Energy Storage

Seminar Talk on *Energy and Environment*

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universitätbonn

Outline

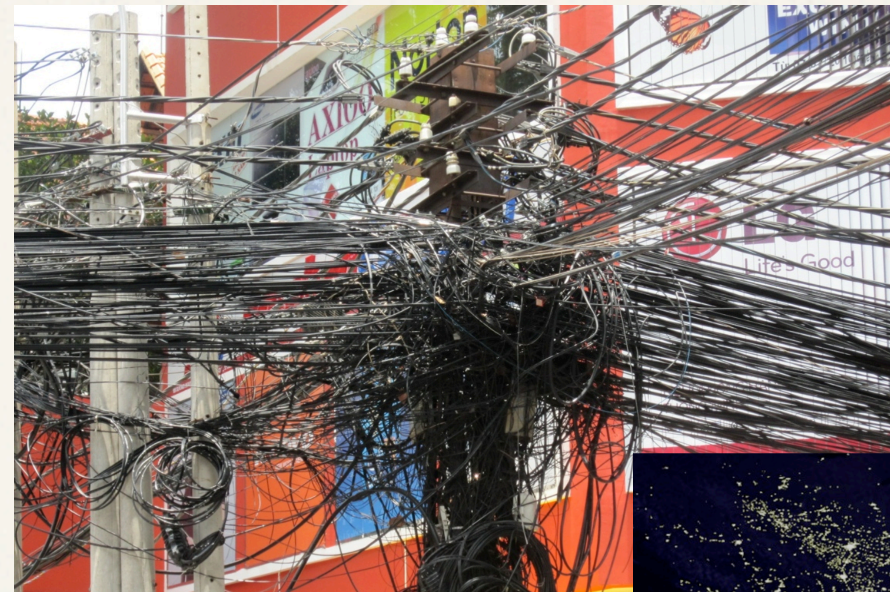
1. Motivation
2. Storage Types
3. Smart Grid Energy Storage

1. Motivation

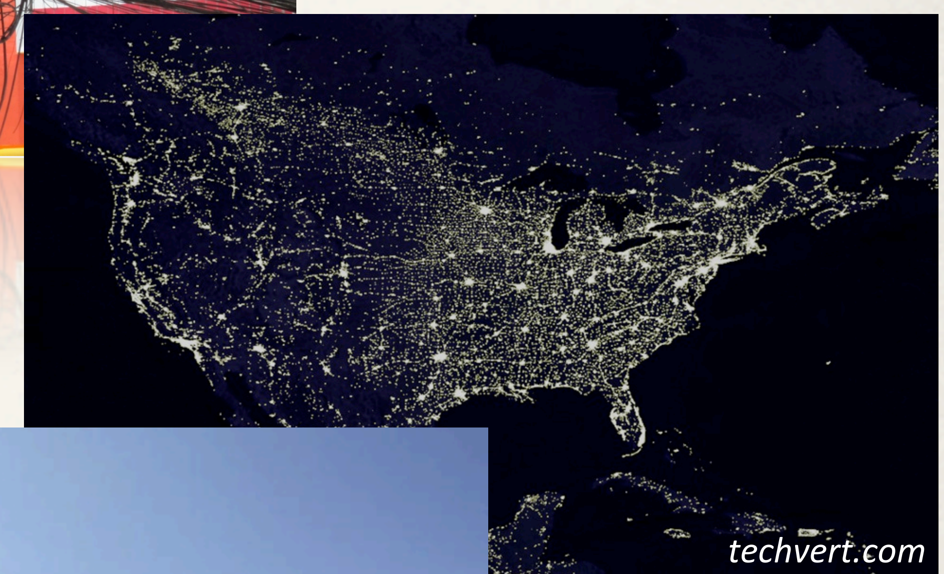
1. Motivation

Why do we need to store Energy?

1. **Supply disruptions** and **power outages**



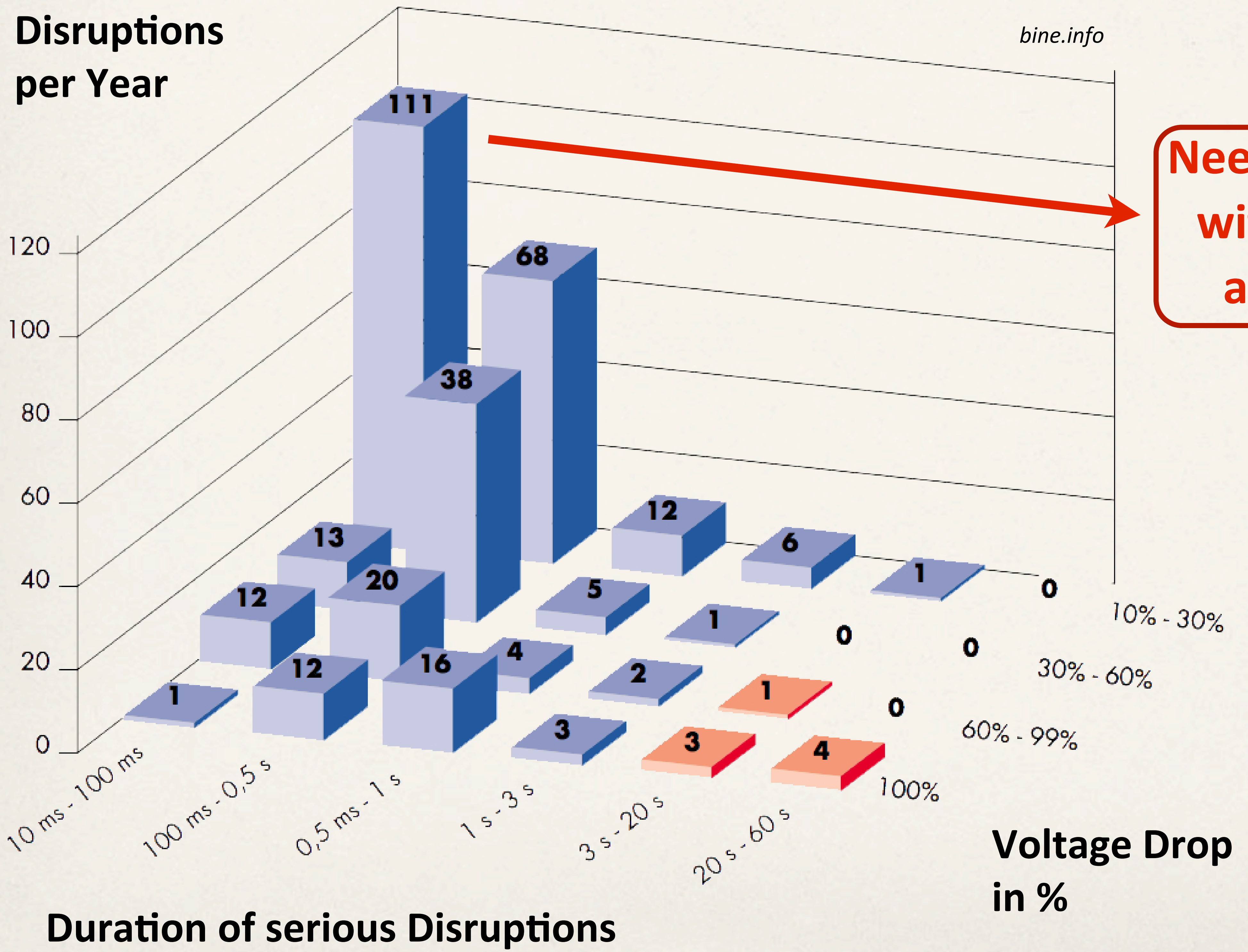
2. **Demand fluctuations**



3. **Discontinuous power supply** by renewable energy sources

1. Motivation

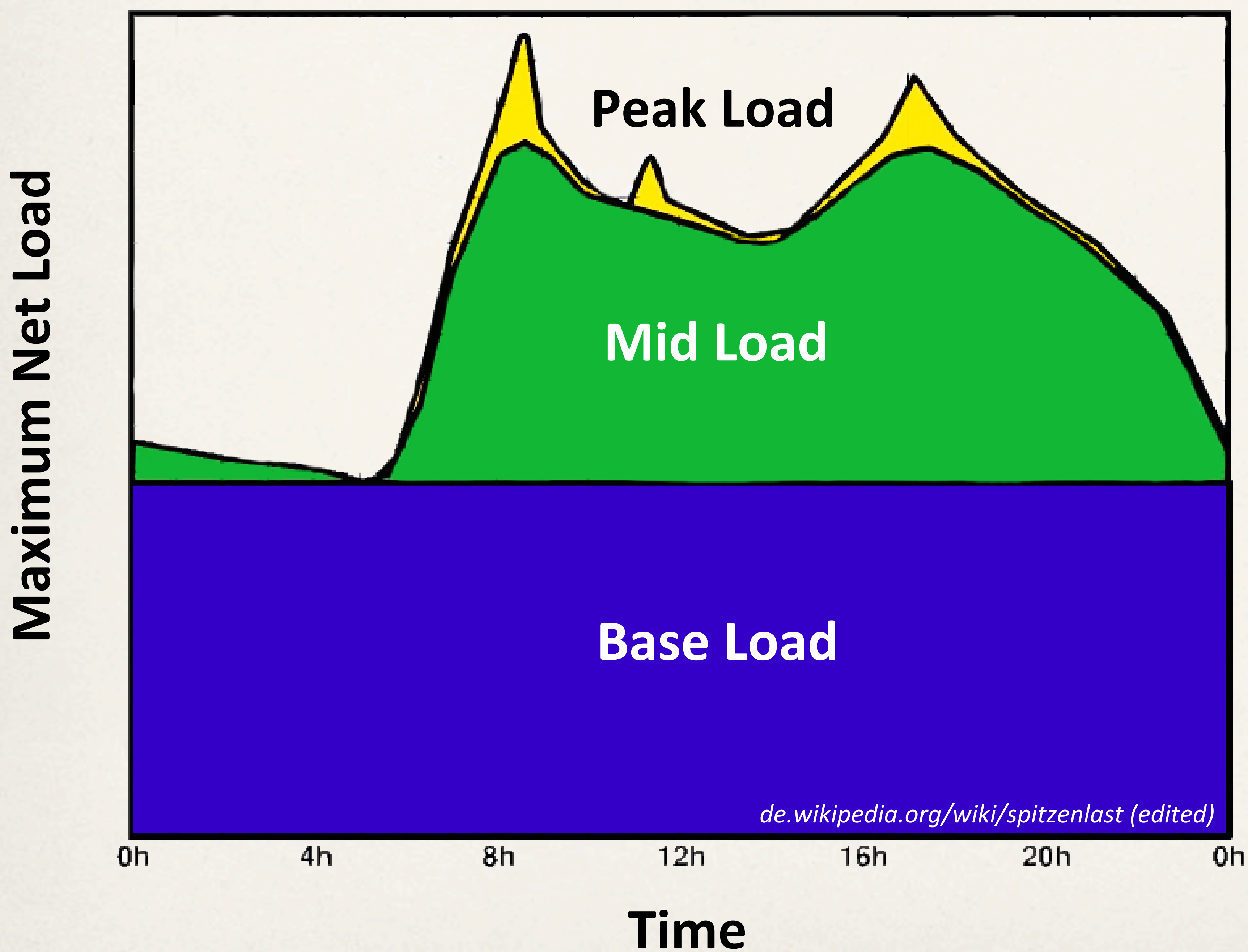
1. How can we account for Supply Disruptions?



Need storage systems with small capacity and fast startup!

1. Motivation

2. How can we account for Demand Fluctuations?



Supply by storage power plants!

Supply by renewable energy and conventional power plants!

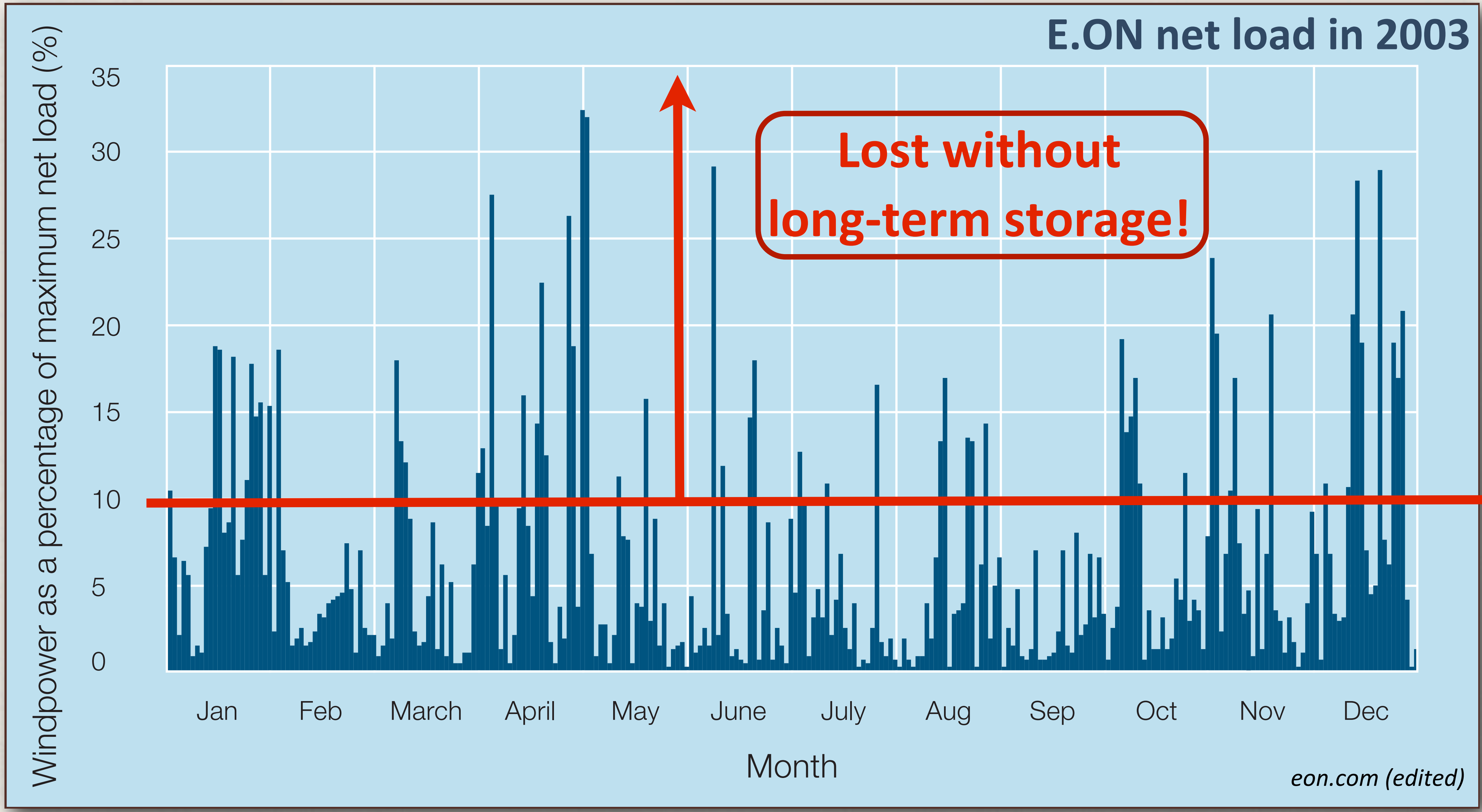
1. Motivation

3. How can we account for the discontinuous Power Supply?

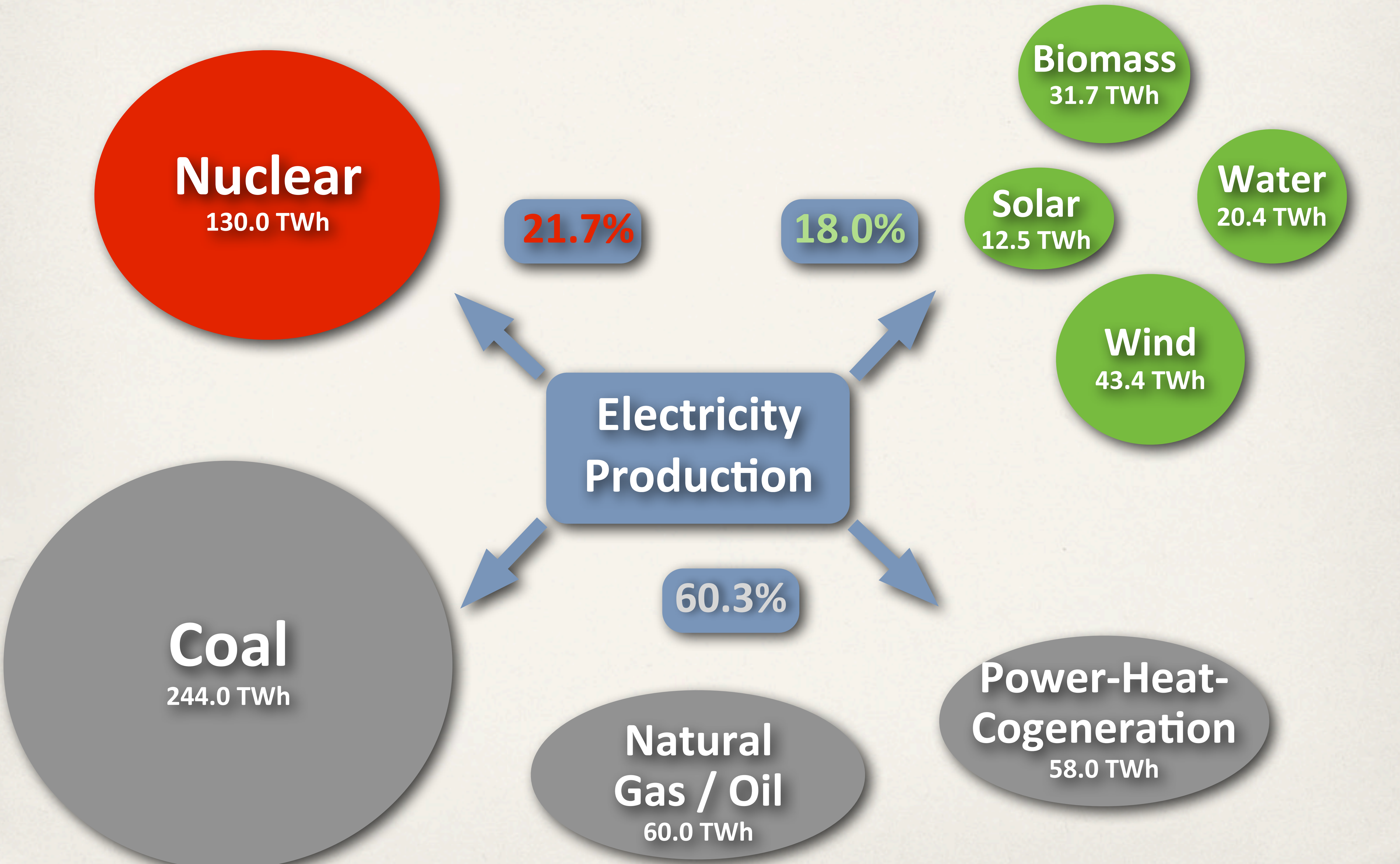
Total net load (average): P = 70 GW

Pumped hydro-electric net load: P = 7 GW

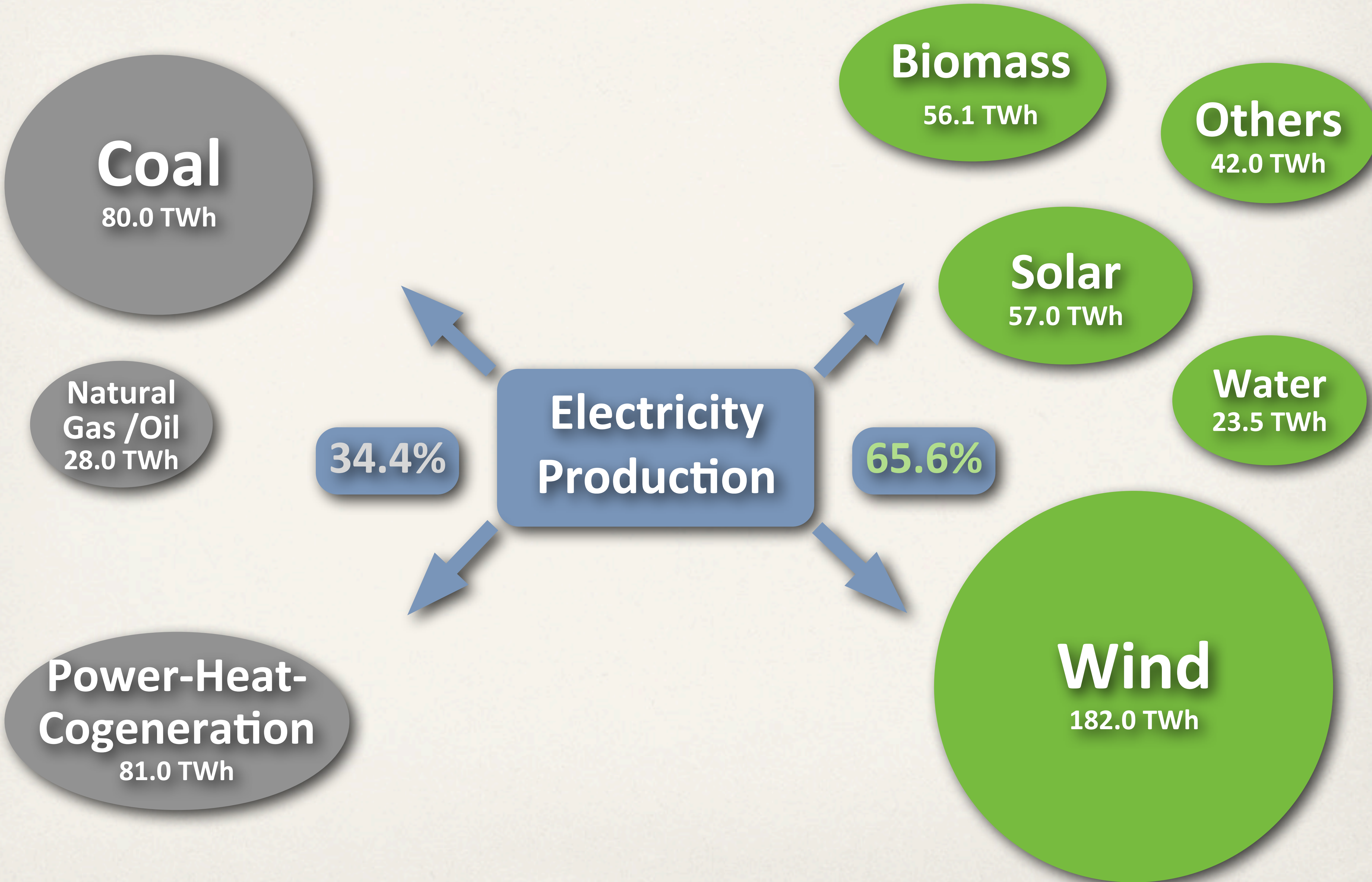
in Germany, 2010



Total Electricity Production in Germany 2010: 600 TWh



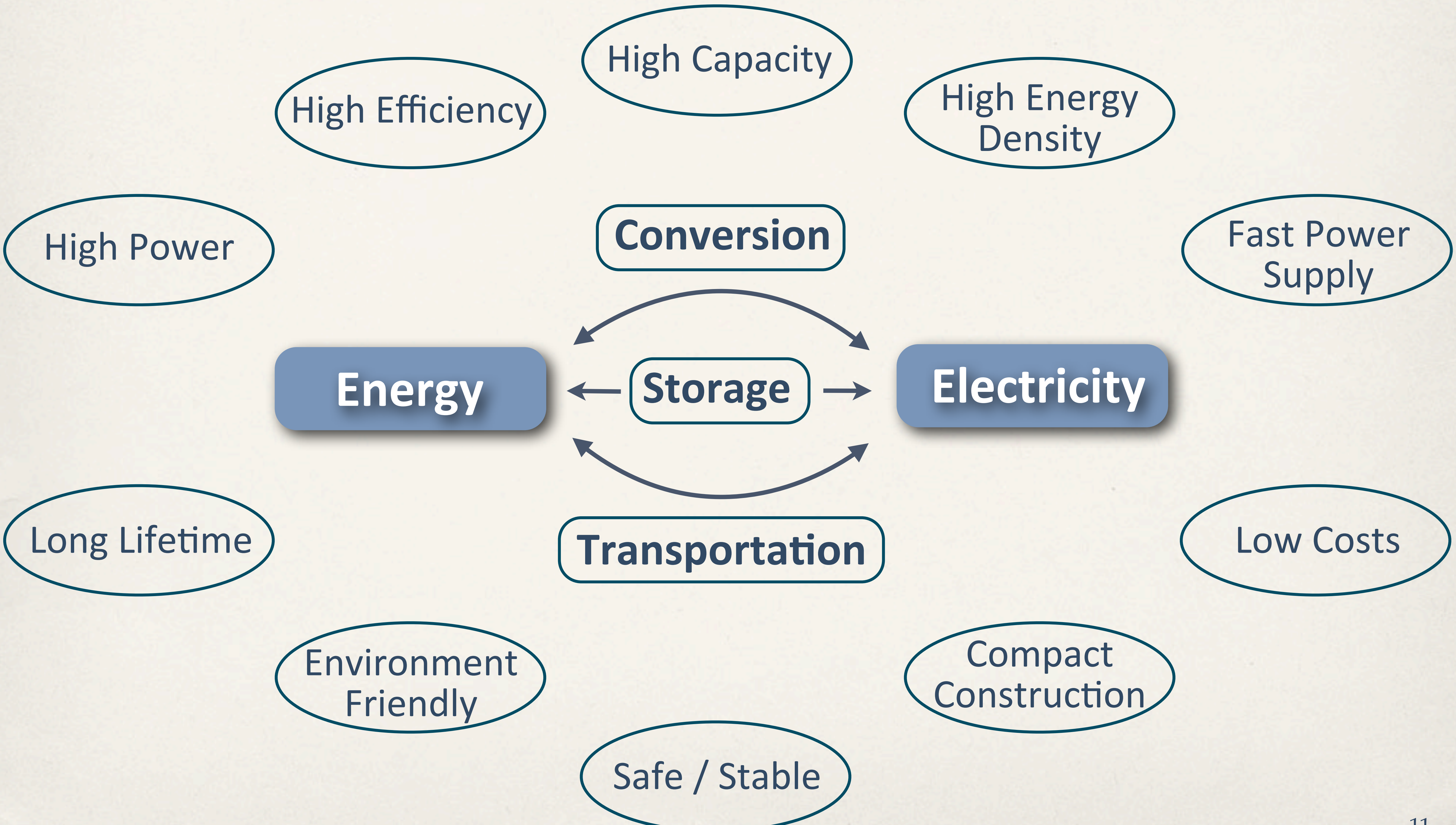
Prognosed Electricity Production in Germany 2030: 550 TWh



2. Storage Types

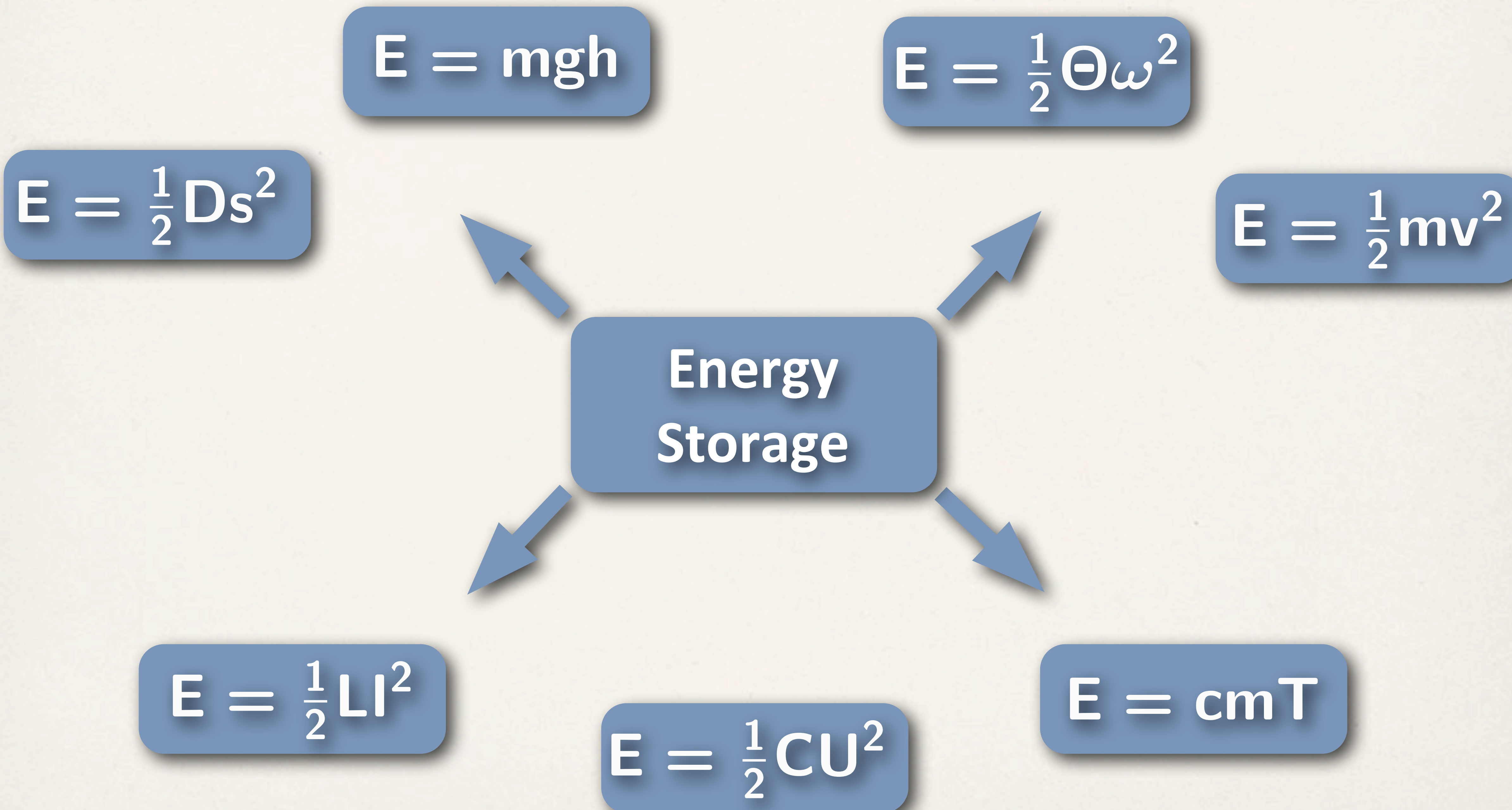
2. Storage Types

Which are the Key Requirements?



2. Storage Types

Which Technologies do we have?



2. Storage Types

Which Technologies do we have?

Energy Storage

Potential:

- Pumped Hydro-Electric Storage
- Compressed Air Energy Storage

Kinetic:

- Flywheel Energy Storage

Electromagnetic:

- Super Capacitor
- Superconducting Magnetic Energy Storage

Chemical:

- Accumulator
- Battery Storage Power Plant

Thermal:

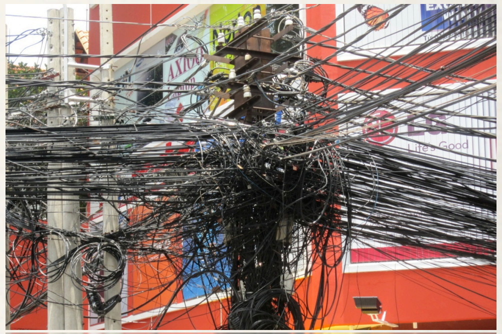
- Heat Storage

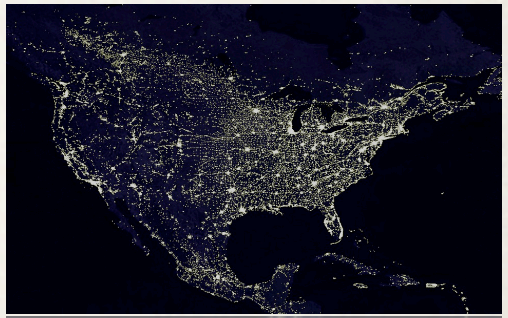
2. Storage Types

Which Technologies do we have?

Type	Max. Power [MW]	Lifetime [Cycles]	Efficiency [%]	Initial Costs [€/kWh]	Energy Density [kWh / t]	Typical Discharge Time
Capacitor	0.01	100 Mio.	95	200 000	0.03	0.01 s
Super Capacitor (EDLC)	0.1	0.5 Mio.	90	10 000	5.0	100 s
Superconducting Magnetic Inductor	7.0	1 Mio.	90	30 – 2000	0.03	0.01 s
Flywheel (CFK)	50	1 Mio.	95	1200	50	100 s
Battery Storage Power Plant	27	< 1000	80	100	30 - 120	4 h
Pump-Storaged Hydropower Plant	1060	?	80	71	0.4	8 h
Compressed Air Energy Storage	290	?	42 - 54	(Test)	9.0	2 h
Hydrogen	0.2	30 000 h	34 - 62	(Test)	33 300	0.5 h

energieverbraucher.de

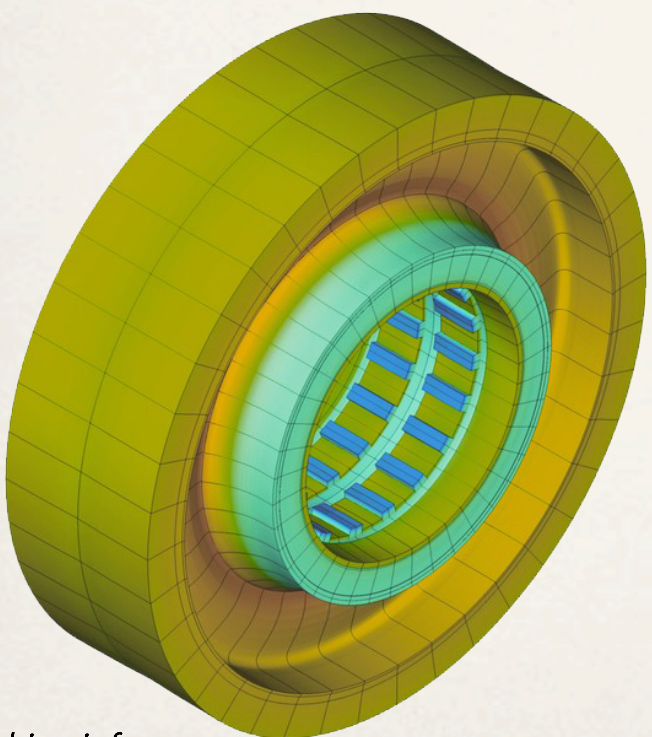




2. Storage Types

An Example: Dynastore®

compact-dynamics.de



bine.info

- Flywheel Energy Storage
- Commercially available
- <u>Technical properties:</u>

  Electric power: $P = 90 - 120$ kW
  Energy capacity: $E = 2800$ kJ
  Load time: $t < 30$ s
  Load cycles: $N > 5 \cdot 10^6$

- <u>Applications:</u>

  Hybrid cars / Formula One
  Voltage stabilizer for companies

2. Storage Types

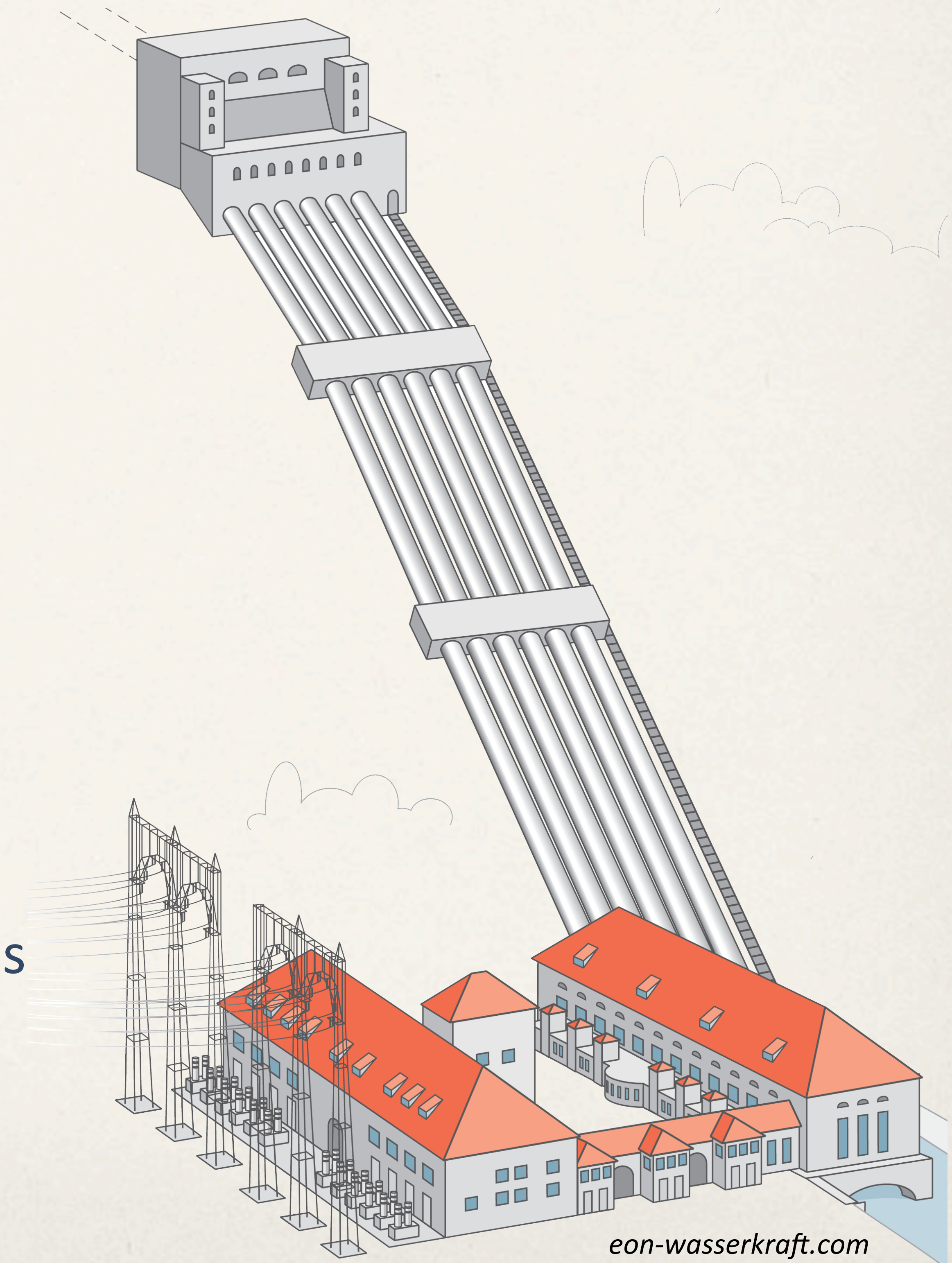
Another Example: Walchensee Power Plant

- Hydro-Electric Power Plant
- Operated by E.ON Wasserkraft
- Electric power: P = 124 MW

  4 x 18 MW (Francis turbine)
  4 x 13 MW (Pelton turbine)

- Output per year: E = 300 GWh

  65% for peak-load of private households
  35% for Deutsche Bahn

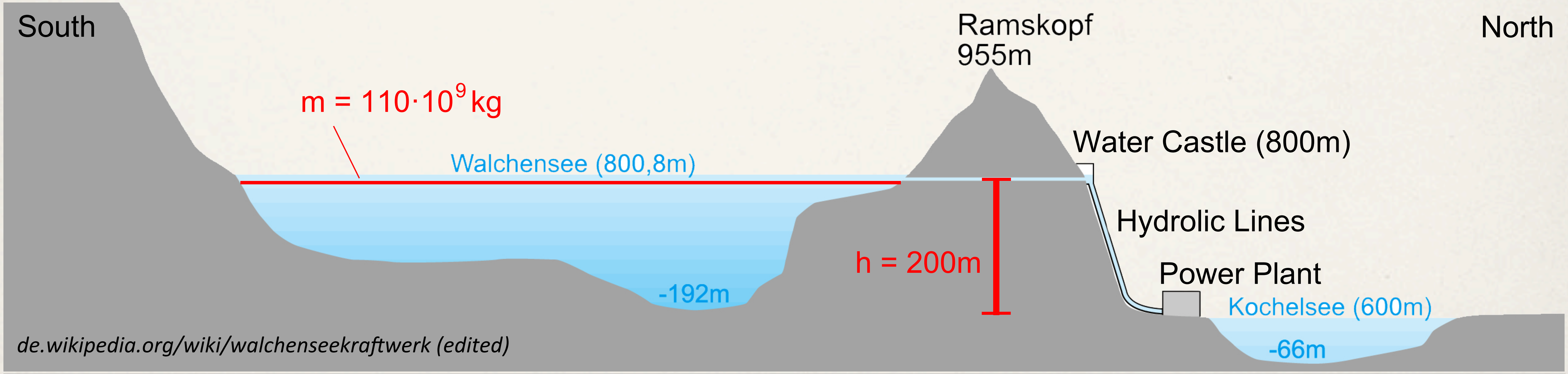


eon-wasserkraft.com

2. Storage Types

Another Example: Walchensee Power Plant

- Stored potential energy: $E_{pot} = mgh \simeq 60$ GWh
- Estimated capacity: $E_{elec} = \varepsilon E_{pot} \simeq 15$ GWh
- Mean operating time per day: $t = 6.6$ h



de.wikipedia.org/wiki/walchenseekraftwerk (edited)

2. Storage Types

Another Example: Walchensee Power Plant

2. Storage Types

Another Example: Walchensee Power Plant

2. Storage Types

What do we have?

in Germany, 2010

31 Pumped Hydroelectric Storage Plants

Rank	Name	State	Power [MW]	Capacity [MWh]	Initial Operation
1	Goldisthal	Thüringen	1 060	8 480	2003
2	Markersbach	Sachsen	1 050	4 018	1979
3	Hornbergstufe	BW	980	6 073	1975

vde.com

- Total power: P = 7 GW
- Total capacity: E = 40 GWh

21607 Wind Power Plants:

P = 27.2 GW

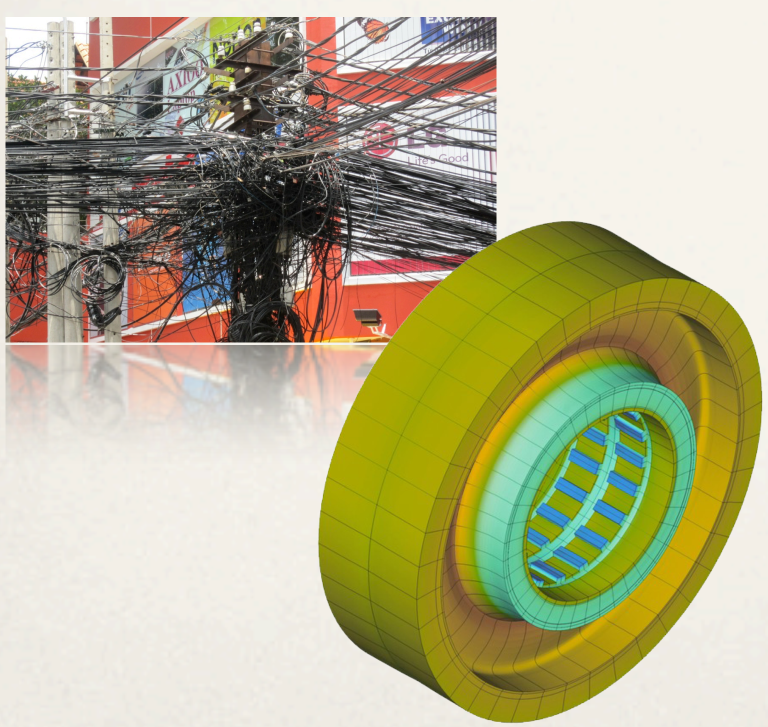
E = 110 GWh **(mean per day in 2010)**

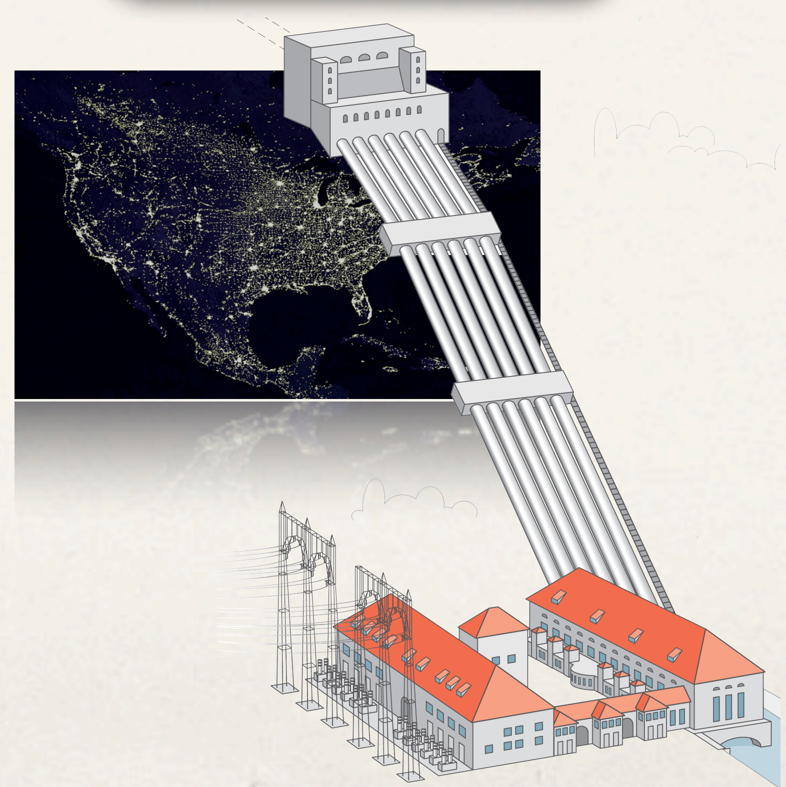
2. Storage Types

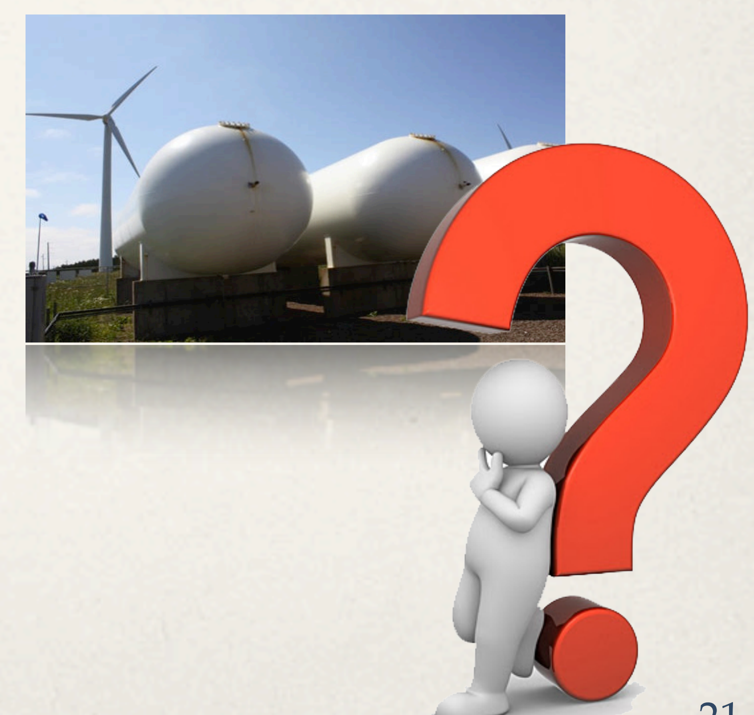
What do we need?

Applications

- **short-term** 0.1ms ... 20s
- **medium-term** 1h ... 10h
- **long-term** 1d ... 10d







3. Smart Grid Energy Storage

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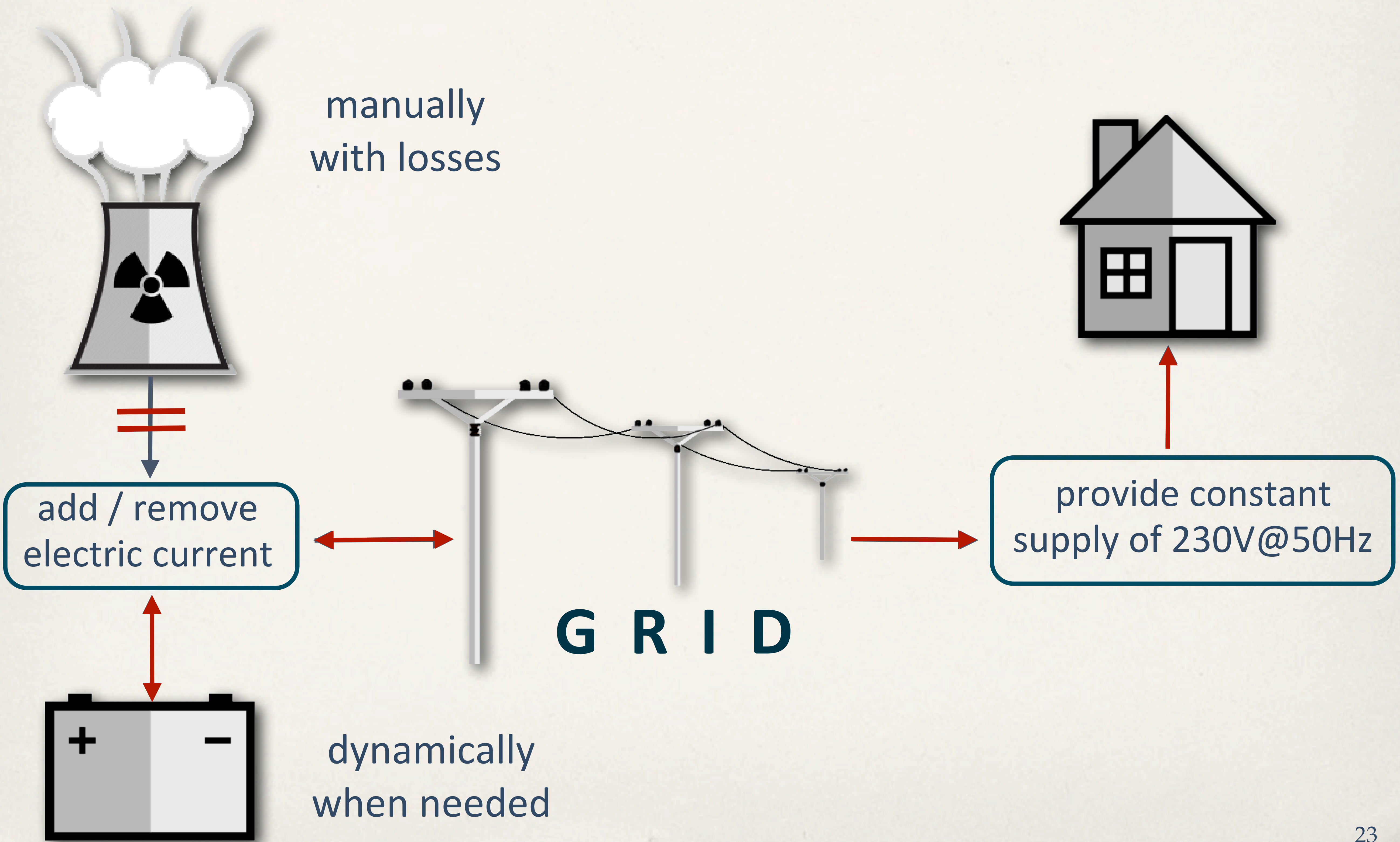
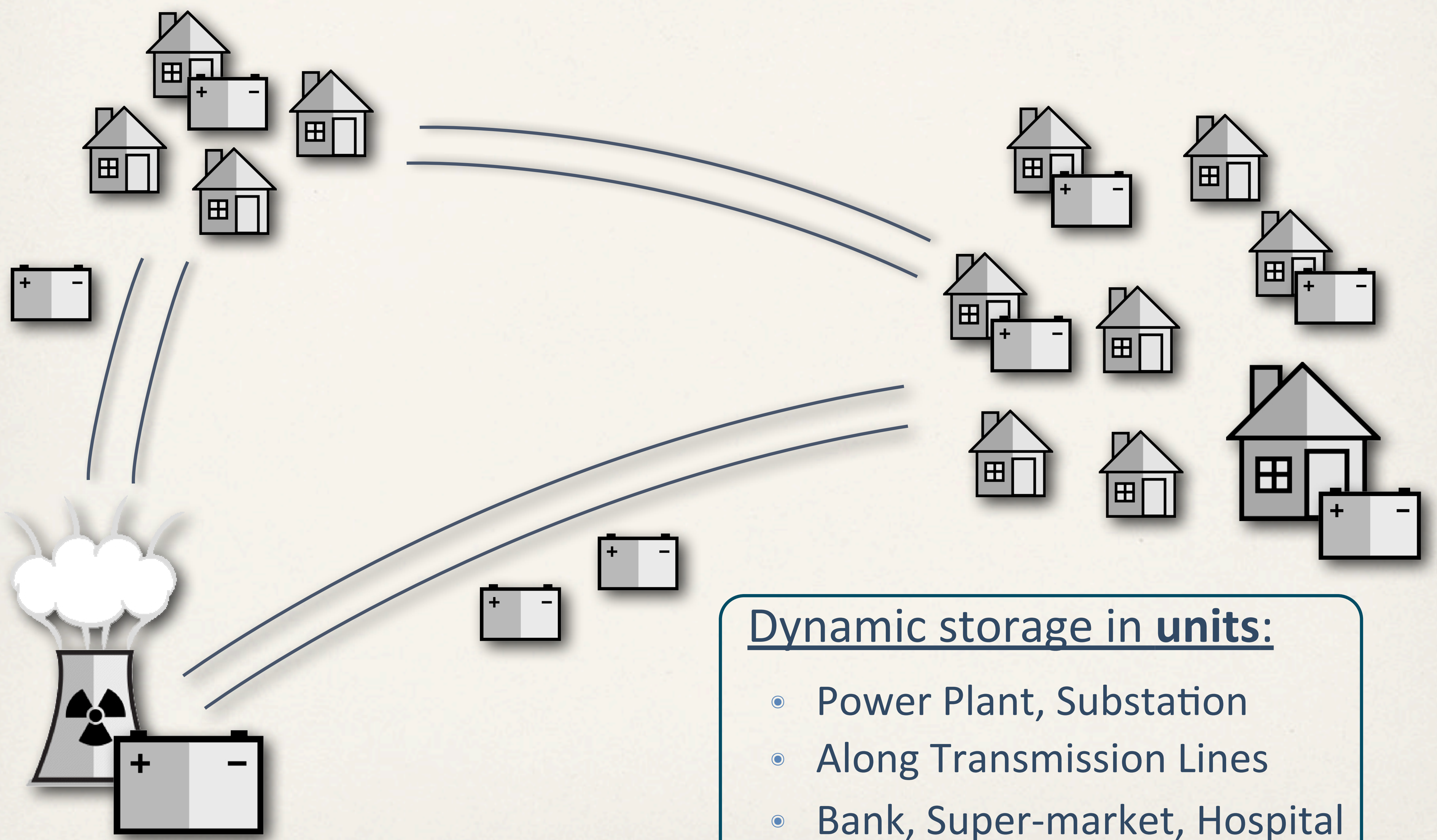
How does the Grid become smart?



3. Smart Grid Energy Storage

How do you store Energy on the Grid?



Dynamic storage in **units**:

- Power Plant, Substation
- Along Transmission Lines
- Bank, Super-market, Hospital
  Private Households

3. Smart Grid Energy Storage

An extended Vision: Vehicle to Grid (V2G)