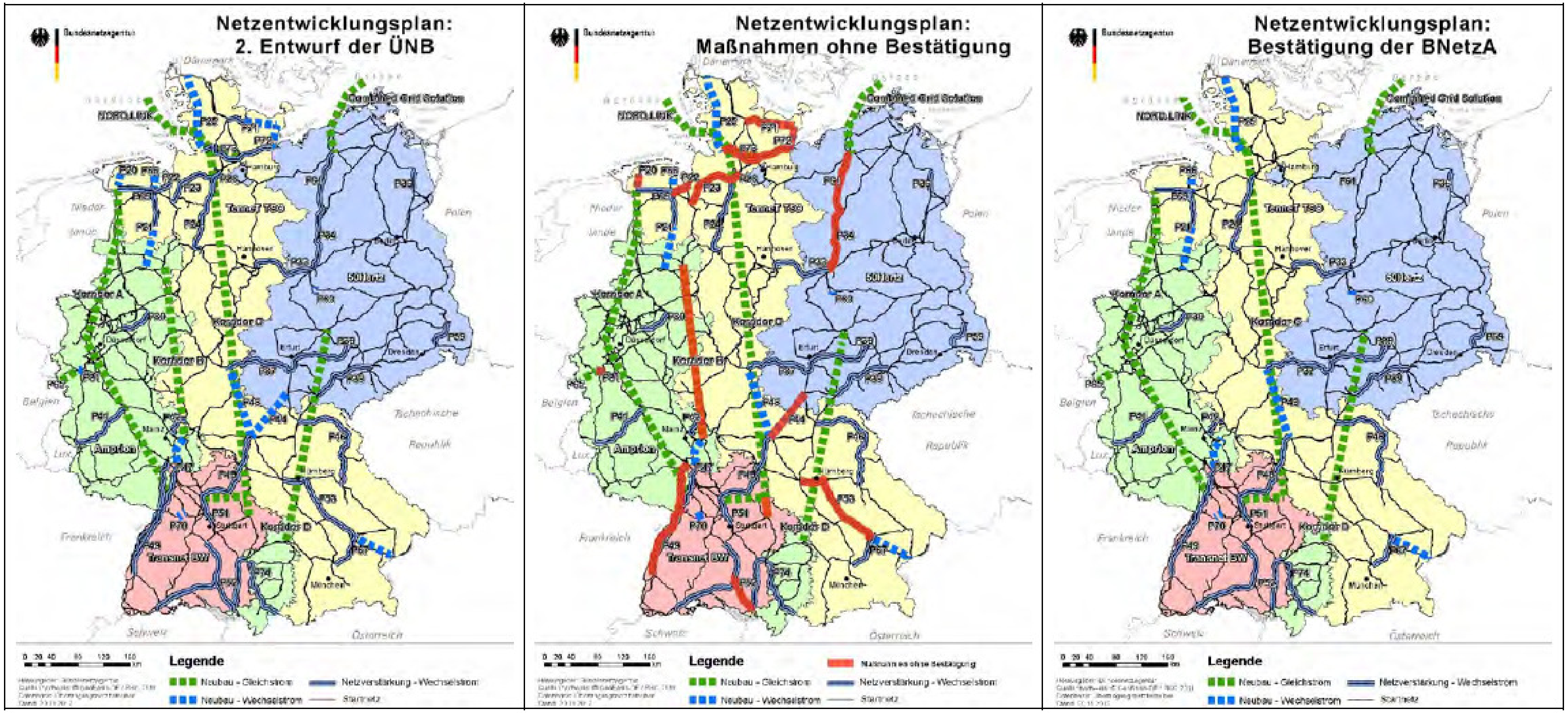
Construction transmission lines total 1.185 km

11. Connection Amprion - Tennet
12. Connection Amprion – Elia

Some 1,200 km AC OHL Extension - but 280 km realized within 8 years

Source: Dena-Grid Study 1, additional information provided by the TSO, own research

Applied and approved German national grid development plan



2,800 km additional grid extension to integrate 50 % Renewables

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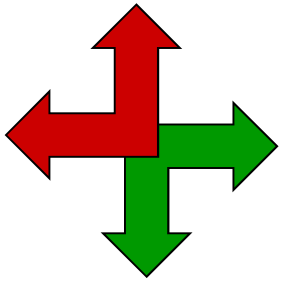
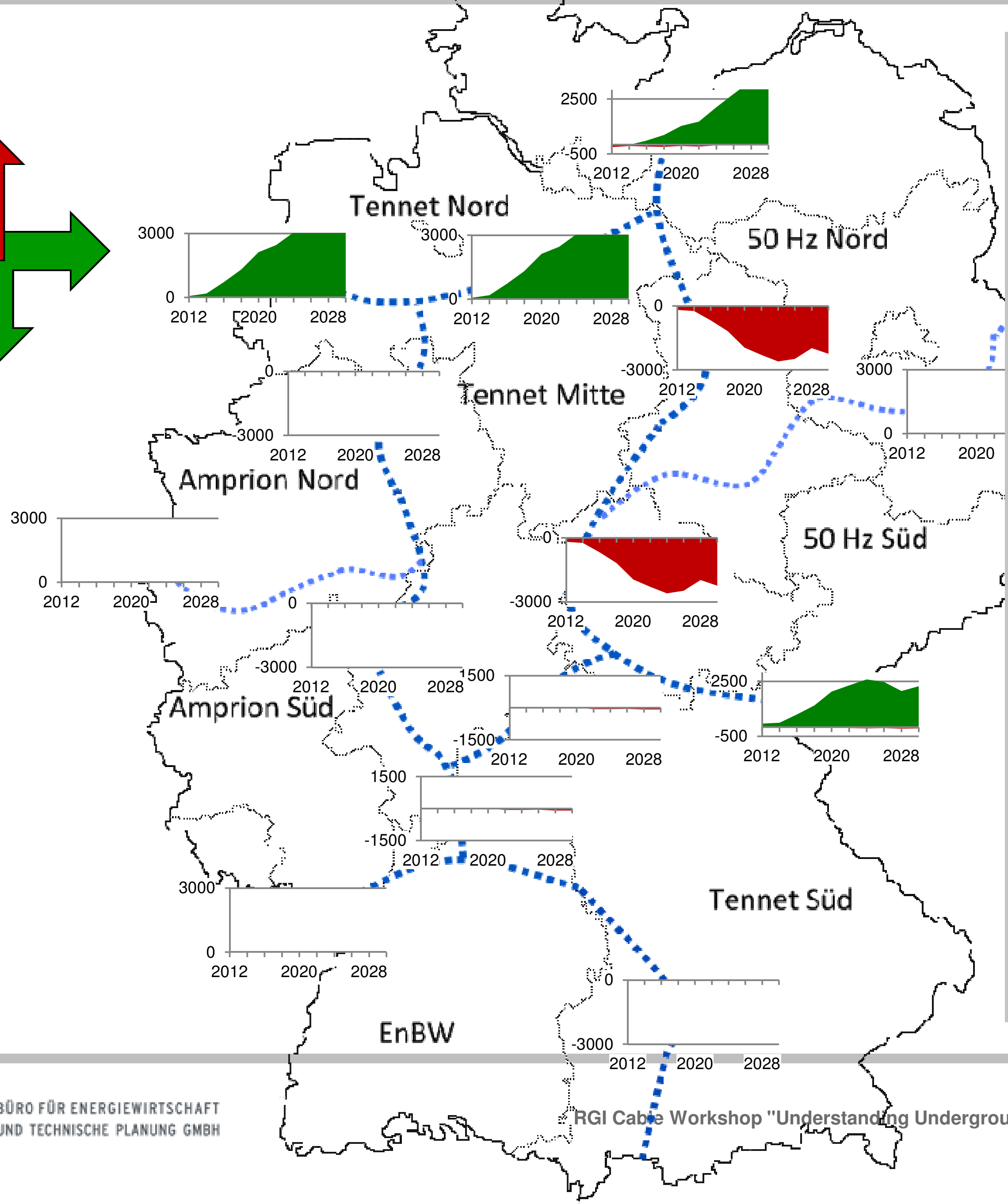
No Grid Extension => Massive curtailments !





Annahme zum Netz:

- Status quo 2011
  + Krümmel-Görries
- No further extensions

Results:

- Bottlenecks > 3.000 h/a
- North –south
- East -west

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Motivation of study for BMU

- Massive Grid extension to integrate renewables
  - Fast grid extension required
  - If not: Massive curtailments !
  - Accelaration of Overhead Lines Permits
    - EnLAG – Energieleitungsausbaugesetz – partial underground cables
    - Bundesbedarfsplan

- **What ist the potential benefit of accelaration of grid extension ?**

Partial Undergrounding might be a suitable approach

Challenges of 380 kV HV underground cables

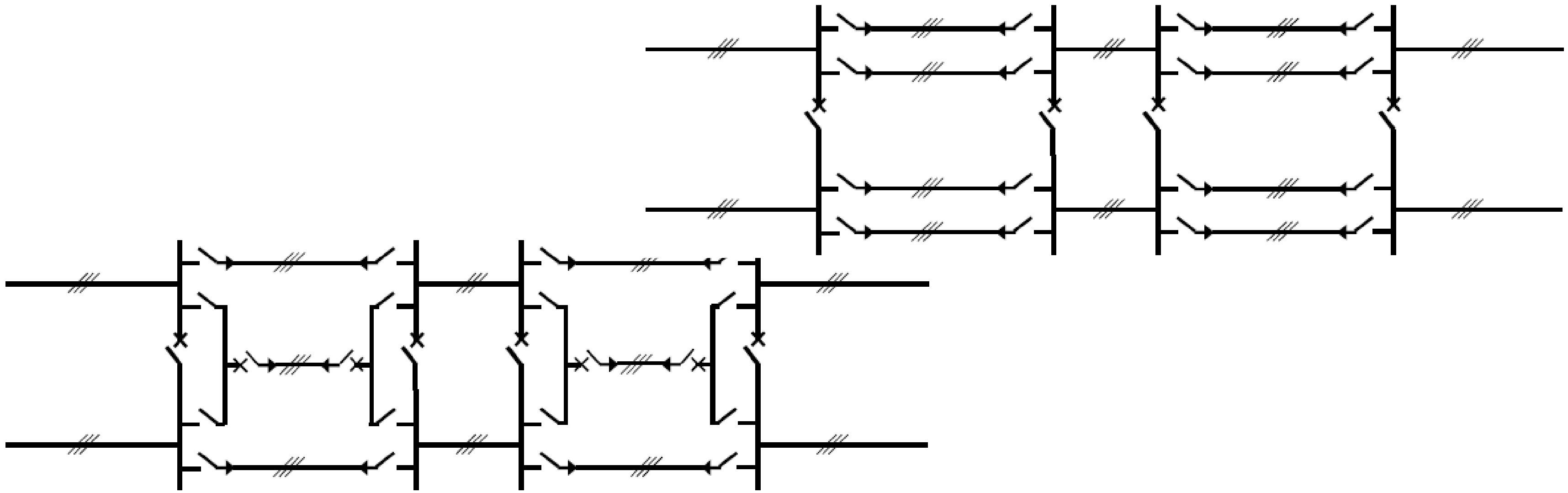
- Overhead lines are standard in tramsmission grid
  - There is a longer history of technical usage compared to buried cables
  - On 380 kV level the share of buried cable is
    - around 1,2 % in Europe (ENTSO-E)
    - and smaller than 0,4 % in Germany

- In comparison to traditional overhead lines buried cables got:
  - A longer breakdown and maintenance duration
    - Statistic show a longer breakdown duration by factor 25
  - Higher capacity is necessary
    - Power factor correction is needed for buried cables longer than 10 km
  - More expensive investment costs
    - Buried cables are depending on the specific layout several times more expensive in comparison to overhead lines for the same transmission function

Not a lot of experience with HV underground cables

Systemic view of partial cabling I

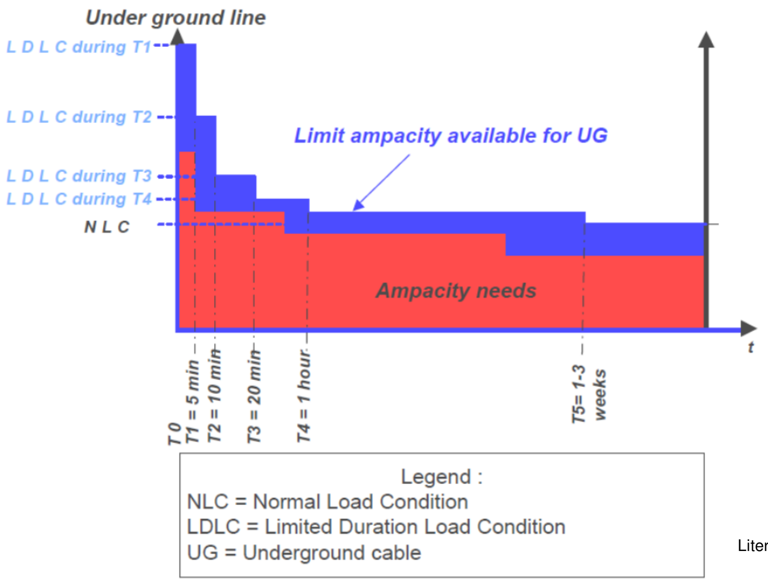
- Impact of a longer breakdown and maintenance duration
  - Due to the (n-1)-criteria security of supply is not immediately influenced
  - With partial cabling there are often more cable systems required compared to overhead lines because of the lower transmission capacity
  - ➔ the failure of a cable system doesn‘t lead to a total breakdown of a transmission system



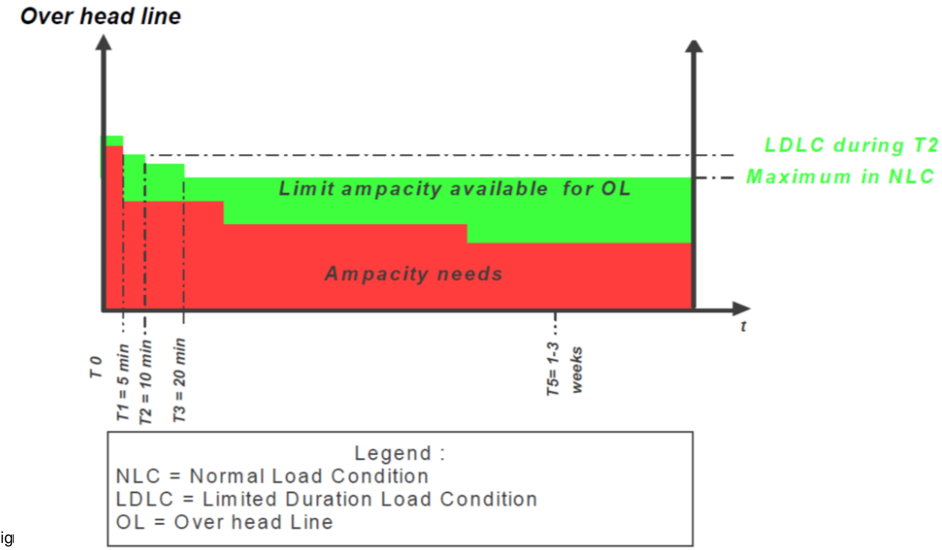
Failure of a cable doesn’t have to affect the transmission system

Systemic view of a part cabling II

- With respect to „General Guidelines for the Integration of a new Underground Cable System in the Network" (Literature Source: Cigré Technical Brochure 250) in (n-1)-cases with partial undergrounding the cable may be overloaded for a acceptable time span
- Potentials have been investigated were appropriate



Literature Sorurce: Cig



Cable overloading capabilities may lead to advantages in failure cases

Systemic view of a part cabling III

- Power factor correction is necessary for HV underground cables longer 10 km
  - Due to the geometrical layout of cables there system behaviour is different from overhead lines
  - Higher technical effort and investment cost result from that difference
  - Additional losses are generated
  - In general, long distance cable transmission is not to be favoured
- All part cabling concepts are planed for less than 10 km so far:
  - Part cabling project ‚Ganderkesee – St. Hülfe‘ by E-On in 2008:
    - 6-7 segments
    - With 1,7 – 8 km
  - Press release by Tennet in July 2011 on ‚Ganderkesee – St. Hülfe‘:
    - 2 segments
    - With 3 – 3,6 km

Partial cabling should be limited to appropriated distances

Systemic view of a part cabling IV

- Comparison of the Investment costs for 2 systems:
  - 68 km overhead lines
  - 60 km overhead lines and 2 underground cabel segments with 3 and 5 km

- Investment costs of the overhead line 68 km (2 systems)
  - 4 x 235/35: 51 Mio. €
  - 4 x 385/35: 58 Mio. €
  - 4 x 560/50: 95 Mio. €

- Part cabling with 3 or 4 cabelsystems(cs)
  - 4 x 235/35 + 3 cs: 123 Mio. €
  - 4x385/35 + 3 KS: 130 Mio. €
  - 4x385/35 + 4 KS: 137 Mio. €
  - 4x560/50 + 4 KS: 170 Mio. €

Cabeling more expensive by factor 1,8 – 2,4

Macroeconomic view on cost

- Grid bottlenecks cause costs for the welfare
- 127 GWh were cut in 2010 that lead to additional costs of 5.6 Mio. € in Germany (with a mean spotprice at EPEX of 44 €/MWh)
- Therefore delayed grid extension will lead to additional costs
- The question comes up if the additional costs for cabeling are acceptable if than a faster grid expension is possible
- The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) assigned a study ‚Grid extension by underground cabeling or overhead lines with special consideration of the feedin of renewables'
  - Download: http://www.erneuerbare-energien.de/inhalt/47934/
  - This study was done by BET (Aachen), IZES (Saarbücken) and PowerEngS(Saarbrücken)

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Not only Invest. Costs have to be assessed while investigating partial cabling

Direct costs of a bottleneck

- $Costs_{Bottleneck} = Costs_{Control\ energy} + Costs_{Redispatch} + cut\ RE * Spotprice_{intraday}$

- Costs for conntrol energy:
  - Power plant technology
  - Location
  - Bidding strategy

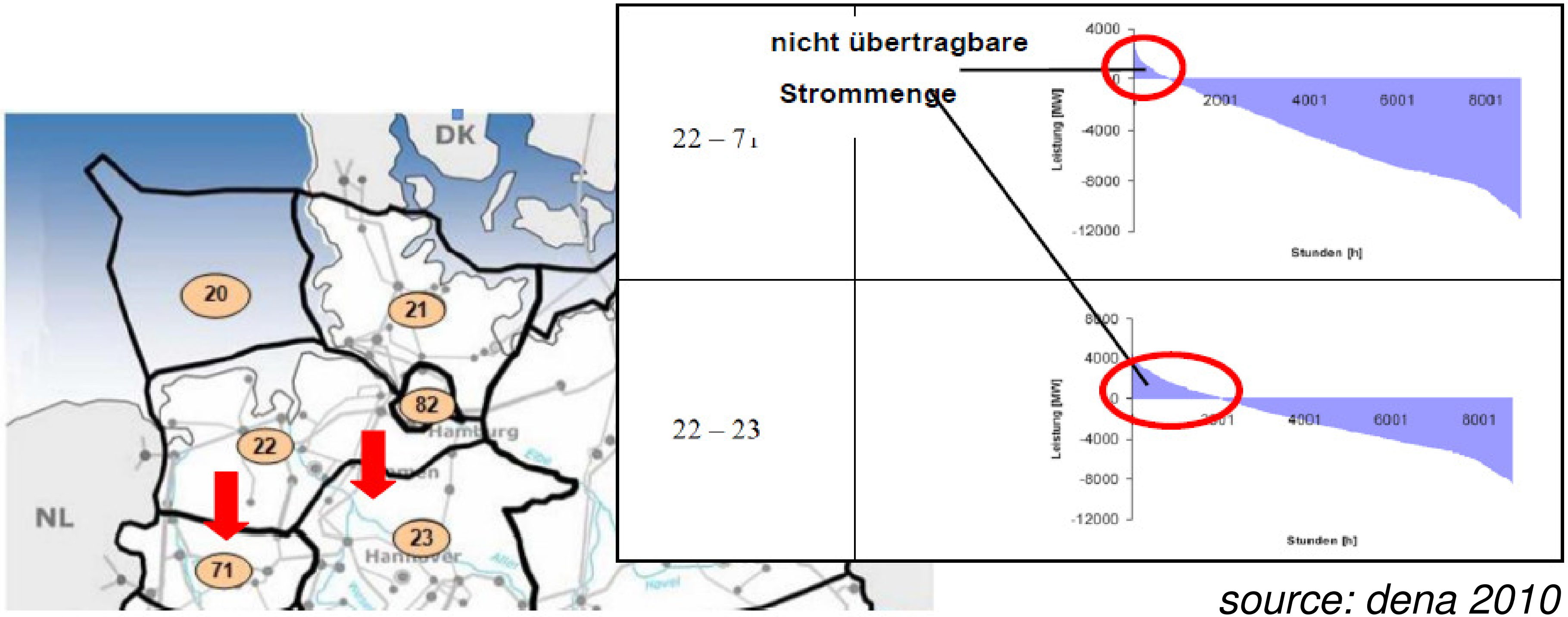
- Costs for redispatch:
  - Corresponds with intraday price
  - Premium is the gap among intraday and day-ahead-price

- Compensation for cut RE feedin
  - Intraday
  - § 11 EEG: additional costs can come up

Costs of a bottleneck are hard to estimate

Example: Bottleneck in PLZ 2 area in year 2020

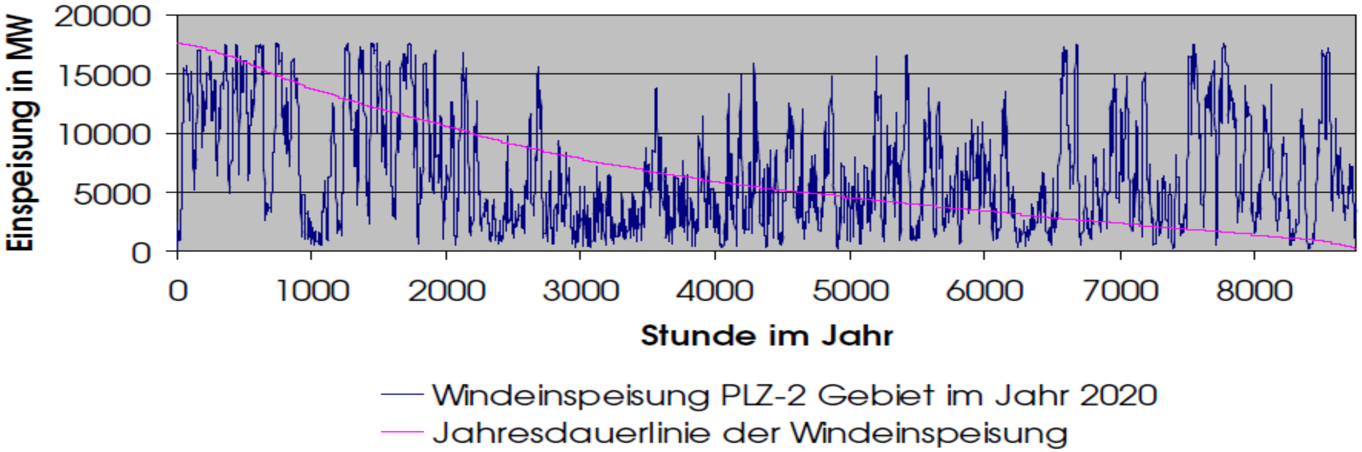
- Northwestern Germany:
  - 2009: >7.600 MW renewables (90% wind)
  - 2020: installes wind capacity larger than 20.000 MW (dena 2010)
  - 2020: not transmittable capacity larger than 7.300 MW (dena 2010)



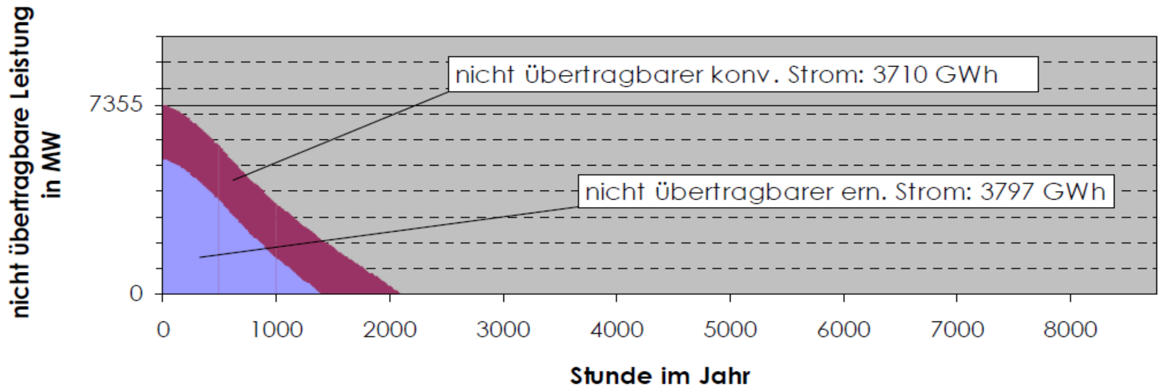
source: dena 2010

Example: not transferable capacity

- Assumption: high wind feedin leads to bottleneck



- Not transferable capacity ~ 7.500 GWh
  - ~ 49 % conventional power
  - ~ 51 % cut renewables



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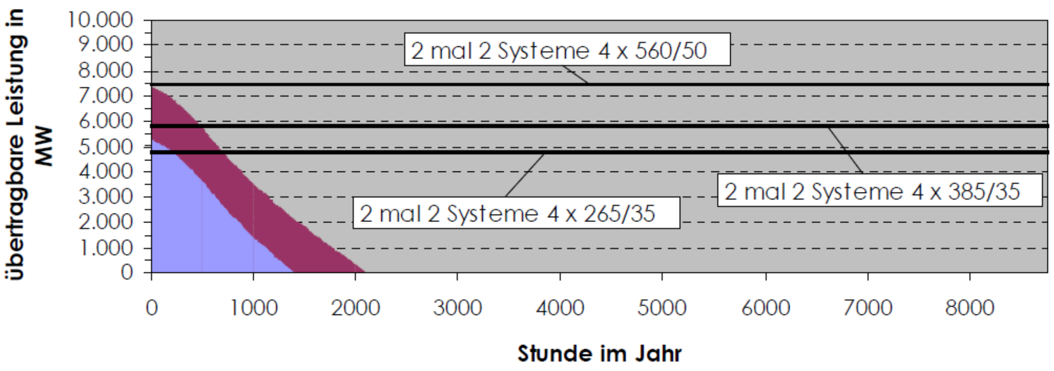
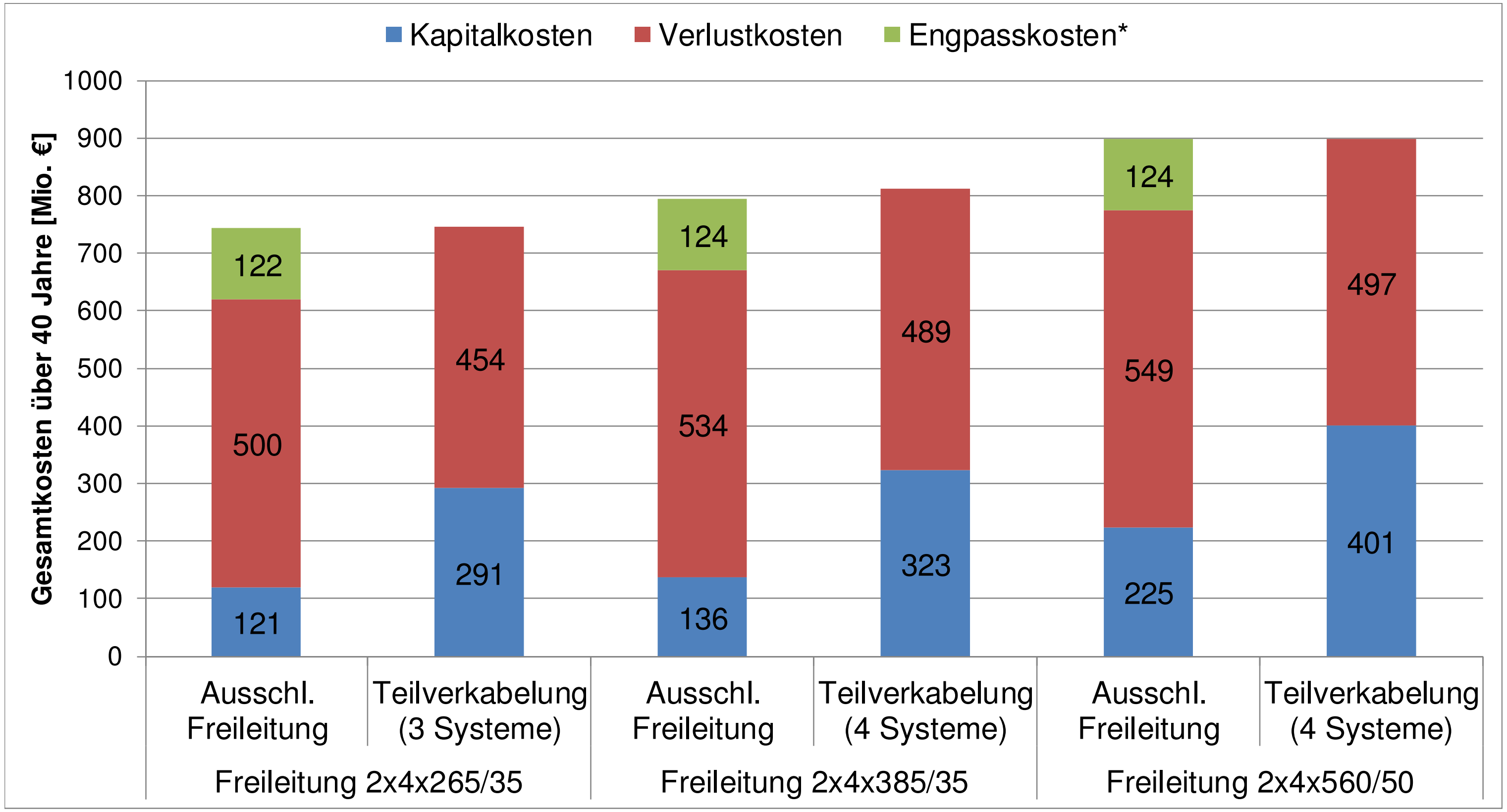
Example: cost of 1-year bottleneck

- Cost redispatch = quantity x (Intraday – Day-ahead price)
  - Ø Intraday price 2010 – Ø Day-Ahead price 2010 = 1,14 €/MWh
- Costs of cut renewables = quantity x Intraday price
  - Estimated spot price 2020: 63 €/MWh (Day-ahead)
  - Intraday price in 2020: 63 €/MWh + 1,14 €/MWh
- Estimated costs of bottleneck:
  - 3710 GWh * 1,14 €/MWh + 3797 GWh * (63 + 1,14 €/MWh) = 248 Mio. €
- To fix the bottlenecks there are 2 corridors including 2 systems needed. Depending on the choosen system the bottleneck stays.
- Costs of bottleneck of one corridor:
  - 4x265/35: 122 Mio. €
  - 4x385/35: 123,5 Mio. €
  - 4x560/50: 124 Mio. €



Example result: macroeconomic comparison



1-year delay corresponds with additional costs for partial cabling

* 1-jährige Verzögerung

Conclusion

- A delayed grid extension will lead to additional costs
- Though investment costs for partial cabling are higher compared to building merely overhead lines, costs of a potential delay may diminish the benefit of overhead lines
- The reduction can correspond to the needed additional cost for part cabeling ➔ Costs of accelerating alternatives can be acceptable compared to overhead lines
- In the BMU study BET/IZES developed a systematic to evaluate bottlenecks in the grid
- It should be possible to interate this systematic into calculation for grid requirements
- In further studies benefits of earlier realization with respect to the system stability may be taken into account as well

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