Energy storage and other options for balancing demand and supply as key technologies for the transition of the electricity system assessed with an interdisciplinary project group

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Structure

1. **The Project** „Energy Storages and Virtual Power Plants"
2. Roughly Estimating **Balancing Requirements** in Future Electricity Systems
3. **Technology Options** – Competition, Ranking and Future Viability
4. Results on **Framework Conditions**
5. **Conclusions**

1. The Project

„Energy Storages and Virtual Power Plants“

Main data to the interdisciplinary project

Task: Interdisciplinary analysis of strategies for balancing electrical energy at a high penetration of renewable energies in power production

Project group:

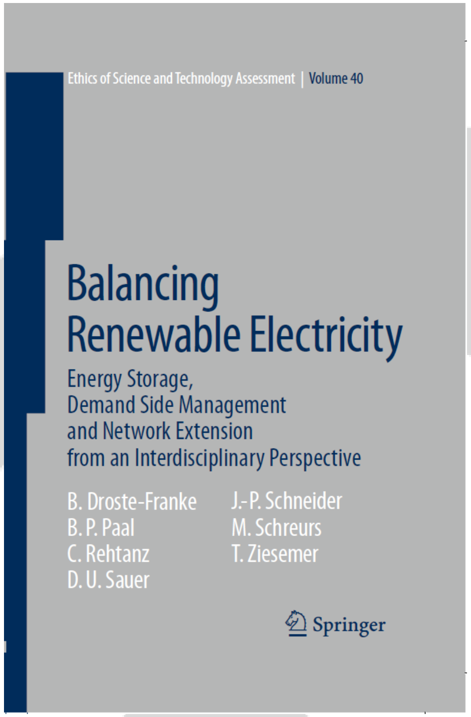
- Priv.-Doz. Dr. rer. pol. Dietmar Lindenberger, Köln
- Professor Dr. jur. Boris P. Paal, Freiburg
- Professor Dr.-Ing. Christian Rehtanz, Dortmund
- Professor Dr. rer. nat. Dirk Uwe Sauer, Aachen
- Professor Dr. jur. Jens-Peter Schneider, Freiburg
- Professor Dr. Miranda Schreurs, Berlin
- Professor Dr. rer. pol. Thomas Ziesemer, Maastricht

Europäische Akademie:

- Dr.-Ing. Bert Droste-Franke, Dipl.-Phys. (Co-ordinator)
- Dr. rer. nat. Ruth Klüser, Dipl.-Chem.

Duration: 1/09-12/11

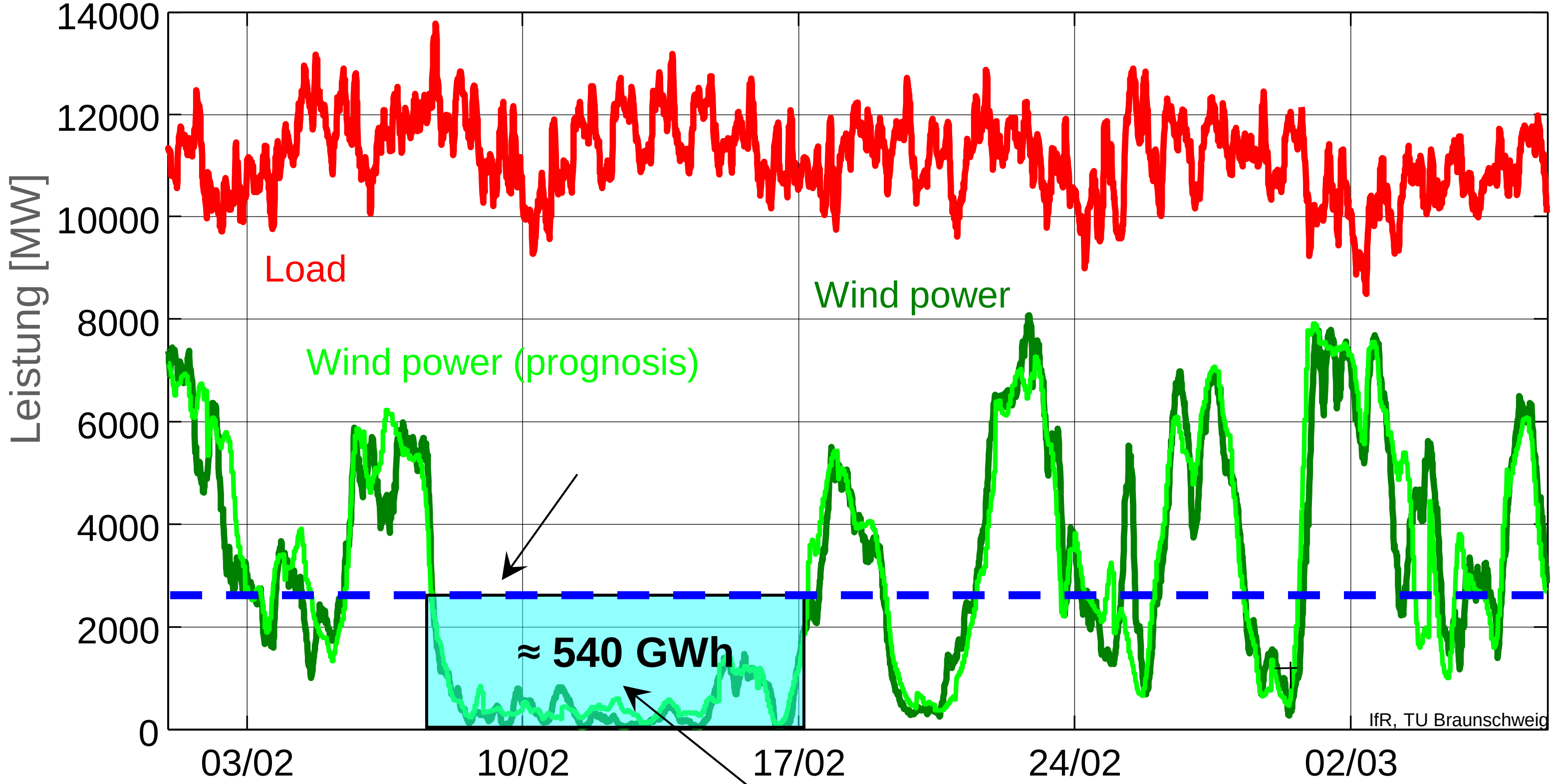
Funding: German Aerospace Center (DLR)



2. Roughly Estimating Balancing Requirements in Future Electricity Systems

Challenges with much wind and photovoltaic power in the system: Balancing longer periods with gaps/excess

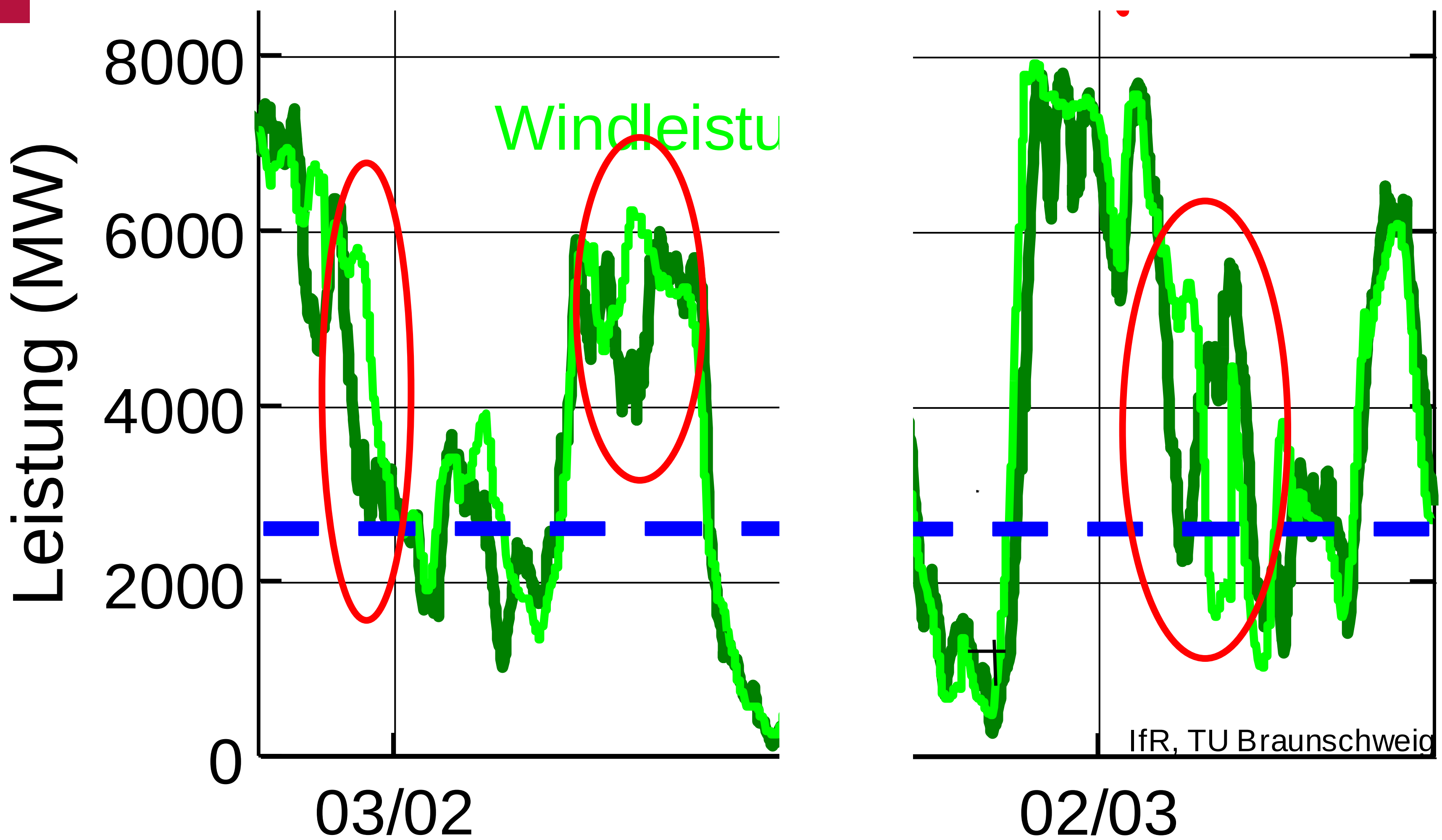
Load and wind power in Vattenfall high voltage grid (01.02.-06.03.2008)



Source: IfR / TU Braunschweig

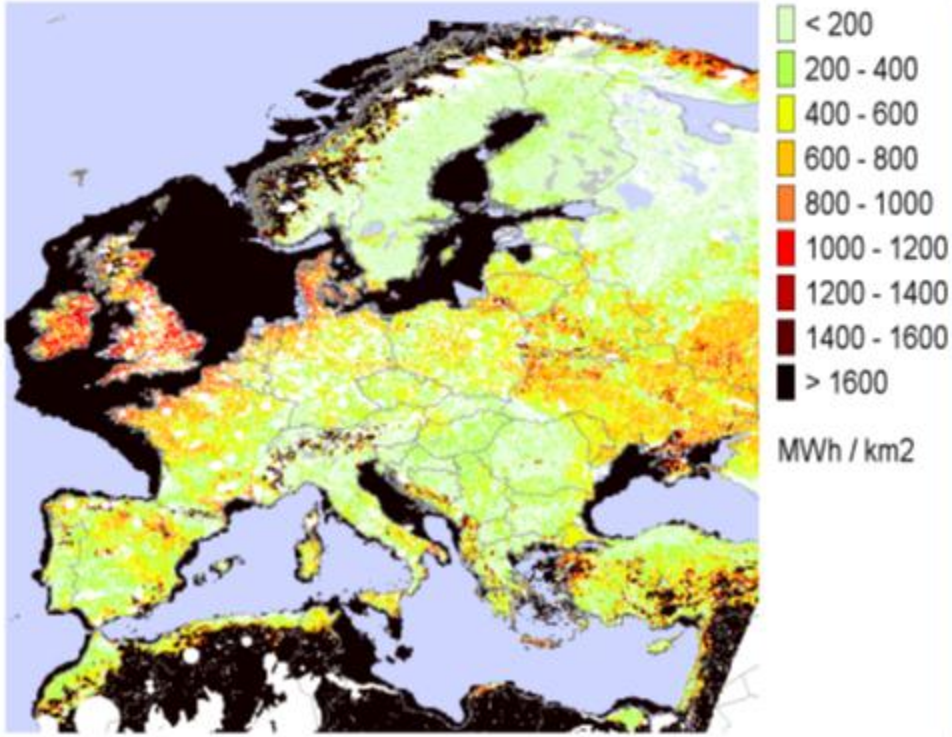
Necessary storage capacity for continuous delivery of mean power
(pumped hydro today: ≈ 40 GWh (7 GW) in Germany,
≈ 90 GWh worldwide)

Further Challenges: Balancing short-term fluctuations

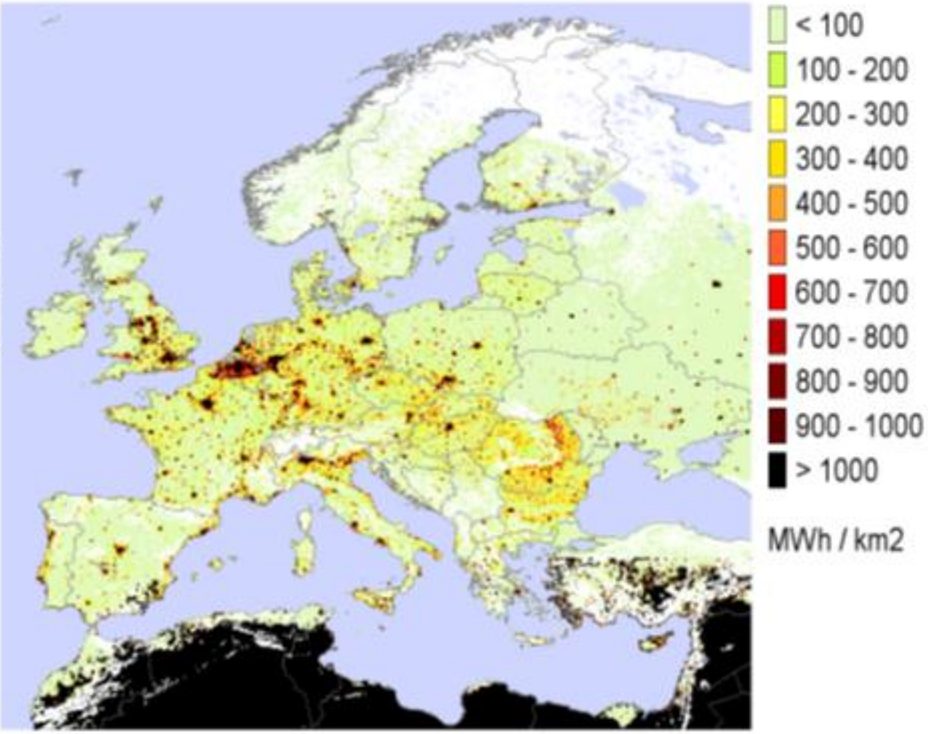


Spatial distribution of power production/demand

Potential for wind



Potential for photovoltaic



Source: SRU 2010 („100% regenerative Stromversorgung in Deutschland 2050“)

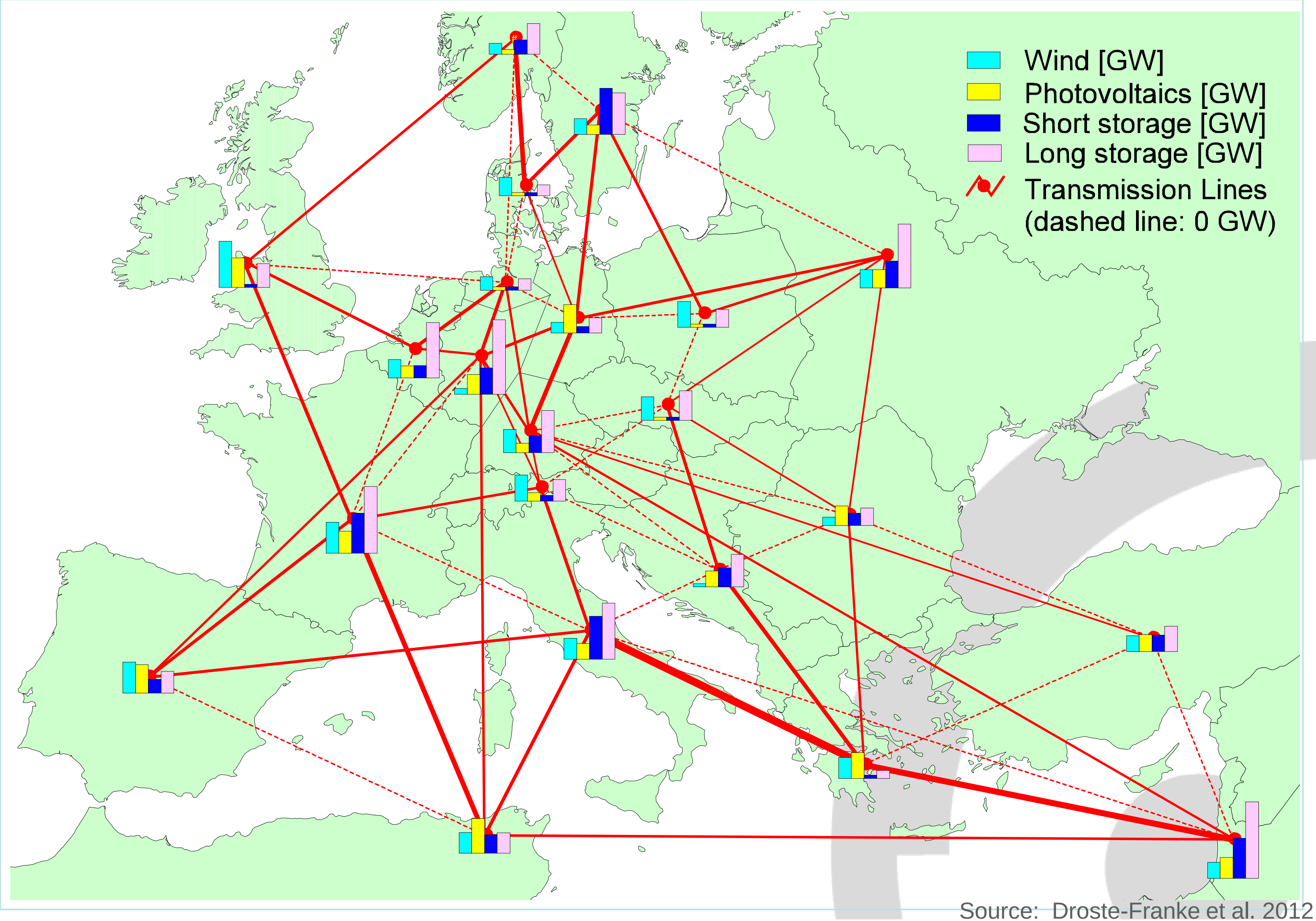
Approach in system analysis of transition

- **General approach:**
  Anlysis of target situation + framework conditions today
- **Scenarios with high share of wind and solar power**
  – highest requirements for balancing electricity
- **Consistency of estimations:**
  harmonised parameters, oriented at existing studies
- **Handling high uncertainties:**
  - Intention to only estimate **orders of magnitude**
  - **Sensitivities** are considered via different assumptions

Results for Germany based on the analysis of existing scenarios

- **Balancing Power required:**
  2040+ at maximum: +18/-24 GW on average, **35 GW peak**
- **Balancing Capacity required for one case:**
  1700 GWh at maximum (218 hours with 80% decrease of installed power) *(other studies: ≤ some 10 TWh storage size)*
- **Transmission grid:**
  3000 km extension required until 2040+ with costs of about **6 to 8 billion €**
- **Distribution grid (demand side management (DSM)):**
  Costs due to required cables and transformers of more than **1000€ per household** from 2020 are awaited

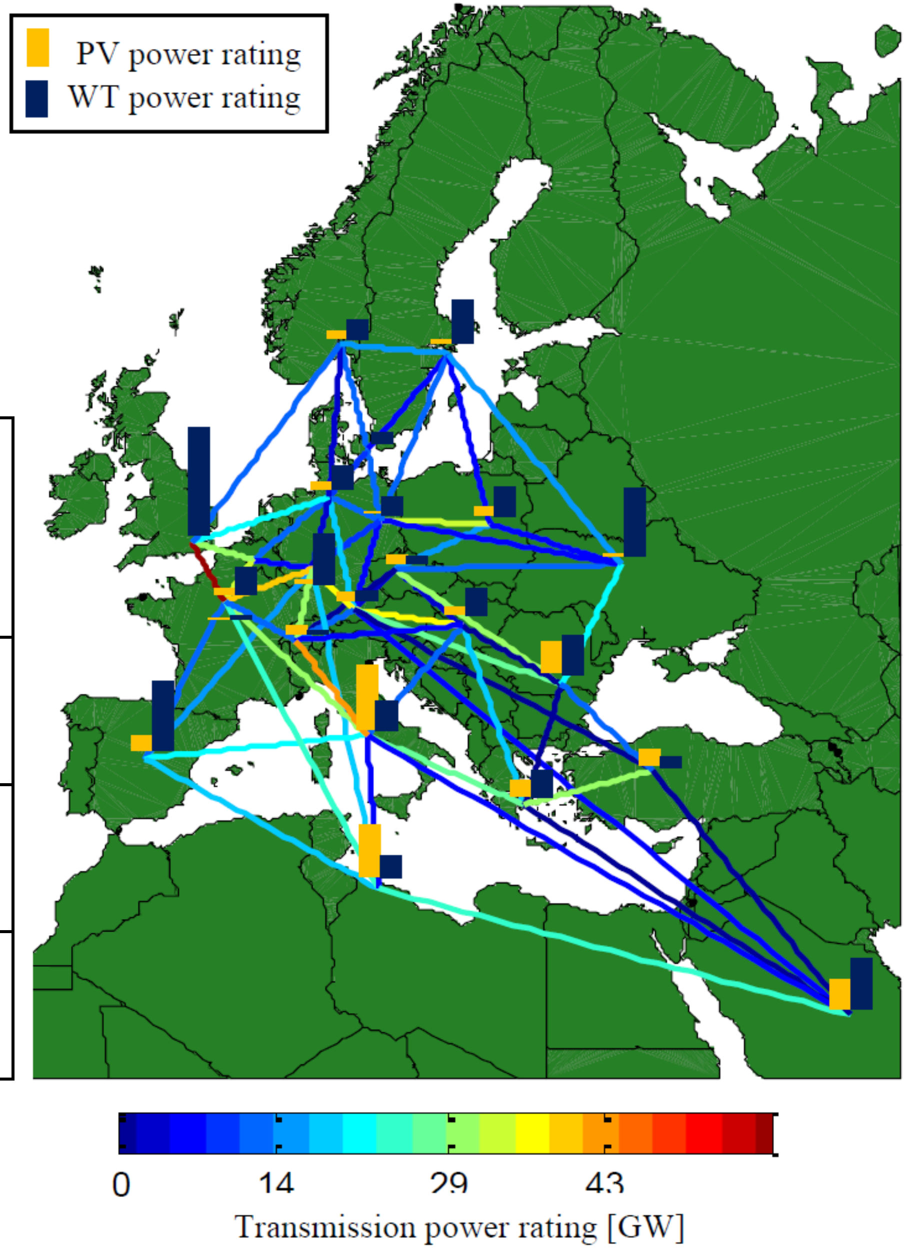
Modelling the target system for Europe



Source: Droste-Franke et al. 2012

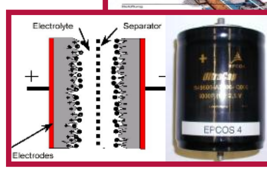
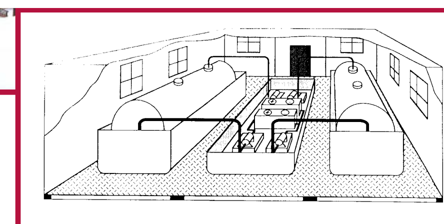
First results of the Europe model, realised after the end of the project

	Short-term storage	Long-term storage
Storage capacity [TWh]	2	320
Discharging power [GW]	230	710
Charging power [GW]	480	570

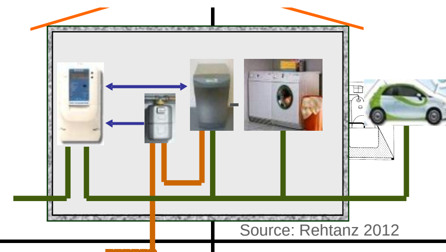


Source: Thien et al. 2012

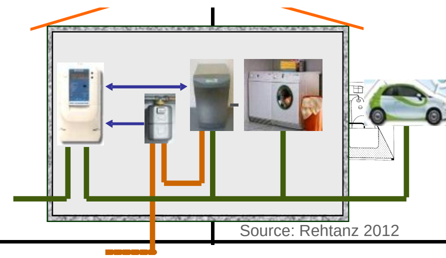
3. Technology Options – Competition, Ranking and Future Viability

Energy storages			**Typical Time Scale/Energy-to-Power Ratio**		
			"Seconds-to-minutes"	**"Daily"**	**"Weekly to monthly"**
			< 15 min.	**1–10 hrs.**	**50–500 hrs.**
Type of construction / typical power	**Modular, Double-use**	**1 kW–1 MW**	Batteries at stationary PV  E-, hybrid-vehicles 		
	Modular	**1 kW–100 MW**	Fly-Wheel  Capacitors 	Batteries 	Redox-Flow-Battery (?) 
	Central	**100 MW–1 GW**		Compressed Air  Pumped hydro 	Hydrogen 

Source: Sauer 2010

Positive control power			**Typical Time Scale/Energy-to-Power Ratio**		
			“Seconds-to-minutes”	**“Daily”**	**“Weekly to monthly”**
			< 15 min.	**1–10 hrs.**	**50–500 hrs.**
Type of construction / typical power	**Modular, Double-use**	**1 kW– 1 MW**	**Demand Side Management**  Source: Rehtanz 2012		
	Modular	**1 kW– 100 MW**		**Bio Gas Power Plants**  Source: umweltfondsvergleich.de	
	Central	**100 MW– 1 GW**	 - Rotating masses - Steam reserve	- Natural gas - Hard Coal  Solarth. Power Pl. Quelle: DLR 2012	- Lignite - Nuclear power  Hydro Storage Power Plants Source: Google 2012

Negative control power			Typical Time Scale/Energy-to-Power Ratio		
			"Seconds-to-minutes"	"Daily"	"Weekly to monthly"
			< 15 min.	1–10 hrs.	50–500 hrs.
Type of construction / typical power	Modular, Double-use	1 kW–1 MW	Demand Side Management		
	Modular	1 kW–100 MW	Curtailing Wind, PV		Producing Gas (power2gas)
	Central	100 MW–1 GW			



Source: Rehtanz 2012

Source: Pixelio 2012

Source: Pixelio 2012

Cost ranking of technological options

(rough estimates on prices in about 10 years in €ct/kWh in brackets)

- **„Long-term storage“: hydrogen** (10), **pumped hydro** (5-10)
- **„Load levelling“: pumped hydro, compr. air (CAES)** (<5)
- **„Peak shaving in distribution grid“: batteries** (mostly 5-10)
- **Also to be taken into account:**
  - **Double use options** (e.g., e-mobility, storages at pv)
  - **Demand side management** (about 10 GW in Germany)
  - **Curtailing wind und pv** in extreme situations
  - **Option overcapacity** of wind/pv + network extension
  - (**Reliable electricity supply** from renewable energies)

Aspects of future viability

- **Environmental effects in 2050** (life cycle screening)
  - **Small effects from applications of energy storages**
    (e.g. external costs ≈0.02-0.3 ct/kWh$_{el}$, lead battery: ≈0.5-1.6 ct/kWh$_{el}$)
  - **SO_2 from production processes gains in importance**
- **Resource use – metals**
  – to be monitored / recycled / exchanged
  - **Availabilities should be monitored:**
    - **Reserves/resources**
    - **Price changes**
    - **Geographical concentration delivery and supply**
  - **High recycling rates should be realised and alternatives be analysed**

4. Results on Framework Conditions

Market conditions and politics

- **Regulative Clarifications**
  (definitions, attribution)
- **International Networking**
  (international solutions, networks, electricity market)
- **Long term boundary conditions**
  (low-carbon targets, boundary conditions)
- **Improvement of system analysis for policy support**
  (extended, coordinated, continuous, monitoring, European perspective)

Funding

- **Removing Historical Heritage of Regulations**
  (long-term, short-term)
- **Technology neutral support of new technologies**
  (temporally limited start up-subsidies, compensating external effects, R&D)
- **Merging externalities to costs and returns**
  (internalising system service costs, business models, implement coordination between measures)

Large scale projects

- **Network extension**
  (planning procedures: acceleration, (inter)national aspects, regulator: accept R&D costs)
- **Handling opposition**
  (participation of affected parties and wider public, planning regime underground resources, further measures for conflict resolution)

Decentralised technologies

- **Realising technical potentials**
  (automised solutions, flexible tariffs, minimising data requirements, adequate legal regulations for data protection)
- **Handling new complex markets**
  (contractual challenges, general regulations)

Conclusions

- **Interdisciplinary analyses** with an „EA-project group“ can be applied to get further insights in the some important correlations for the transition of energy systems
- **Relevant statements are possible** on basis of existing studies/data with rough analyses carried out in the project:
  - The **requirement for balancing increases** and a **heterogeneous mix of technological options** will prospectively be applied
  - A **first ranking of options** is derived and further discussed
- **Framework conditions could be identified which should be improved already today** – to go into the „right“ direction
- **Interdisciplinary analyses** should be **further extended and carried out continuously** accompanying the transition process

Thank you for your attention!

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