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Conceptual Modeling of Energy Storage Systems

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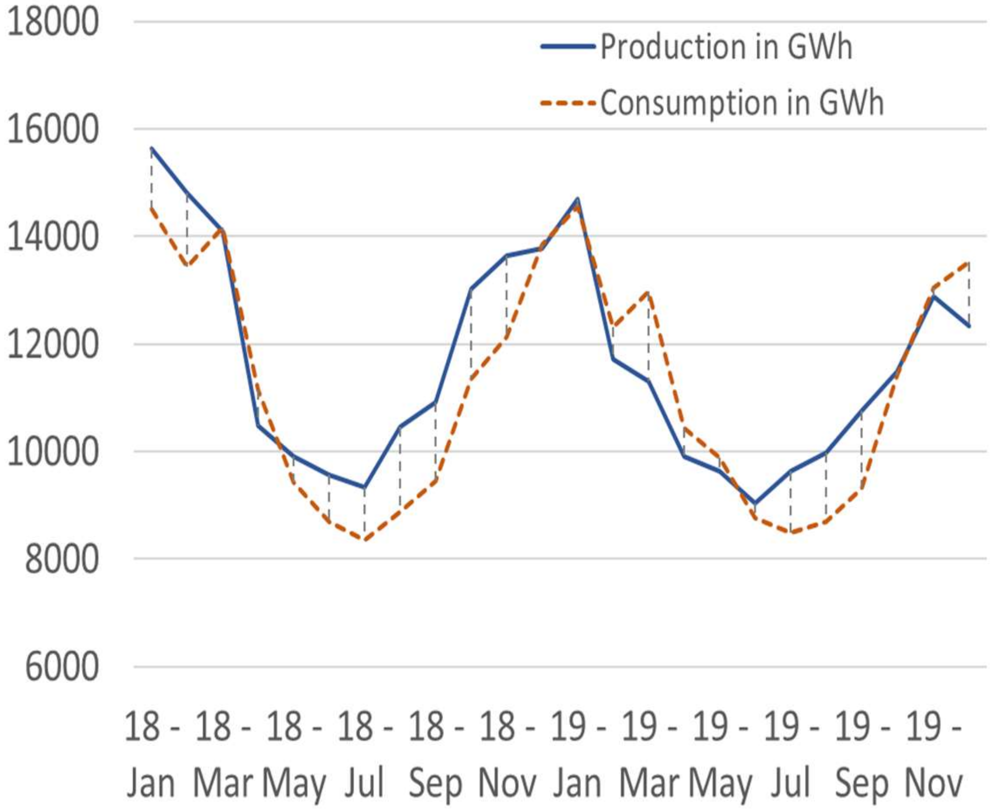
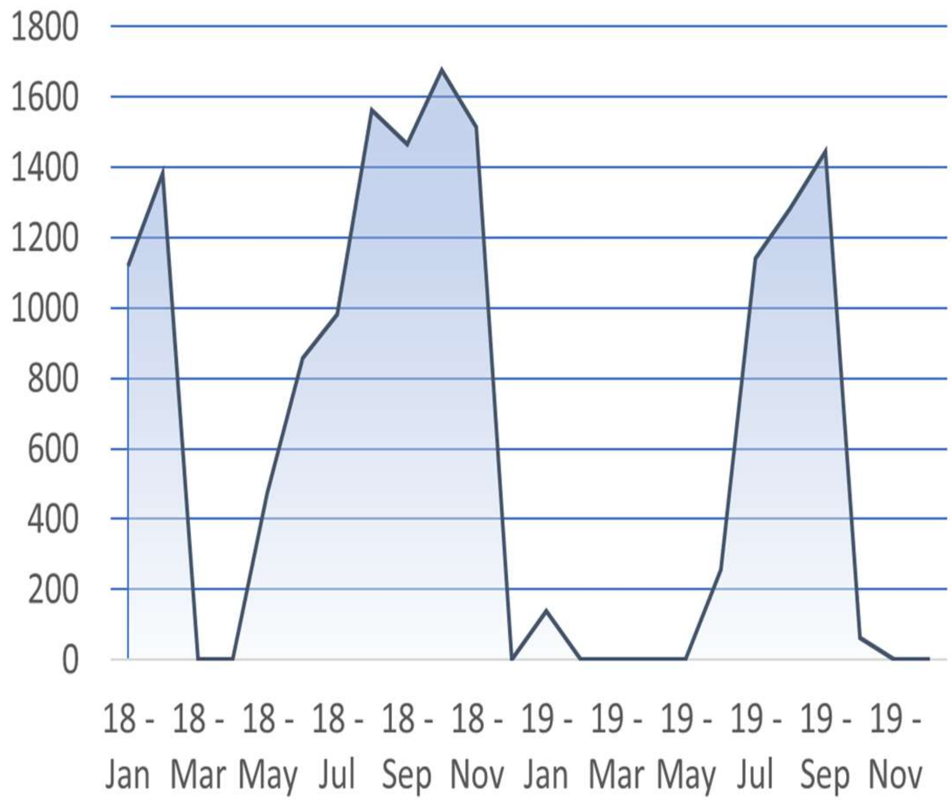
Agenda

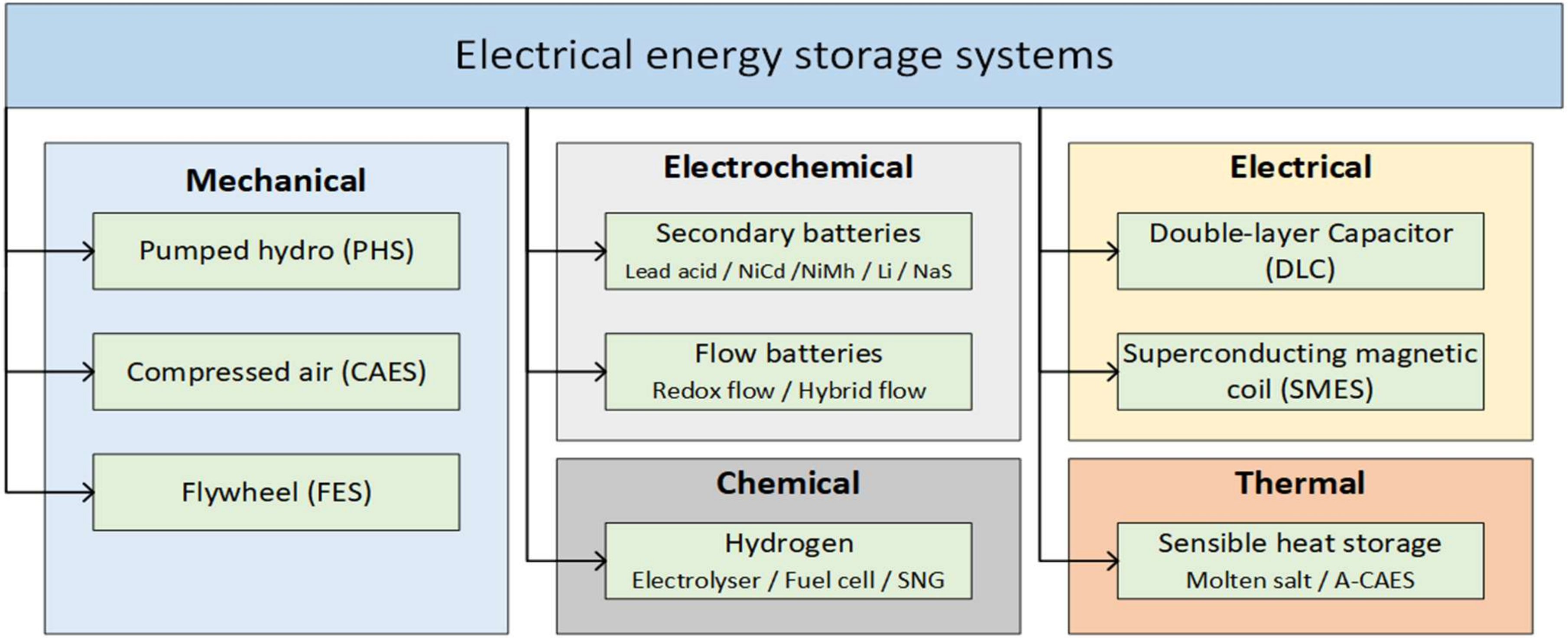
- Energy Storage in Norway
- The Role of the Decision Maker
- Research Question and Research Method
- Case Study – Vestsiden Middle School
- Exploring Conceptual Models in a Case Study
- Conclusions

Energy Storage Potential in Norway

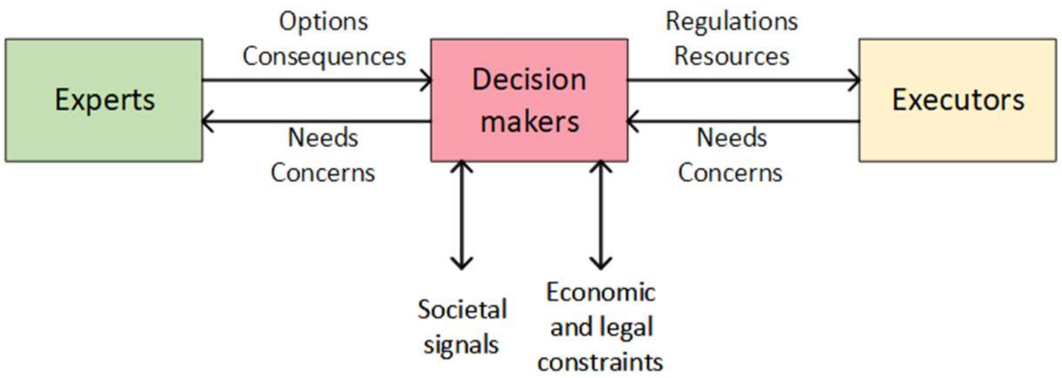




Energy Storage Technologies



Decision Makers



- Implementation of Renewable Energy is driven by Decision Makers. They rely on experts to determine their options and consequences of their choice.

- The complexity of Renewable Energy makes it difficult to select the most suitable and technically feasible alternative and communicate the consequences in a sensible way.

Research Questions

Main research question:
How can conceptual modeling contribute as a useful and valuable tool when investigating and evaluating concepts for energy storage of renewable energy?

Sub-questions:

Meta^0:

- How can we guarantee a continuous supply of energy and ensure flexibility in a grid based on renewable energy sources?
- What potential solutions for energy storage exists, and are they technically feasible and economically viable?
- How large is the energy surplus in the Norwegian power grid, that potentially can be stored?

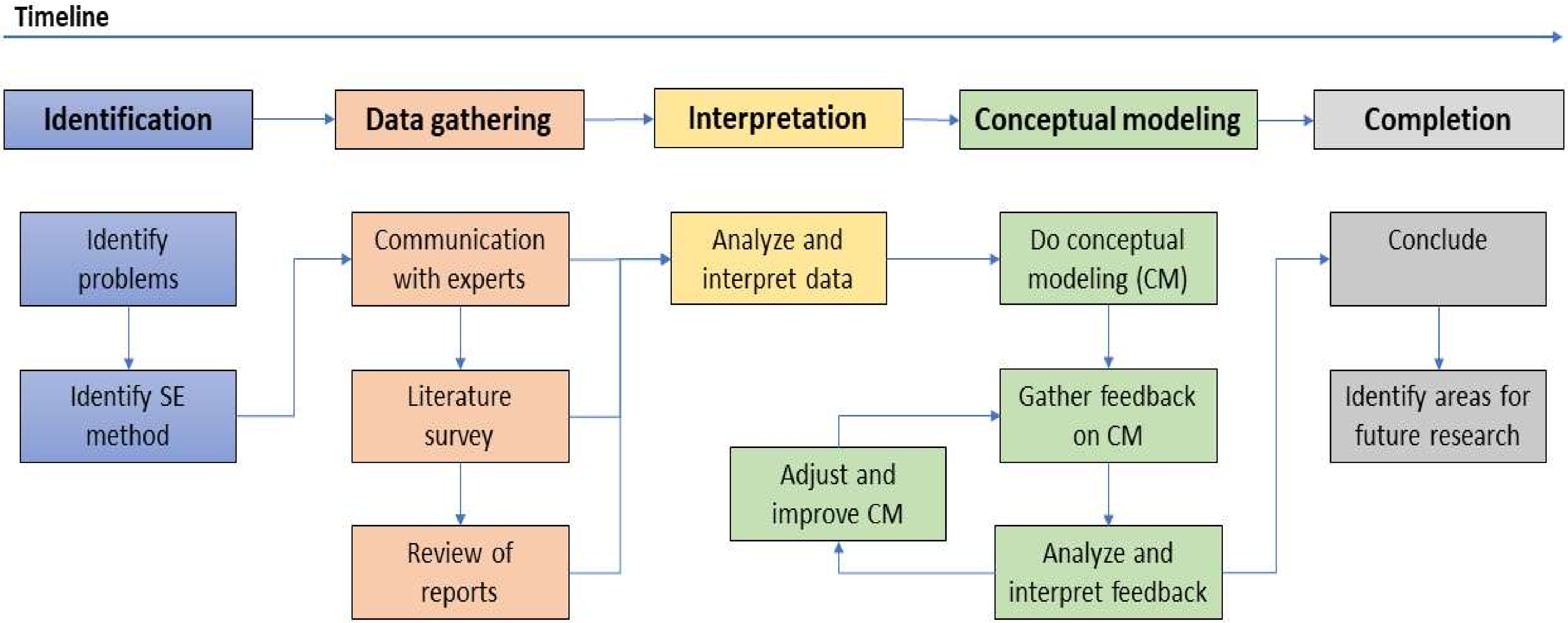
Meta^1:

- How can conceptual modeling contribute to communicate and evaluate systems for energy storage?

Areas for investigation:

- Climate change and the transition from fossil fuels to renewable energy sources.
- Production and consumption, both in Norway and local small scale projects.

Research Design



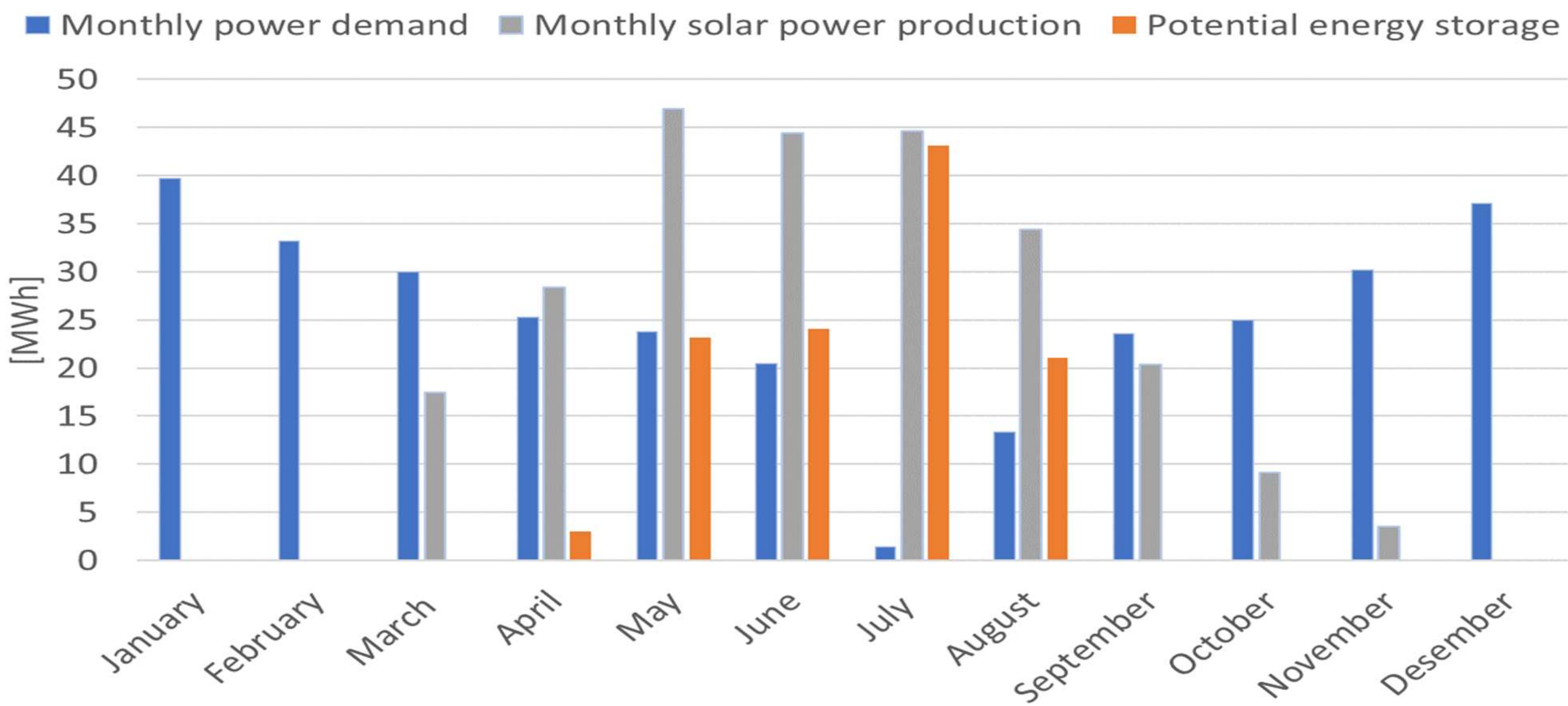
Case Study

Vestsiden Middle School, Kongsberg

- Microgrid
  - Connected to public power grid
  - Cnnected to geothermal heat grid
  - Local battery storage
- Future Pilot Installation (2021)
  - Local hydrogen production and storage from excess solar power
  - Local power prod from hydrogen
- USN provide algorithms for Energy Management System
- Regional project funding, 2019 - 2020

Case Study – Vestsiden School

Energy Production and Demand



Assessment Criteria for the Decision Makers

PESTEL

Political - **Feasibility** - **National goal compliance**	**Economical** - **CAPEX** - **OPEX**	**Social** - **Benefit for society** - **Potential harm (e.g. noise)**
Technical - **Maturity** - **Complexity**	**Environmental** - **Footprint** - **Impact on nature**	**Legal** - **National laws** - **Local regulations**

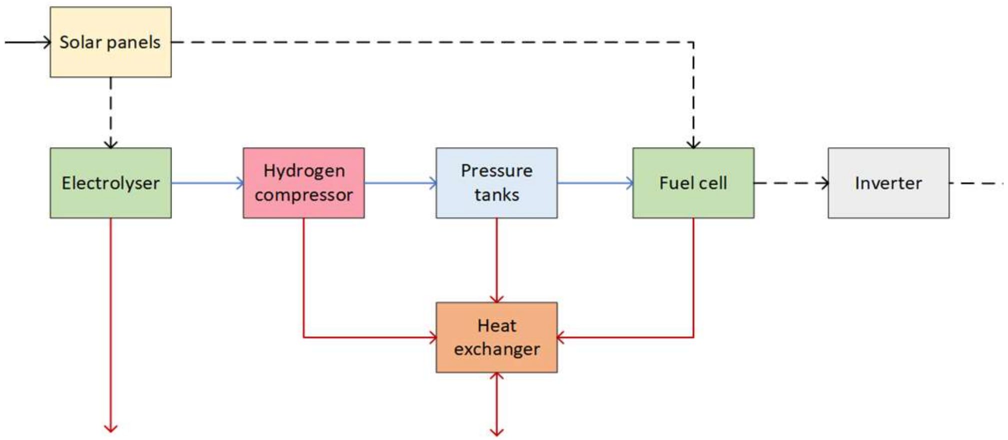
Assessment Criteria for the Decision Makers

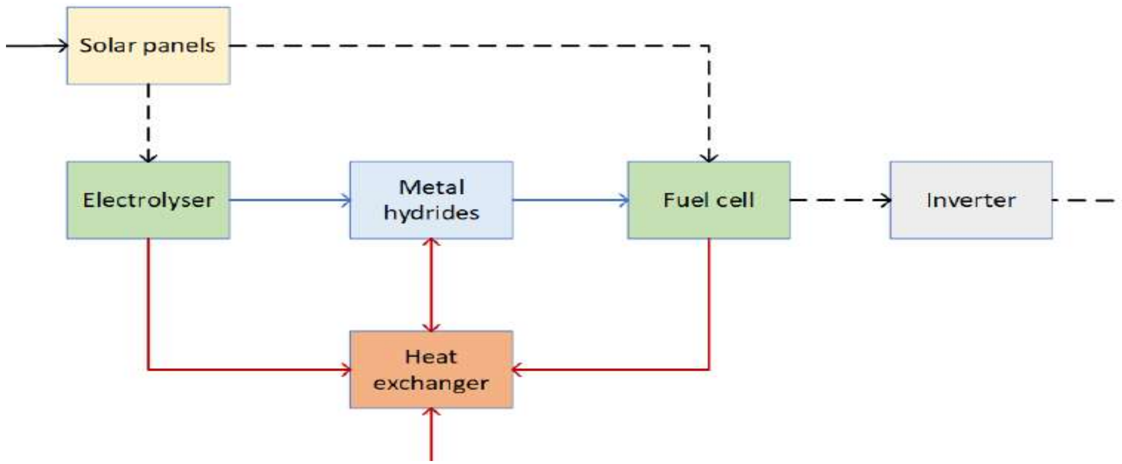
Key Performance Drivers

	Key Performance Parameters					
	Capacit y	Efficiency	CAPEX	OPEX	Discharge time	Footpri t
Hydrogen Storage (Compressed Gas)	1 - 1000 GWh[1]	40% (el.)[1]	> 5000 $/kW[2]	2% invest:[3] > 100 $/kW	1 h - 1 month[1]	Small
Pumped Hydro Storage	0.1 - 10 GWh[1]	75-85%[3]	900-1650 $/kW[3]	2% invest:[3] 18-33 $/kW	10 h - 1 month[1]	Large
SaltX Tech.[4]	10 MWh	33% (el.) 90% (thrm.)	200 $/kWh	*LCOS:* 0.15 $/kWh	4-36 h	Small

Conceptual Model

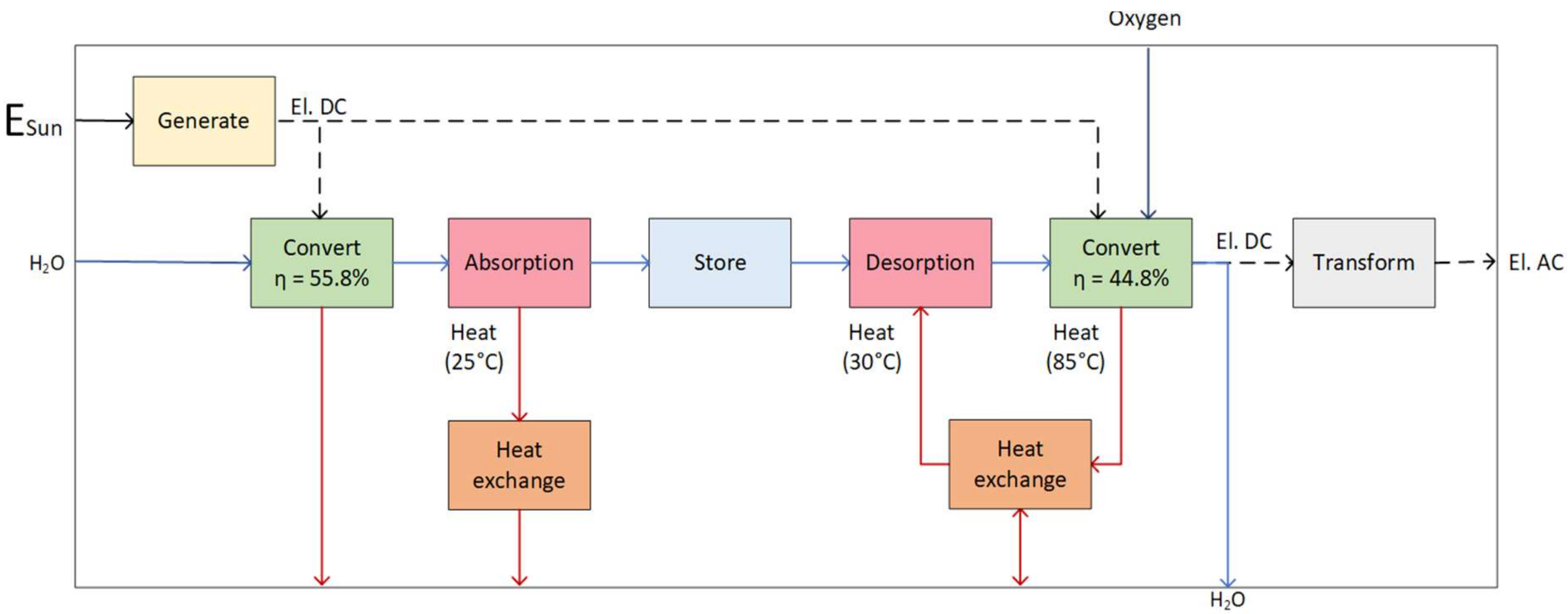
H2 Storage Options (Compressed gas vs Metal Hydrides)





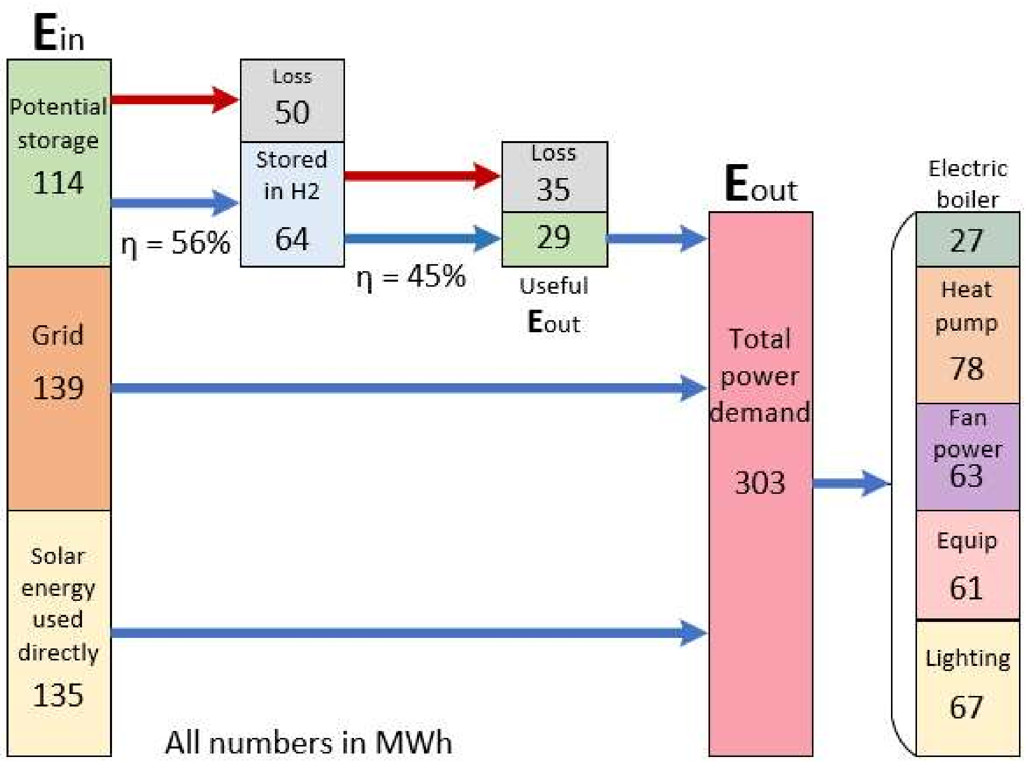
Conceptual Model

Functional Model (Metal Hydrides)



Conceptual Model

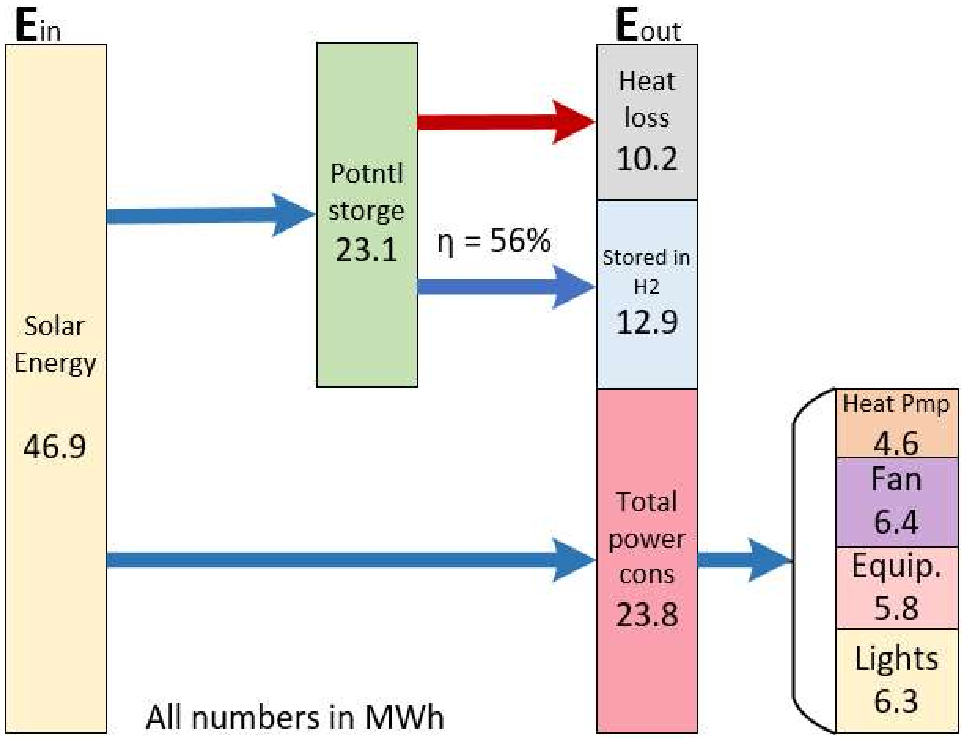
Annual Energy Balance (Metal hydrides)

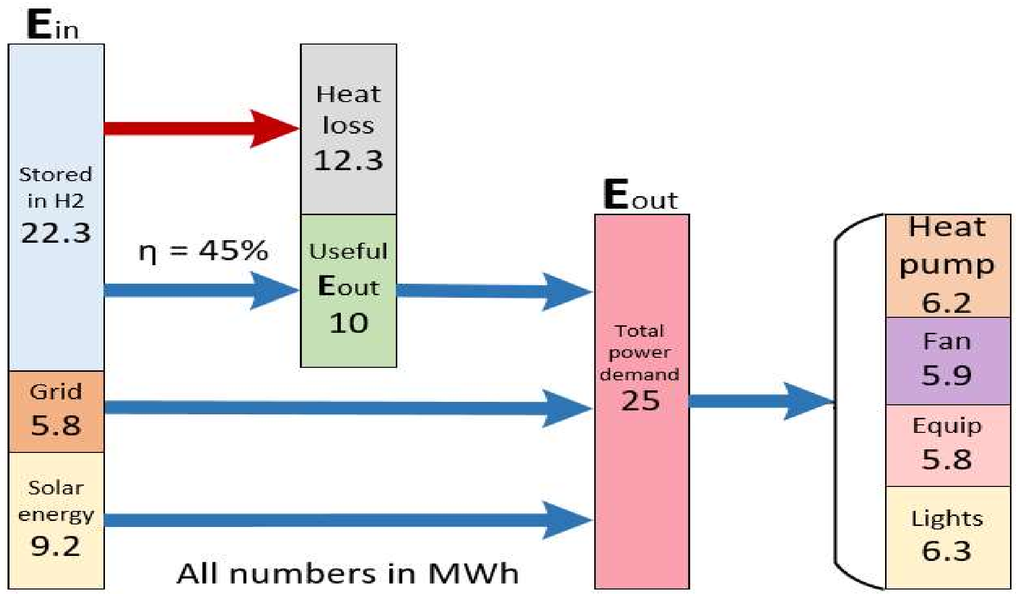


- It is essential to find the correct level of simplification so that the experts can use the models to evaluate options and communicate these options to the decision-makers.

Conceptual Model

Monthly Energy Balance (Metal Hydrides, July vs October)





Conclusions

- The models give a **good overview of the flow of energy** through the system. This overview can contribute to the improvement of the efficiency in the system.
- A weakness in the conceptual modeling for the hydrogen system is that we have not sufficiently emphasized the possibilities for utilization of the waste heat. The lack of emphasis is due to **over-simplification** of the system. The reuse of waste heat in hydrogen storage systems will increase the efficiency and make hydrogen a more economically viable storage solution.
- Simple visualization of the energy storage concepts using **conceptual modeling requires a comprehensive study of the technologies**.
- To give a useful and valuable representation of the concepts is it essential to find a **balance between how detailed and how simplified** the models should be.
- The strength of the models is that **one can quickly get an understanding of the concept** and get an overview of the main features of the system.
- Conceptual modeling **contributes to a clear and useful representation** of the systems. We can use these simplified models to communicate the system behavior at a high level.
- Our work indicates that the **models help support the technology selection process** for energy storage systems.

Thank You for your Attention!

We will answer your questions in writing.