Hydrogen Storage Applications in Industrial Microgrids

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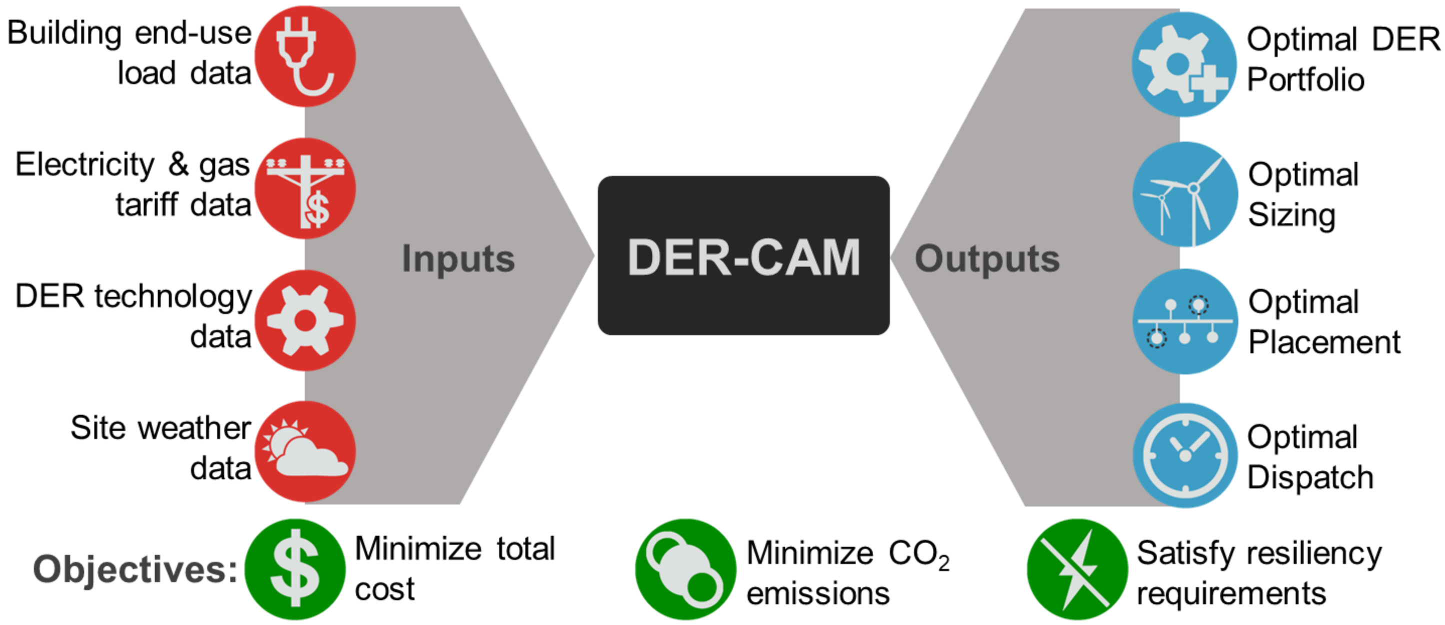
Agenda

1. Motivation & Research Question
2. The Model
3. Case Study
4. Results
5. Future Work

1. Motivation and Research Question

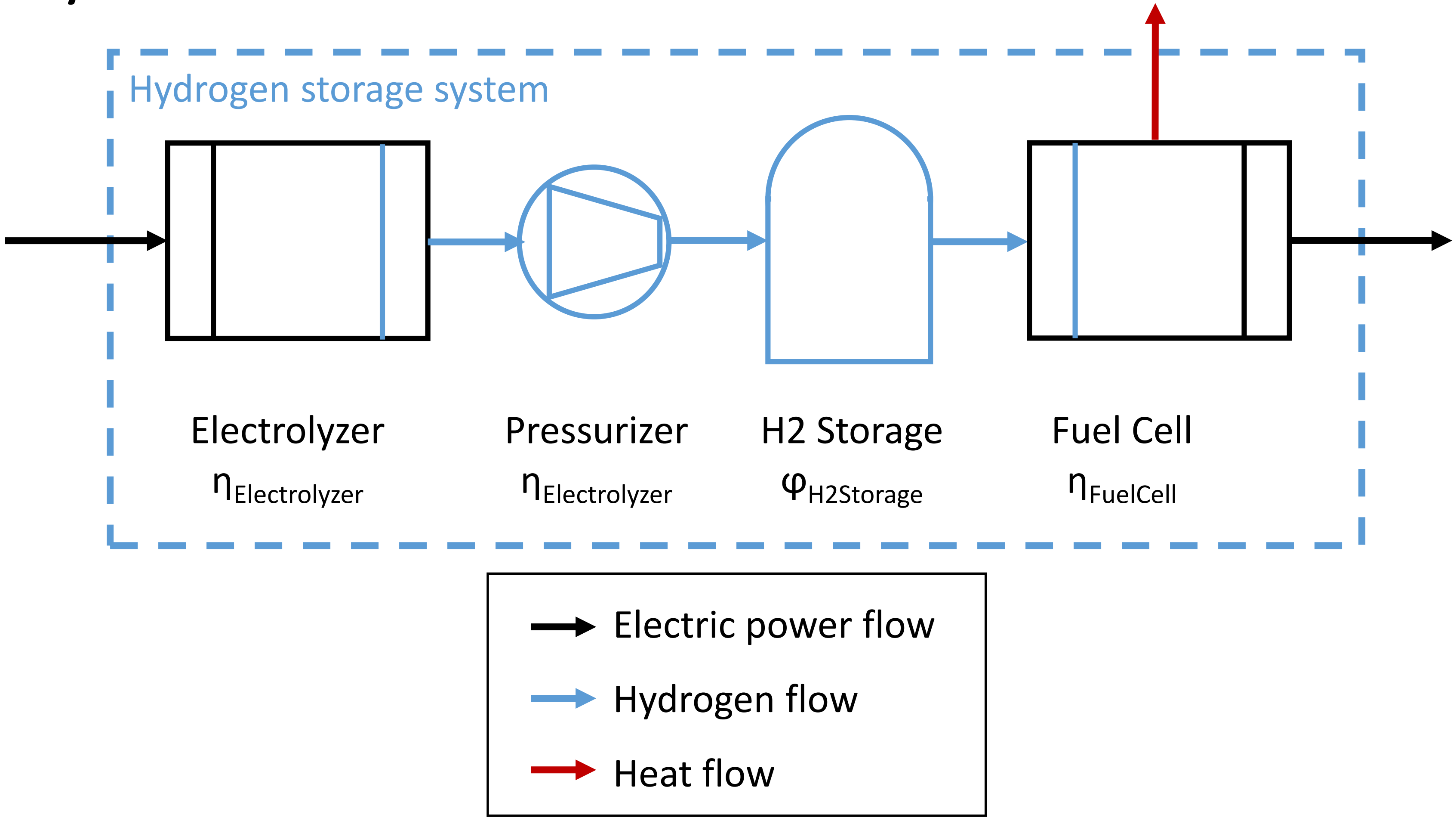
- Literature has shown that the suitability of storage options is highly dependent on the specific application.
- We enable complex analyses by extending DER-CAM, a support tool used to determine optimal investment and scheduling of DER in microgrids.
- We investigate the **cost-effectiveness of hydrogen storage systems** in industrial microgrids.
- We validate the approach by a case study, using two sets of industrial data.

2. The Model: DER-CAM



- **Investment & Planning:** determines optimal equipment combination and operation based on *historic* load data, weather, and tariffs
- **Operations:** determines optimal week-ahead scheduling for installed equipment and *forecasted* loads, weather and tariffs

2. The Model: Hydrogen Storage System



2. The Model: Parameters

- We can specify technologies by a suitable choice of parameters.
- In this study, we use a system most suitable for highly variable infeed: a Polymer Electrolyte Membrane (PEM) electrolyzer, a metallic pressurized vessel, and a Proton Exchange Membrane Fuel Cell (PEMFC).

Component		**Investment**	**Efficiency**
Electrolyzer		2,000 USD/kW	70%
Pressurized vessel		15 USD/kWh	95%
PEMFC	**250 kW**	1,884 USD/kW	60%
	100 kW	2,300 USD/kW	
	10 kW	2,527 USD/kW	
	5 kW	3,946 USD/kW	
CHP	**250 kW**	2,219 USD/kW	35% (electric) 45% (thermal.)
	100 kW	3,140 USD/kW	
Li ion battery		500 USD/kWh	81%

References: PEM electrolyzer: [6], [12], [13]; pressurized vessel: [14]; PEMFC: [15-17]; battery: [18]

3. Case Study: Load Data

- We used real **load data from two manufacturing companies** with significant heat loads.

Data	**Load 1**	**Load 2**
Process	Wood processing	Molding process
Annual electricity demand	218 MWh_{el}	24.0 GWh_{el}
Peak demand	118 kW_{el}	5.9 MW_{el}
Annual gas demand	1.3 GWh_{th}	3.2 GWh_{th}
Electricity tariff scheme	A-10	E-20
Gas tariff scheme	G-NR1-E	G-NR1-E

- We evaluate both load scenarios using TMY3 weather data from the San Francisco International Airport.
- Both loads are subject to PG&E electricity and gas tariffs, including **TOU and demand peak rates**.

4. Results: Scenarios

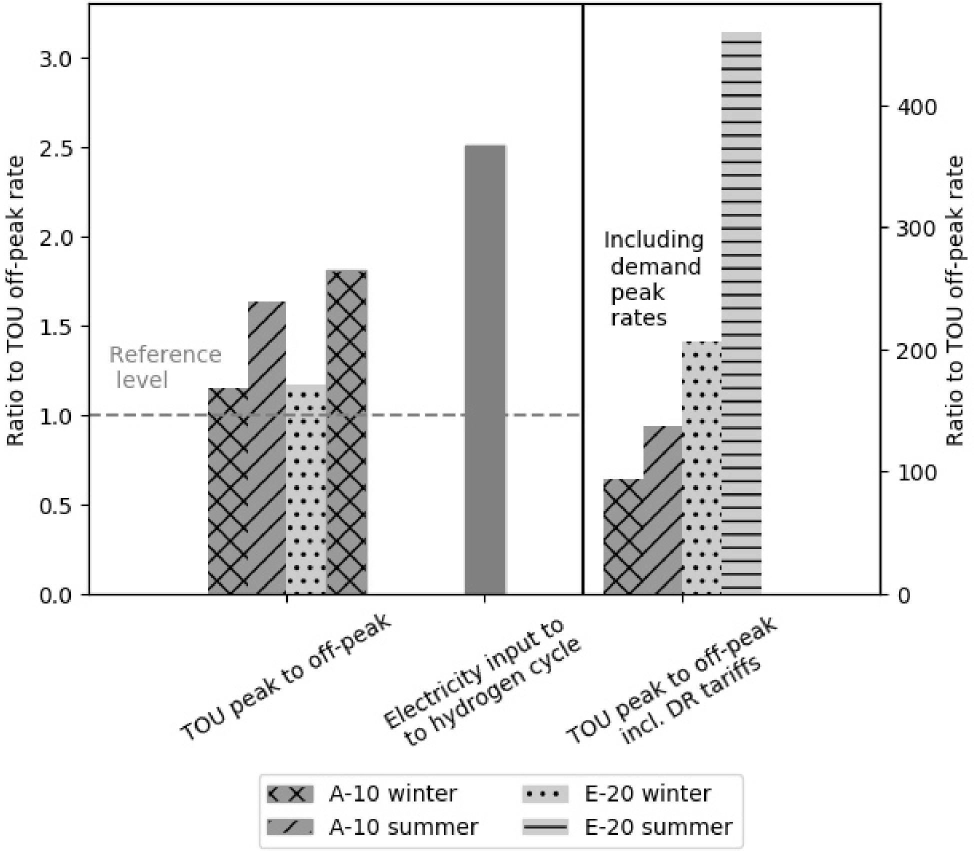
- BAU: Business as Usual
- Scenario 1: Investment into hydrogen storage enabled
- Scenario 2: Investment into PV and hydrogen storage enabled
- Scenario 3: Investment into PV, PEMFC with CHP and hydrogen storage enabled
- Scenario 4: Investment into PV, hydrogen and electric storage enabled

4. Results: Hydrogen Storage Only

Scenario	**BAU**	**1**	**2**	**3**	**4**
Total energy costs [kUSD]	4,474	4,419	4,041	4,048	4,041
CO2 emissions from operation [t]	8,061	8,150	6,438	6,451	6,438
PV [kW]	-	-	3,092	3,096	3,096
Electrolyzer [kW]	-	68	53	72	52
H_2 storage [kWh]	-	1,330	1,011	1,410	985
Fuel Cell [kW]	-	750	250	250	250
Electric storage [kW]	-	-	-	-	207

- Hydrogen storage has the **potential to flatten demand** and reduce exposure both to high TOU rates in peak hours and demand rates.

4. Results: Hydrogen Storage Only



4. Results: CHP Fuel Cell

Scenario	BAU	1	2	3	4
Total energy costs [kUSD]	4,474	4,419	4,041	4,048	4,041
CO2 emissions from operation [t]	8,061	8,150	6,438	6,451	6,438
PV [kW]	-	-	3,092	3,096	3,096
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Electric storage [kW]	-	-	-	-	207

- **CHP ability of fuel cells can be an interesting option** for industrial loads but our analysis does not show improved economic results under the given conditions.

4. Results: Versus Electric Storage

Scenario	**BAU**	**1**	**2**	**3**	**4**
Total energy costs [kUSD]	4,474	4,419	4,041	4,048	4,041
CO2 emissions from operation [t]	8,061	8,150	6,438	6,451	6,438
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- Also, despite the low round-trip efficiency and high investment costs, hydrogen storage systems **can be economically competitive with other storage systems**.

4. Results: Versus Electric Storage`

- Despite the low round-trip efficiency, the **results is not as clearly cut as expected**, especially when comparing to electric storage.
- Any **sensitivity analysis** obviously gives one technology an advantage over the other.
- **Possible reasons** are the longer life expectancy as well as the low minimum load of components.
- Future feasibility of hydrogen systems for industrial microgrids will **strongly depend on the development of economic and technical characteristics**.
- Also, **other usages of hydrogen** on-site will probably be pivotal.

Future Work

- Further **simulations & extensions**:
  - Simulation of investment decisions under varying cost assumptions and technology developments
  - …

- Further **extensions** of the model:
  - Enable usage of hydrogen for industrial processes
  - Include a vehicle fleet driving on hydrogen
  - Allow for hydrogen usage in DER working on gas
  - …

Take-Away and Questions

- How do we ensure stable system operations?
  - How do/will we estimate load and generation?
  - Which information is necessary?
  - Who is managing system stability?
- How do future electricity markets integrate a growing number of prosumers?
  - What should be valued? Time-dependency, locational value, capacity factors
  - Which ancillary services markets should exist?

Thank you!

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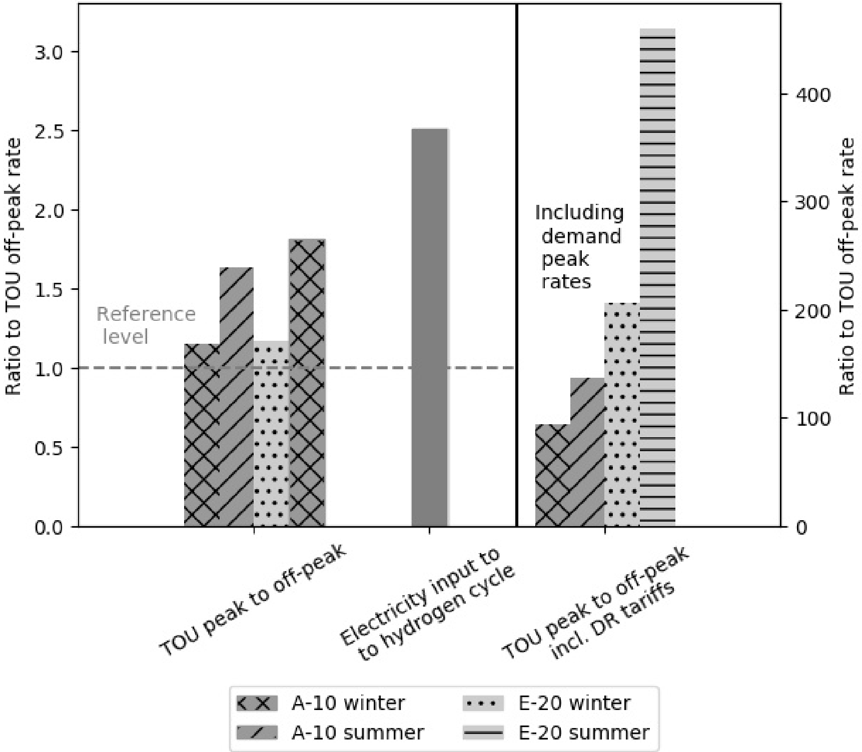
2. The Model: Electrolyzer

- Through this work, DER-CAM has been extended to model electrolyzers and hydrogen storage.
- The storage cycle has been formulated as a general storage system based on a newly introduced fuel type “hydrogen”.
- The technologies used for electrolysis, tank, and re-conversion can be freely specified by a suitable parametrization.
- High- and low-level balance equations ensure conservation of energy.

4. Results: Ability of load-shifting

- Numeric results for hydrogen storage as only investment option:
  - Load 1 (small): no investments
  - Load 2 (big): 1.2 % savings
    - 68 kW electrolyzer
    - 1,330 kWh H_2 storage
    - three 250 kW units of PEM fuel cells



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4. Results

- Hydrogen storage systems **can be economically viable to mitigate daily on-site load variability** in industrial microgrid settings, if confronted with TOU and demand rates.
- **CHP ability of fuel cells can be an interesting option** for industrial loads but our analysis does not show improved economic results under the given conditions.
- Also, despite the low round-trip efficiency and high investment costs, hydrogen storage systems **can be economically competitive with other storage systems**.
- Hydrogen storage can be as good as conventional batteries in terms of **CO2 emissions** despite high losses.