Utilizing unused renewable energy

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Problem

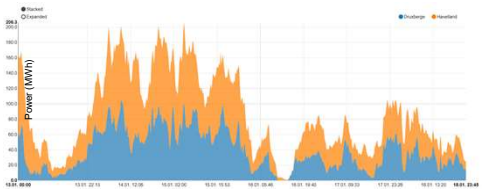

Figure 1: Peaks and lows of onshore wind power plants in Germany

- Power production is inconsistent
- Excess energy is generated

Source: https://www.energy-charts.de/power.htm?source=wind-onshore&year=2020&week=3

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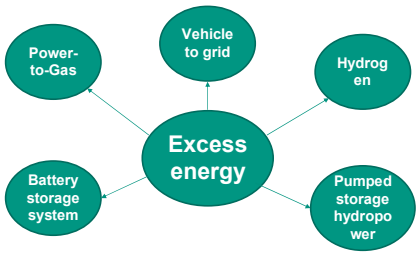
Energy storage systems



Possible solution?
Which system fits best?

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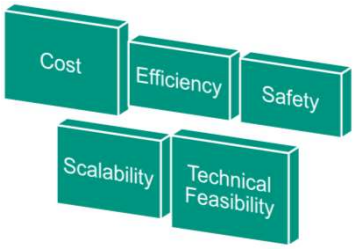
Framework



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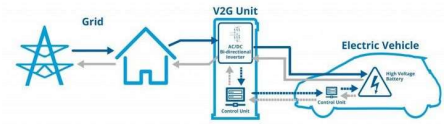
Vehicle to grid



Source:
https://www.zhaw.ch/de/engineering/institute-zentren/ine/smart-city-leitfaden/uebersicht-anwendungsbeispiele/vehicle-to-grid-v2g/

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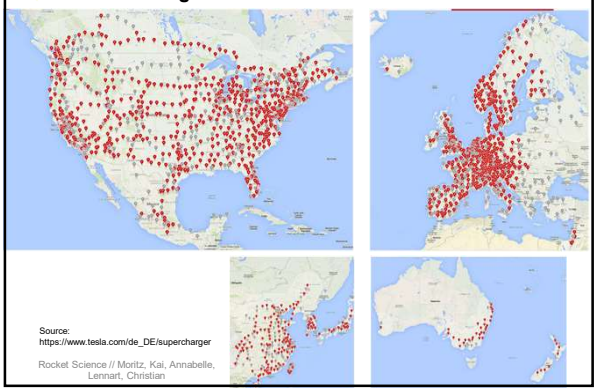
Vehicle to grid



Source:
https://www.tesla.com/de_DE/supercharger

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Vehicle to grid

Sofurce: https://www.welt.de/wirtschaft/plus203191334/E-Auto-Solaranlage-Stromspeicher-So-gut-ist-die-340-Euro-Flatrate.html

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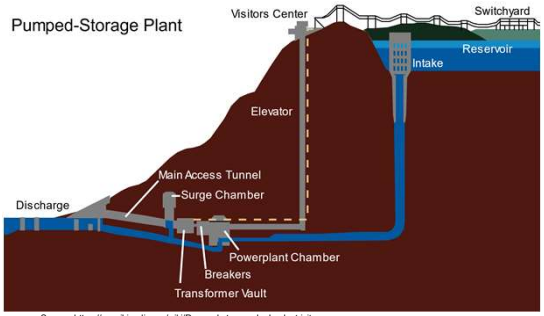
Pumped storage hydropower



Source: https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity

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Pumped storage hydropower

- Lifecycle 20 to 50 years
- Disadvantages
  - Geographical restraints
- Advantages
  - Fulfills cost-criteria
  - Scalable to high capacities

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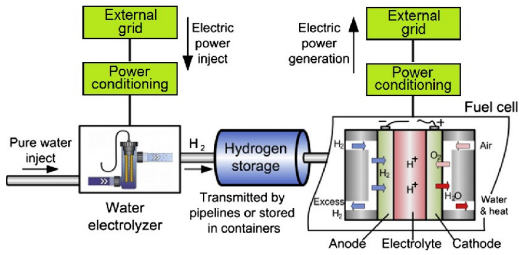
Hydrogen as an energy storage system



Source:https://www.researchgate.net/figure/Topology-of-hydrogen-storage-system-electrolyser-storage-vessel-and-fuel-cell-after_fig1_311679888

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Hydrogen as an energy storage system

- Lifecycle: 30 to 45 years
- 45% round-trip efficiency
- Disadvantages
  - Expensive
  - Inefficient
- Advantages
  - Power and Energy are independtly scalable
  - Hydrogen production enables further usage

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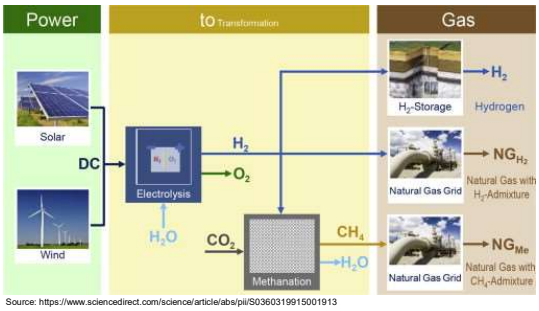
Power-to-Gas



Source: https://www.sciencedirect.com/science/article/abs/pii/S0360319915001913

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Power-to-Gas

- Lifecycle: 5 to 10 years
- Around 70% efficiency

- Disadvantages
  - Expensive
  - Lack of infrastructure

- Advantages
  - Easy scalable
  - Diverse uses of Hydrogen
  - Relatively high efficiency

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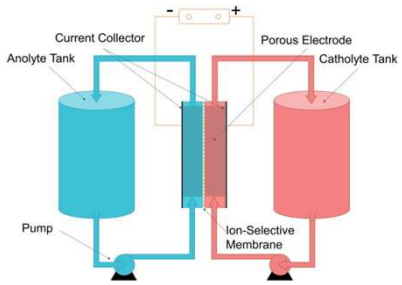
Batteries

- Vanadium Redox Flow Battery



Source: https://en.wikipedia.org/wiki/Vanadium_redox_battery#/media/File:Redox_Flow_Battery.jpg

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Vanadium Redox Flow Battery

- 12,000-20,000 cycle life (90% capacity drop)
- 330 - 970 €/kWh
- 75% efficiency

- Disadvantages
  - Toxic chemicals
  - Early stage in development

- Advantages
  - Power and energy are separated
  - Discharge up to 20h

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Comparison

Criteria / Systems	Cost	Efficiency	Safety	Scaling	Technical feasibility	Total
Vehicle to grid	- - -	+	+ + +	- -	- - -	-18
Pumped storage hydropower	+	+ + +	+ +	+ +	- -	+6
Hydrogen	- -	- - -	+ +	+ + +	+ + +	+8
Power-to-Gas	- -	+	+ +	+ + +	+ + +	+12
Batteries	+ + +	+ +	+ +	+ + +	+ +	+25

Table 1: Comparison between energy storage systems

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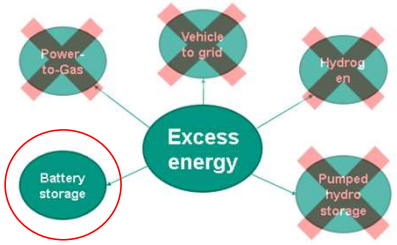
Conclusion

- Various technologies technically feasible and scalable
- Overall best solution → **Battery storage**



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Recommendations

- Construction of Battery Storage Facilities as soon as possible
- Best *current* solution
- Rapid developments in Hydrogen usage and infratructure could substitute Batteries in the future

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