Design and Operation of a Grid to Mobility Demonstrator

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EEVC INFRASTRUCTURE CONVENTION

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Agenda : Offgrid charging and Grid to Mobility demonstrator

- Charging infrastructure context
- Full scale BEV charging stations operated with 100% renewable energy ?
  - Charging profiles
  - Solar profiles
  - Stationnary batteries
- Grid to Mobility Demonstrator – H_2 refilling station
  - Design and cost
  - 350 and 700 bar protocols
  - Gas booster compression

Infrastructure – Where do we stand in Switzerland ?

- Internal combustion engine vehicles (ICEVs)
  - 3461 refilling stations [1] (incl. 65 on the highway, and 140 CNG)
  - **46 000 km of driving range delivered per day and per station** (based on total vkm from [2])
- Battery electric vehicles (BEVs)
  - 300 fast chargers (incl. 17 Tesla superchargers)
  - Smart home charging cannot fulfill all needs
    - 33% of EU inhabitants live in detached house, appartement buildings not yet equiped
- Hydrogen fuel cell vehicles (FCEVs)
  - One public station and 3 private/research demonstrators

Tesla Supercharger network in CH [3]

Station type	Energy/fuel for 46 000 km per day [4]
ICEVs	3700 L of gasoline (8 L/100km)
BEVs	8.5 MWh (18.6 kWh/100km)
FCEVs	420 kg H_2 (0.93 kg H_2/100km)

HRS network in CH

[1] Union pétrolière Suisse, rapport annuel 2015
[2] Office Fédéral des Routes, Trafic et disponibilité 2015
[3] https://www.tesla.com/fr_FR/supercharger February 2018
[4] Based on EPA ratings for Honda Accord and Clarity, www.fueleconomy.gov

Infrastructure – Weekly demand

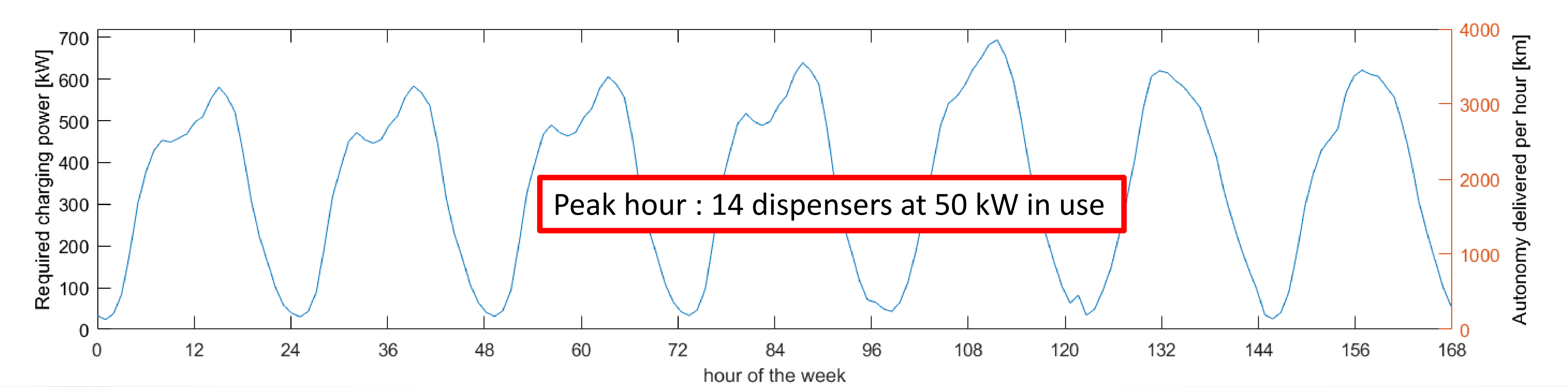
Refilling station profile

- Average from 387 US Gasoline stations [5]
- Assuming no charging losses
- Seasonal variations observed in the US probably not applicable in CH (summer driving season in US)

Vehicle	BEV		FCEV	ICEV
Charging mode	Home outlet (16-32 A)	Fast charger	HRS	Conventional refilling station
Energy carrier flowrate	2 to 6 kW	50 kW up to 150 kW	Up to 2 kg·min^{-1}	35 L·min^{-1}
Autonomy flowrate	0.2 – 0.6 km·min^{-1}	3-5 km·min^{-1} (50 kW) 9-15 km·min^{-1}(150 kW)	160-220 km·min^{-1}	370-430 km·min^{-1}

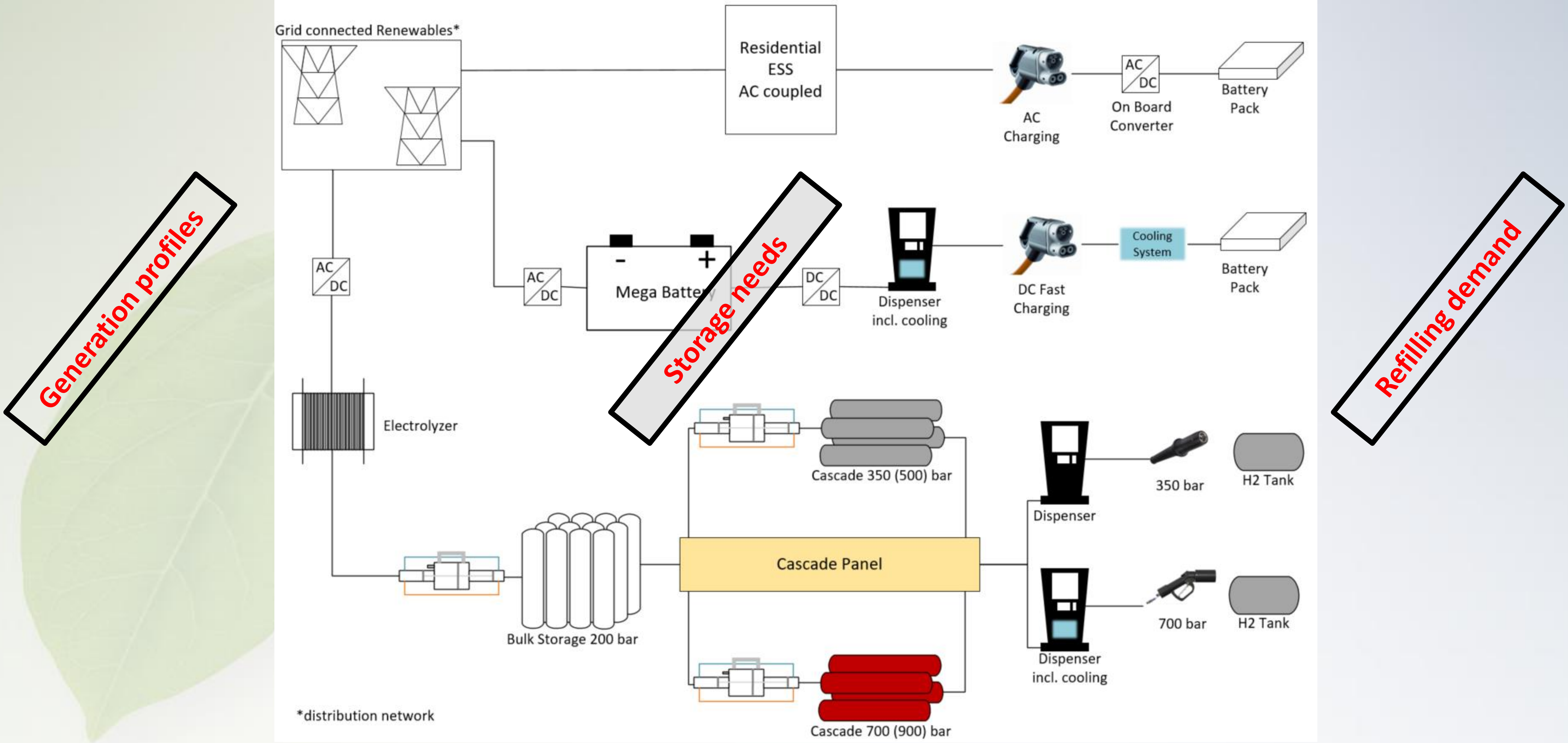






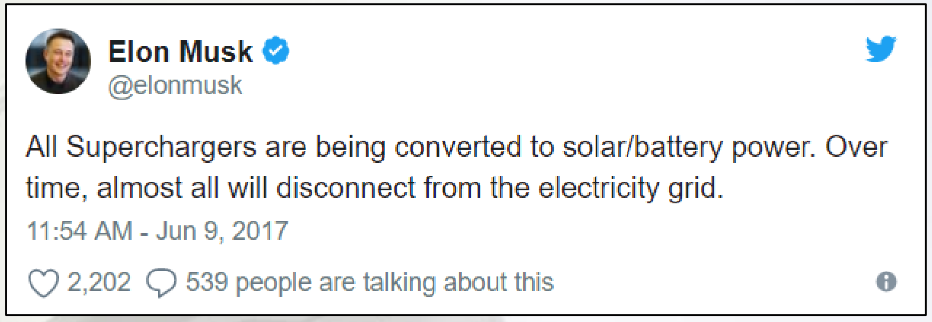
[5] Nexant Inc., Hydrogen Delivery Infrastructure Options Analysis, Report DE-FG36-05GO15032, 2008

Infrastructure – Refilling pathways



Y. Ligen *et al.* (2017), Mobility from renewable electricity: infrastructure comparison for battery and hydrogen fuel cell vehicles, EVS 30, Stuttgart, 2017

Offgrid Infrastructure ?



- 15 000 km / year / vehicle → 2.7 MWh
- Average Swiss solar irradiance : 1200 kWh / m^2 / year

➔ 12 m^2 of PV (c.a. one parking spot) with adequate seasonal storage should fulfill the needs for one car

But… how to deliver the same service with full scale infrastructure ?

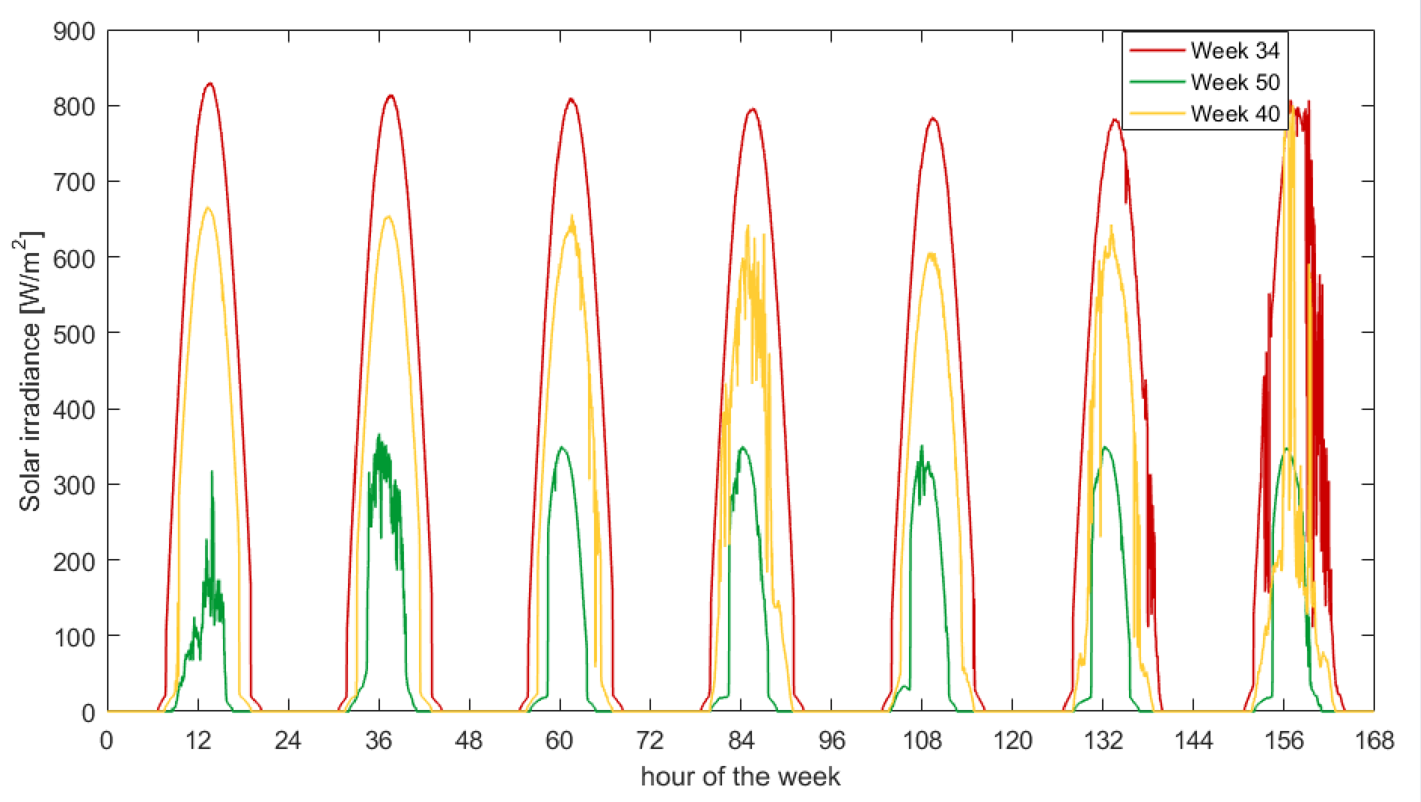
Offgrid Infrastructure ? – Available solar/wind energy

- One year of data collection in Martigny (Valais, CH) – 1 min resolution
  - Solar irradiance (alternatively TMY data from [6] can be used)

- Clustering (k-medoids methodology [7])
  - Reduce simulation periods
  - Adequately preserve significant characteristics
    - stochastic effects versus average values (e.g. clouds)
    - peaks
  - Avoid arbitrary selection

- 3 representative solar weeks

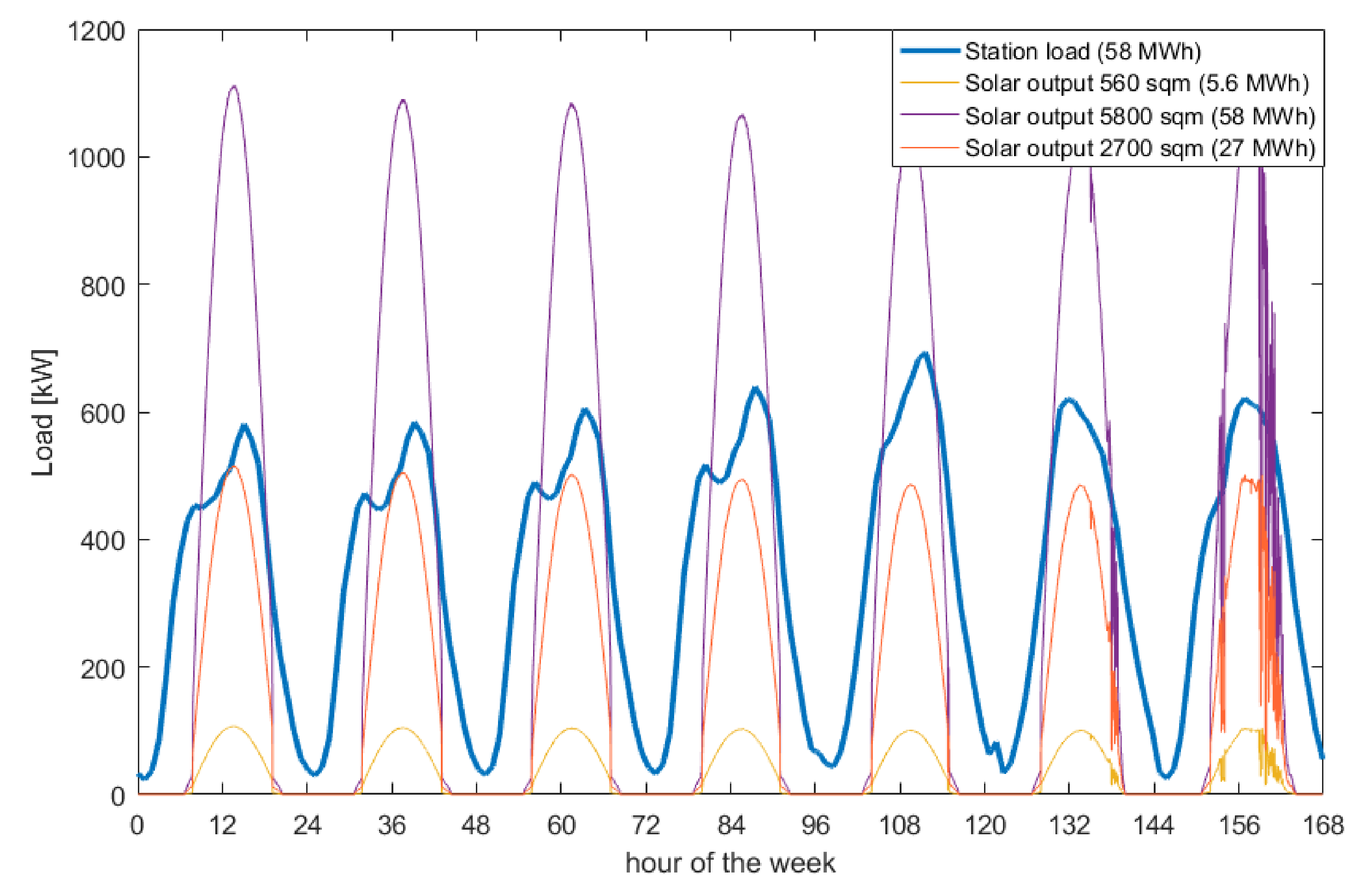
January	50	50	50	50		July	34	34	34	34	
February	50	50	50	50		August	34	34	34	34	34
March	50	40	40	40	50	September	34	40	40	40	
April	40	34	40	34		October	40	40	40	40	
May	34	40	34	40	40	November	50	50	50	50	
June	34	34	34	34		December	50	50	50	50	



[6] http://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#TMY
[7] F. Domínguez-Muñoz *et al.*, "Selection of typical demand days for CHP optimization," *Energy and Buildings*, vol. 43, no. 11, pp. 3036–3043, Nov. 2011.

Offgrid Infrastructure ? – Best case with representative Week 34

- 560 m² of roof area available [8]
  - Covering only 10% of station needs [9]
- 2700 m²
  - 100% autoconsumption possible without storage
  - 46% self sufficiency
- 5800 m² (Football field surface)
  - Minimum surface for 100% self sufficiency

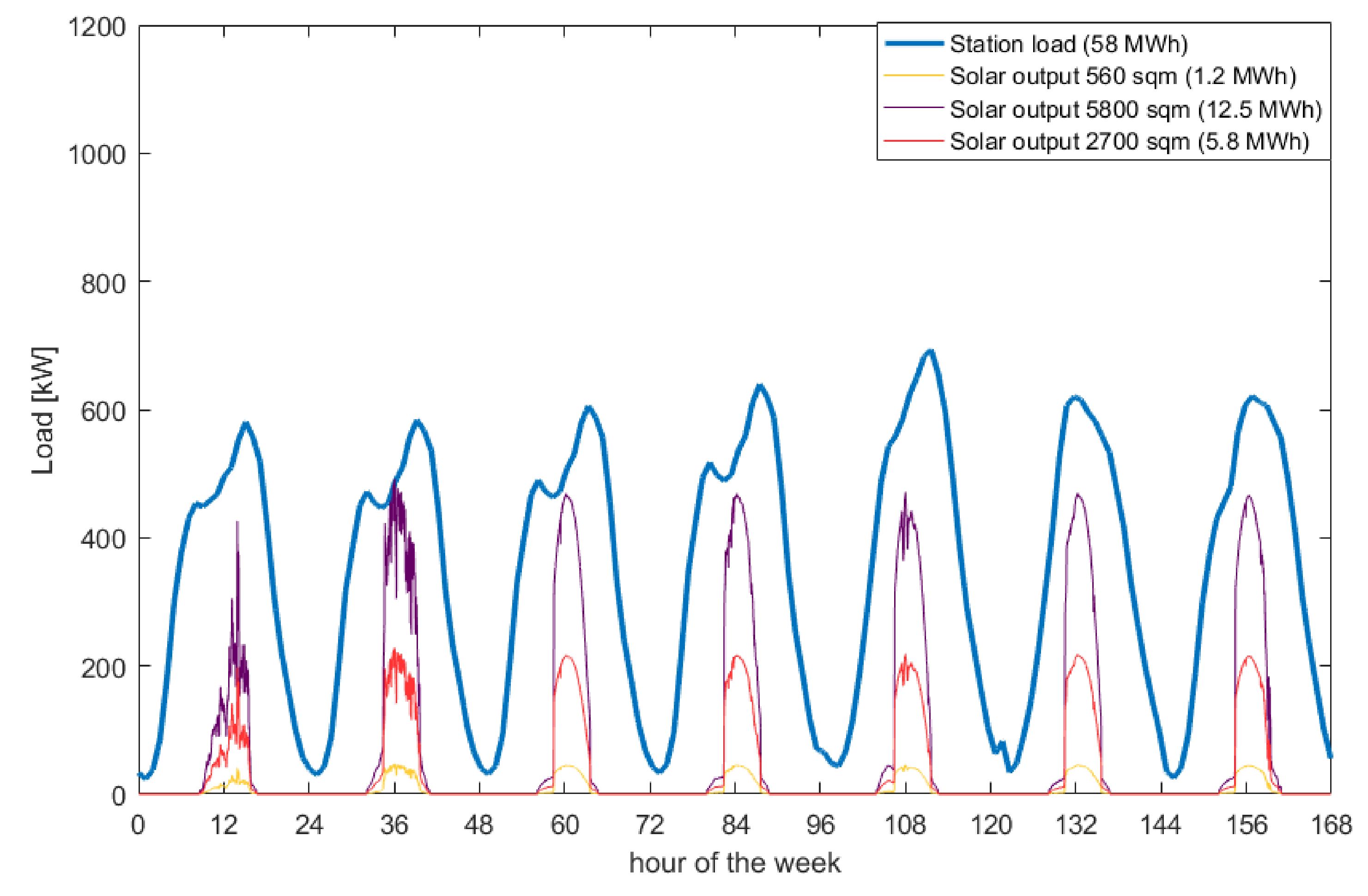


[8] average value based on the 28 highway stations located on the Swiss A1 and A9, 14 have between 450 and 750 m² available
[9] considering 20% solar PV efficiency e.g. LG or SunPower

Offgrid Infrastructure ? – Worst case with representative Week 50

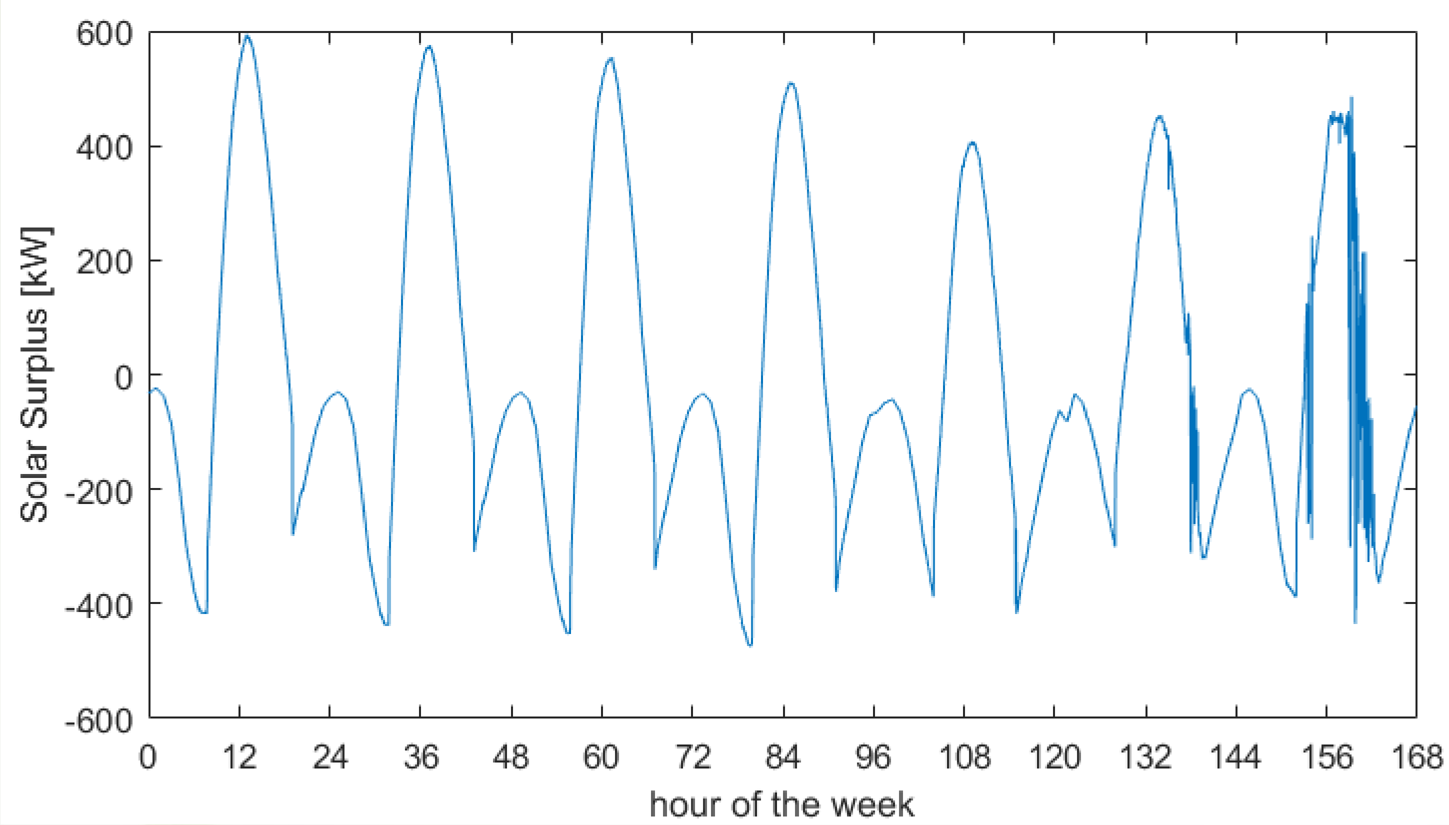
- 560 m²
  - Covering only 2% of station needs
- 2700 m²
  - 10% of station needs
- 5800 m²
  - **22% of station needs**

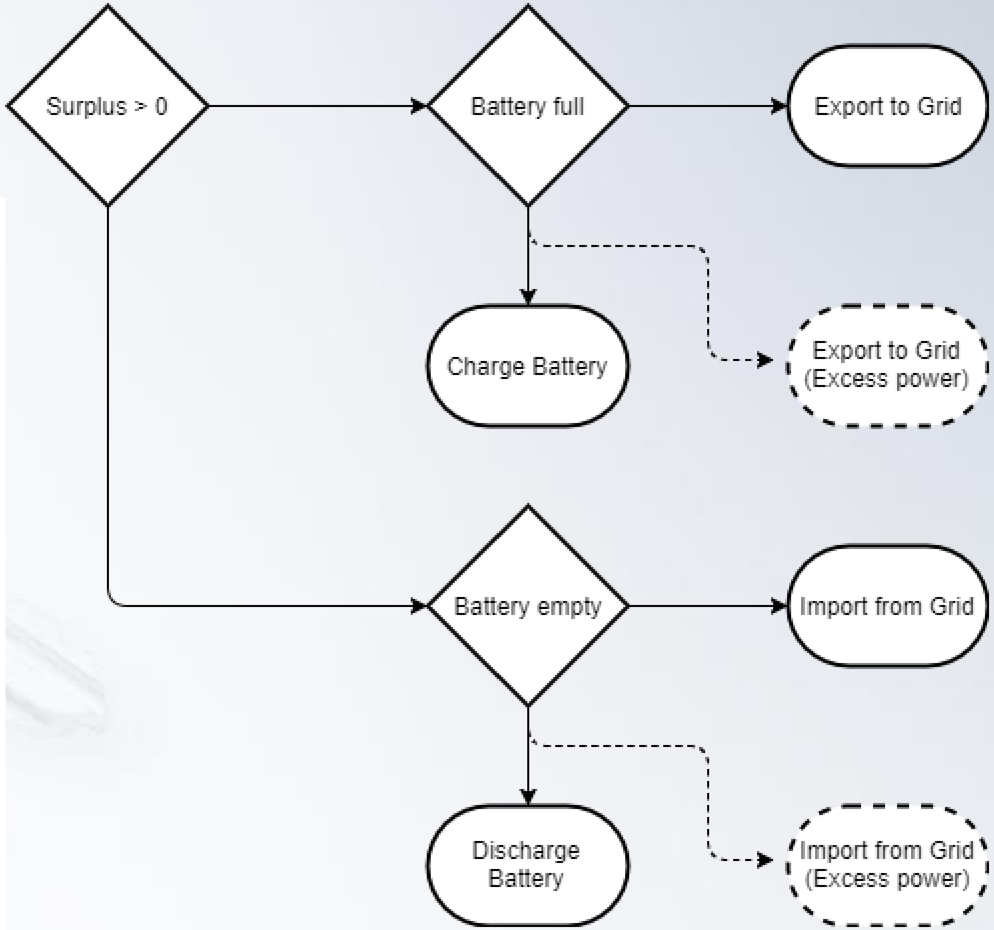
➔ Irrealistic without seasonal storage



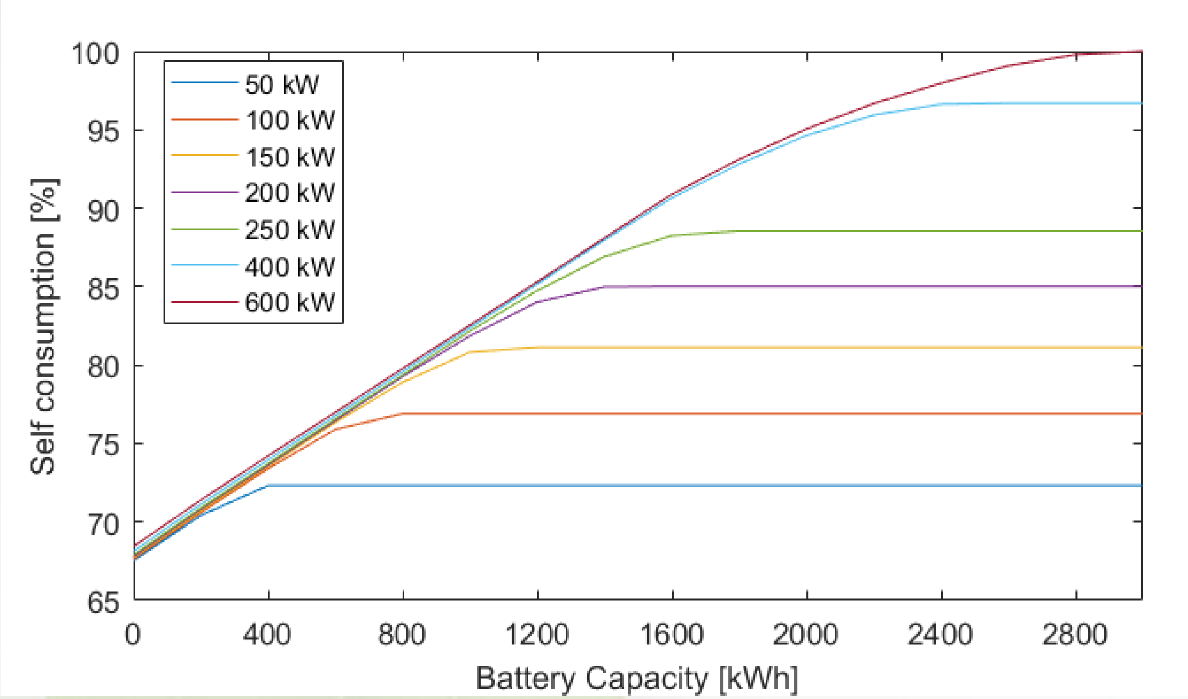
Offgrid Infrastructure ? – Role of a stationnary battery

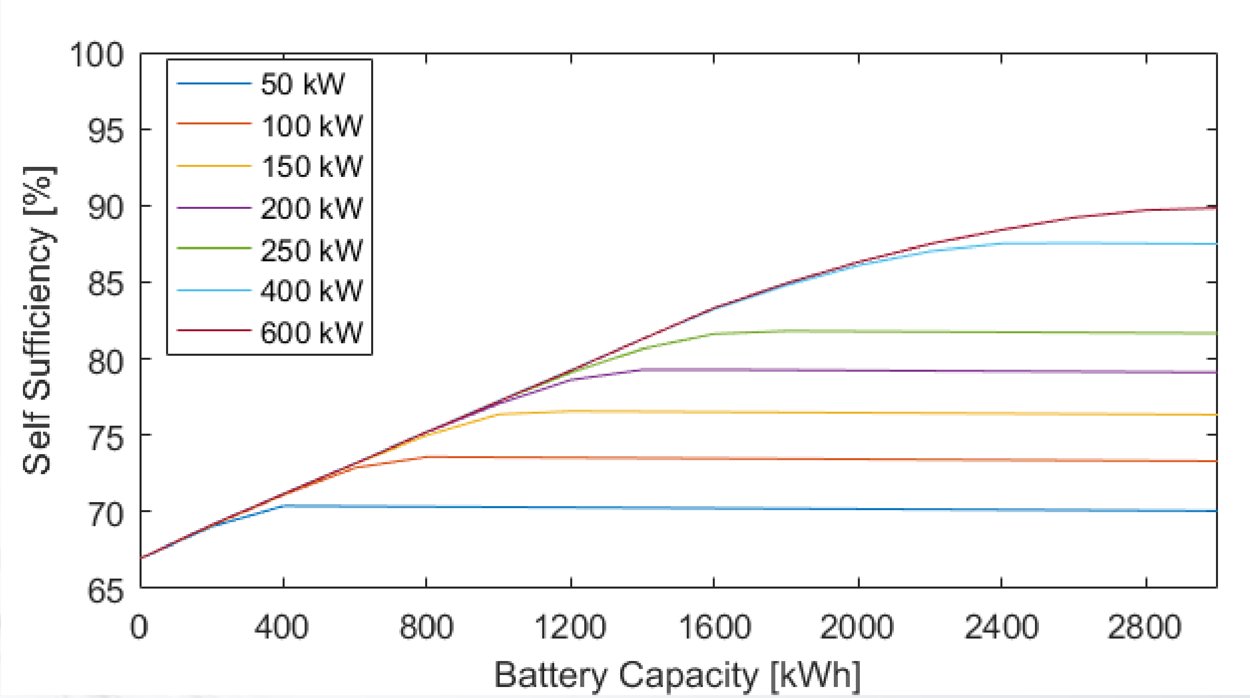
$$Solar\ Surplus = PV\ production - Station\ consumption$$





Offgrid Infrastructure ? – Role of a stationnary battery



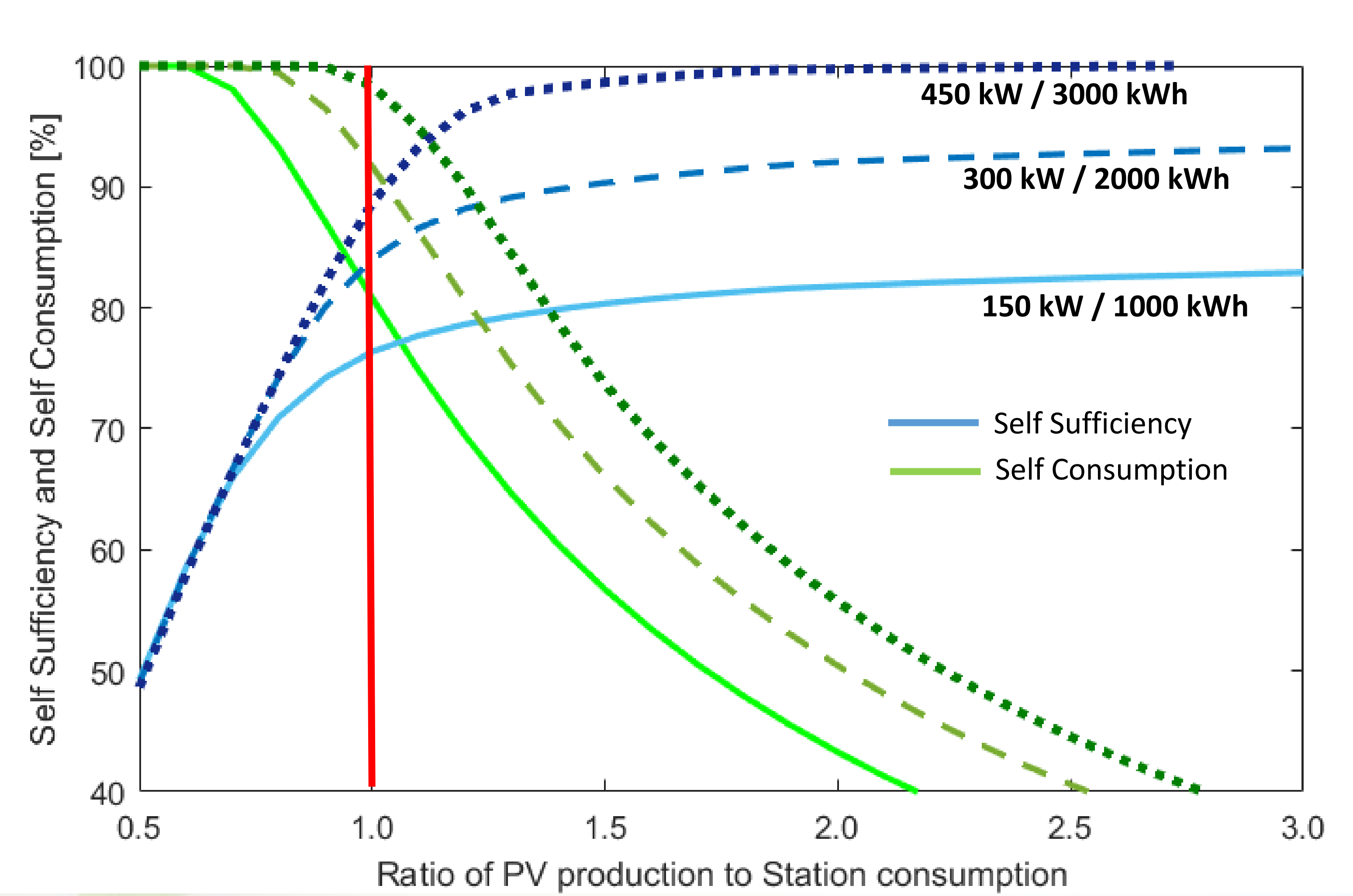


$$\textit{Self Consumption} = 1 - \frac{\textit{Exports to Grid}}{\textit{Total Solar Production}}$$

$$\textit{Self Sufficiency} = 1 - \frac{\textit{Imports from Grid}}{\textit{Total Consumption}}$$

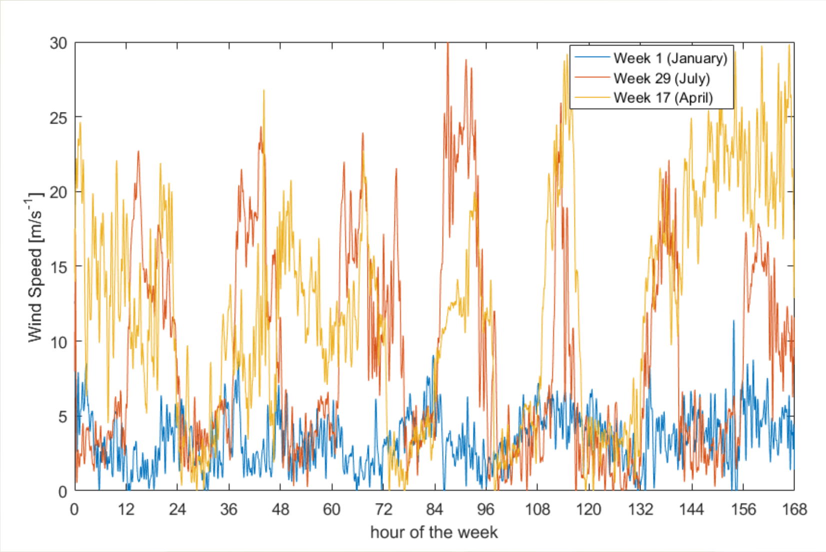
- **A good natural match** between solar generation and refilling stations : > 65% self consumption and self sufficiency without battery
- 100% self sufficiency not achievable due to battery efficiency → **increase the ratio** $^{PV\ Production}/_{Station\ consumption}$

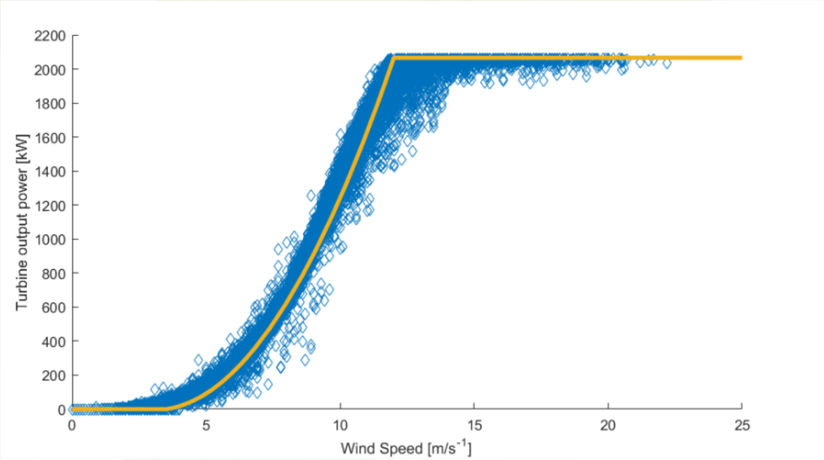
Offgrid Infrastructure ? – Role of a stationnary battery

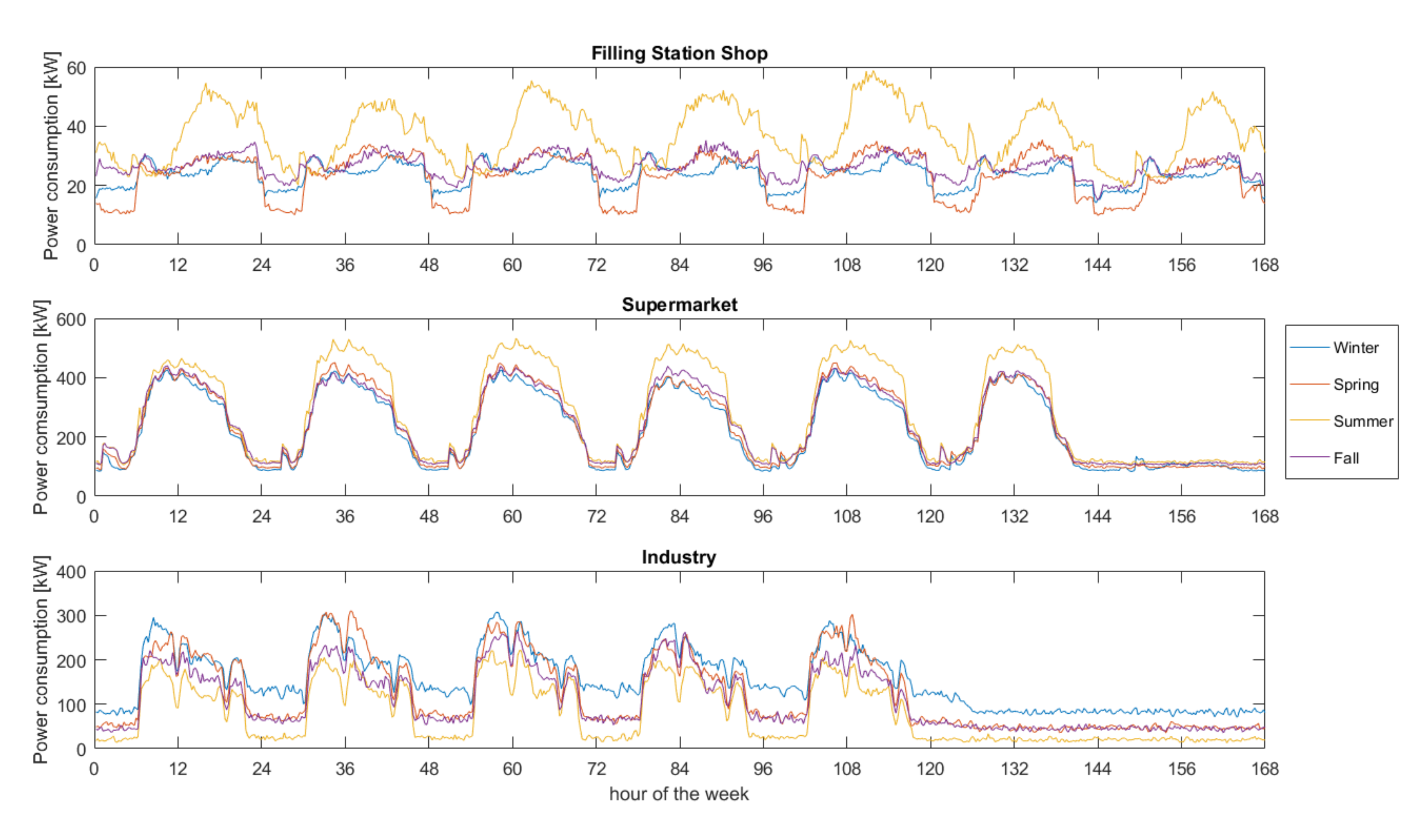


200 kW / 400 kWh Vanadium Redox Flow Battery connected to a 80 kW charger in Martigny

Offgrid Infrastructure ? – Sinergies required and sector coupling







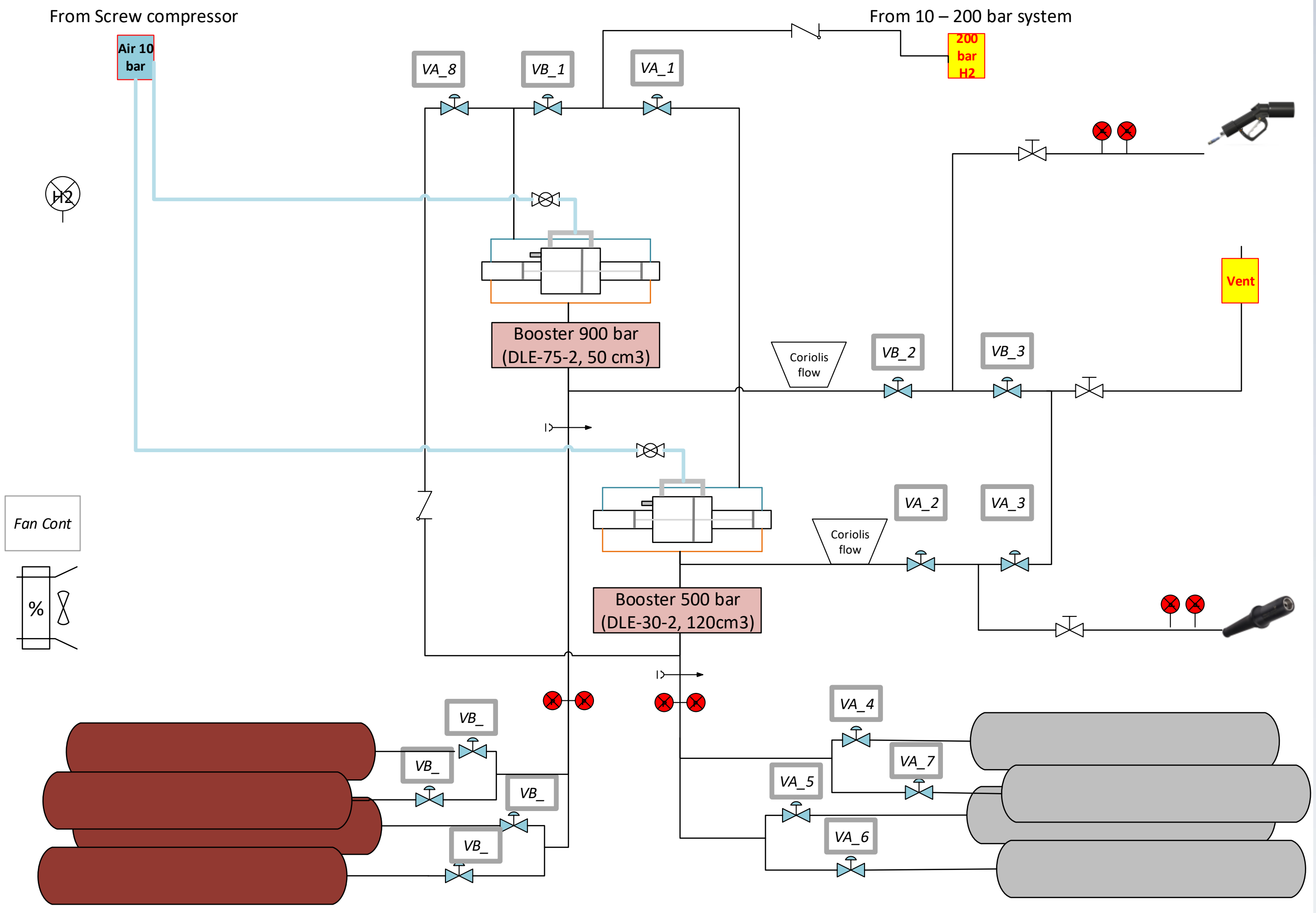
Clustering method applied to wind speed data and turbine profile from a local utility provider

Collection of 2016 data from consumers in Martigny, anonymized, only average values, no clustering

Grid to Mobility demonstrator – H_2 station

Equipment	Model	Indicative Cost
Air compressor 10 bar	Kaiser 37 kW	45 000 CHF
Gas Booster, 4 stages 10 – 900 bar	Maximator	> 35 000 CHF
Coriolis flow meter	Kem Kuppers	10 000 CHF /unit
Pressure sensor	AST	400 CHF /unit
High pressure valves	Maximator	800 CHF /unit
Dispenser	Weh 70 MPa Staubli 35 MPa	15 000 CHF 4 000 CHF
Pipping	Maximator 6.35 mm	36 CHF/m
Supply storage	200 bar, 1.8 m^3	25 000 CHF
Fueling storage	500 bar, 4 x 50 L	10 000 CHF

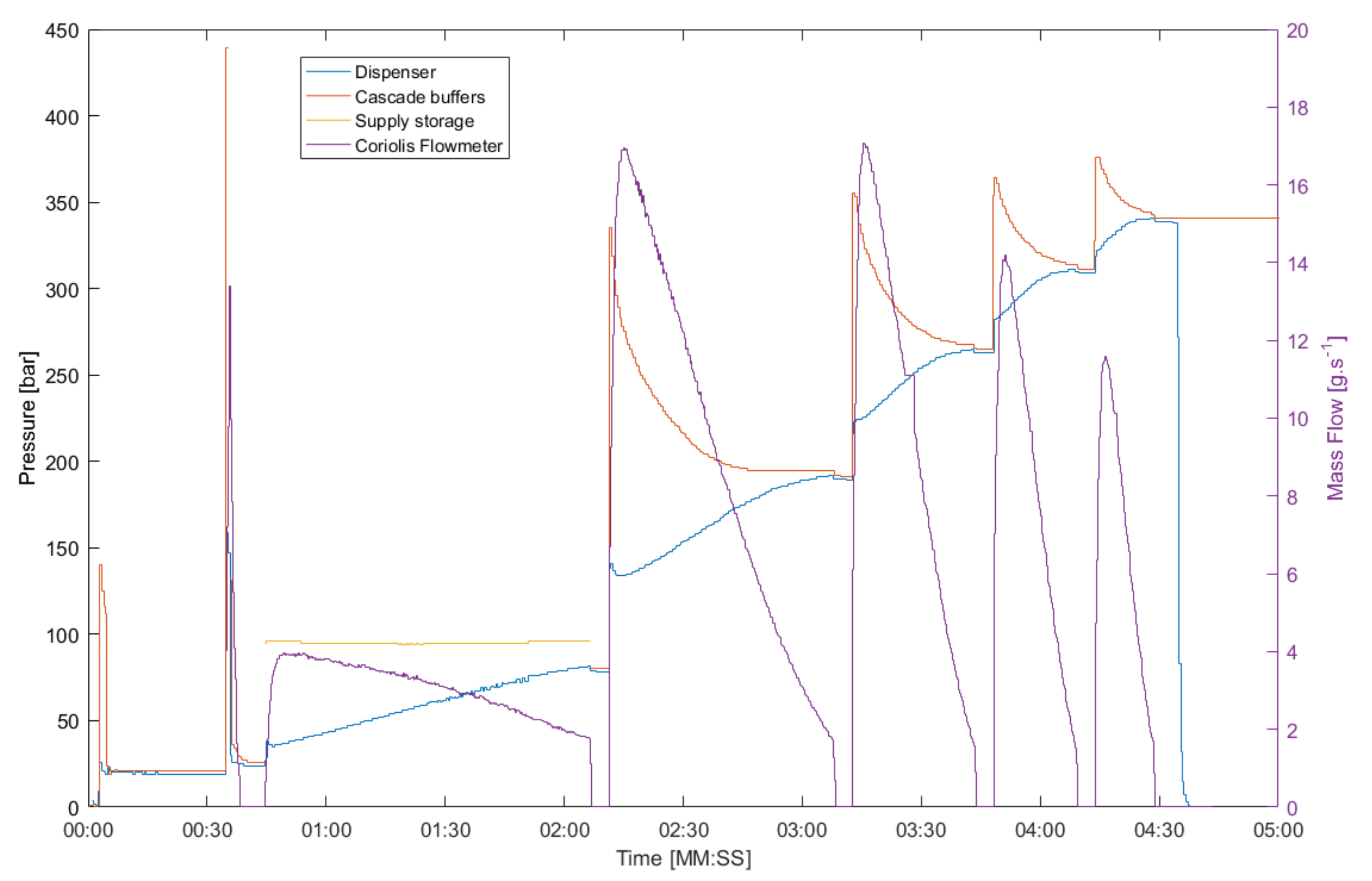
+ control system (based on Siemens PLC), supporting frames, safety equipment…



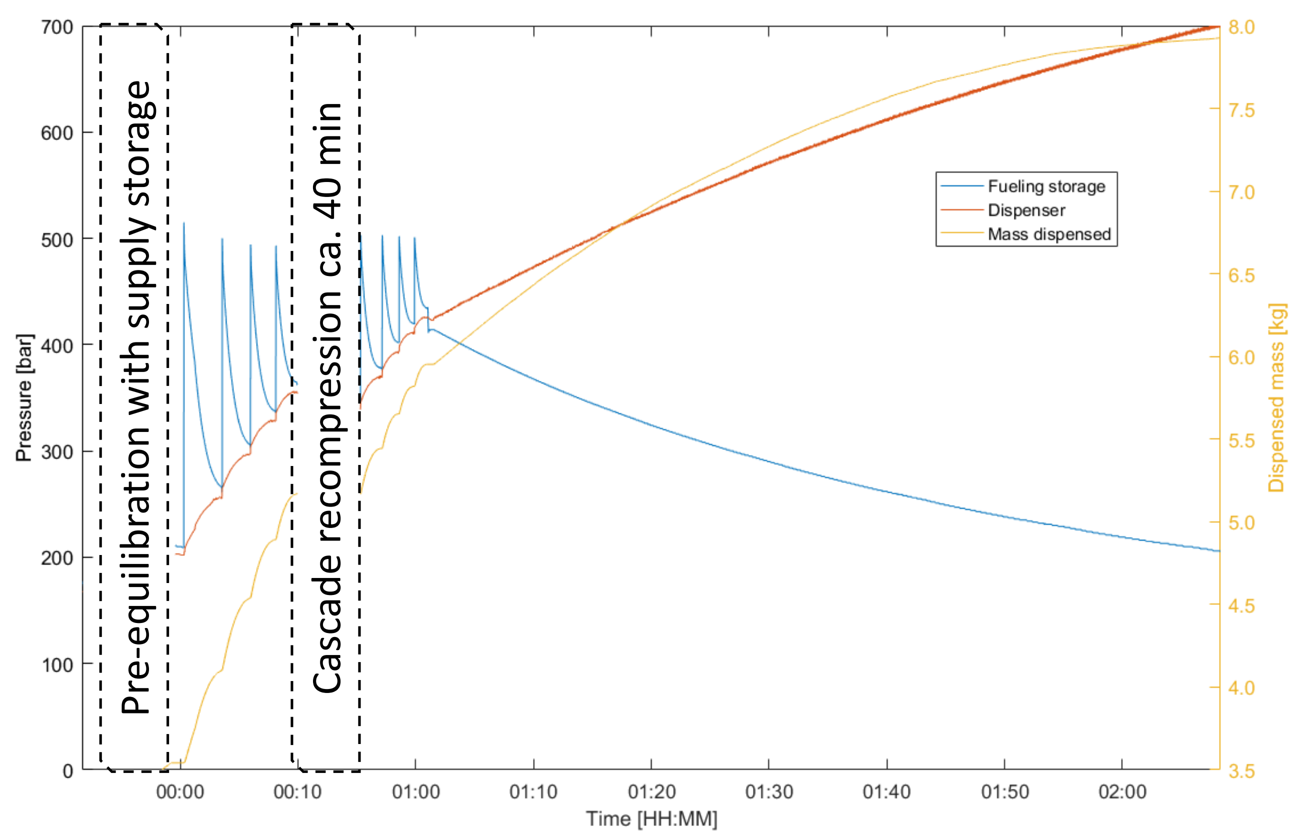
Upgrade to «slow» 700 bar for ~40 kCHF (20% of station cost)

Grid to Mobility demonstrator – 350 bar protocol

- 5 fully automated stages
  - Leak test
  - Pressure determination
  - Equilibration with supply storage
  - Cascade with fueling storage
  - Vent

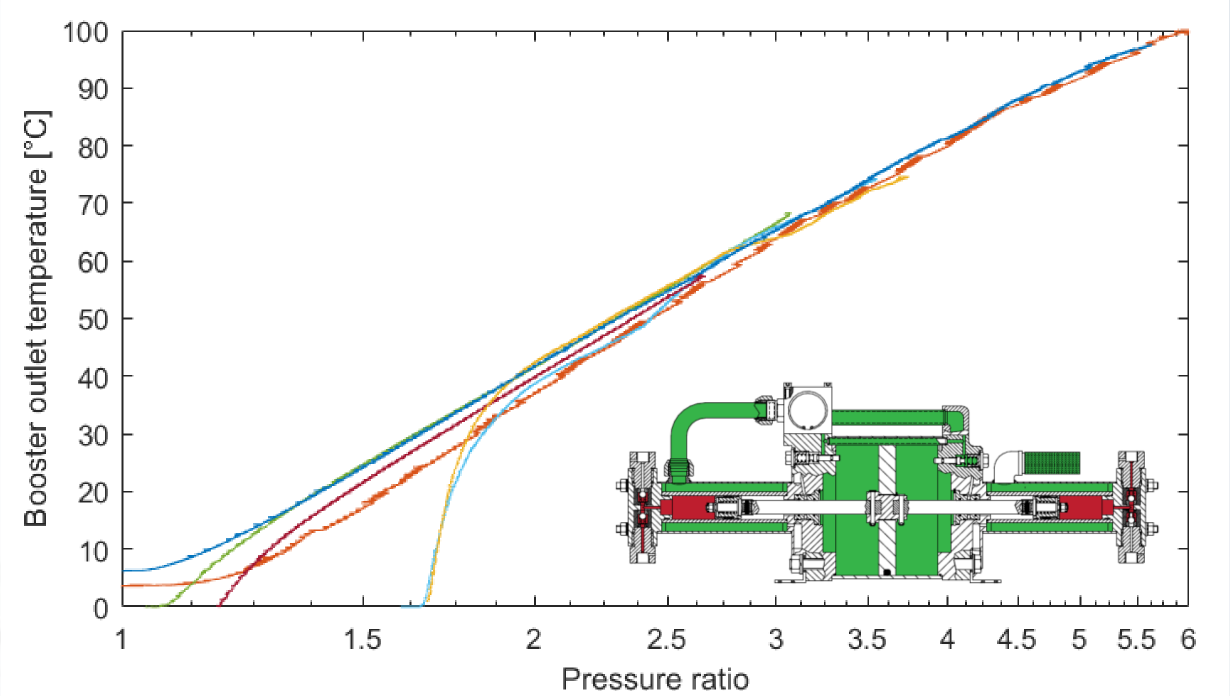


Grid to Mobility demonstrator – 700 bar and slow refills



- 2 Cascades at 500 bar followed by a booster phase
- Booster phase : ca. 2 kg in 1h → + 3.5 km of autonomy/min ⇔ 50kW charger

Grid to Mobility demonstrator – Gas booster compression



- Home made electrolyser systems design and automation, 50 kW alkaline (10 bar) and 25 kW PEM (40 bar)
- 2 booster stages to reach supply storage pressure : 200 bar
- 2 booster stages for the fueling storage and 700 bar refills

Battery AND Hydrogen, Solar AND Wind, Mobility AND Residential…

- Both BEVs and FCEVs for different needs
- Wind, Solar, Hydro : we need a combination of everything
- Full scale offgrid charging already challenging for one week

	BEV infrastructure	FCEV infrastructure
Energy efficiency (passenger car)		
Micro Infrastructure at home		
Scale up potential		
100% renewable , Off grid potential		(if off site electrolysis)
Seasonal storage, sector coupling		
Cost ?	Infrastructure cost comparison : see M. Robinius *et al.*, “Comparative Analysis of Infrastructures: Hydrogen Fueling and Electric Charging of Vehicles,” Elektrochemische Verfahrenstechnik, 2018.	

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Thank you

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