THE GREEN VILLAGE

AUTONOMOUS ENERGY SYSTEM DESIGN PRINCIPLES

16.09.2021

TODAY'S LECTURE

- Project presentation
- General system overview
- Design process: background, challenges and outcome
- Green Village system specifics

THE GREEN VILLAGE

AUTONOMOUS ENERGY SYSTEM PROJECT

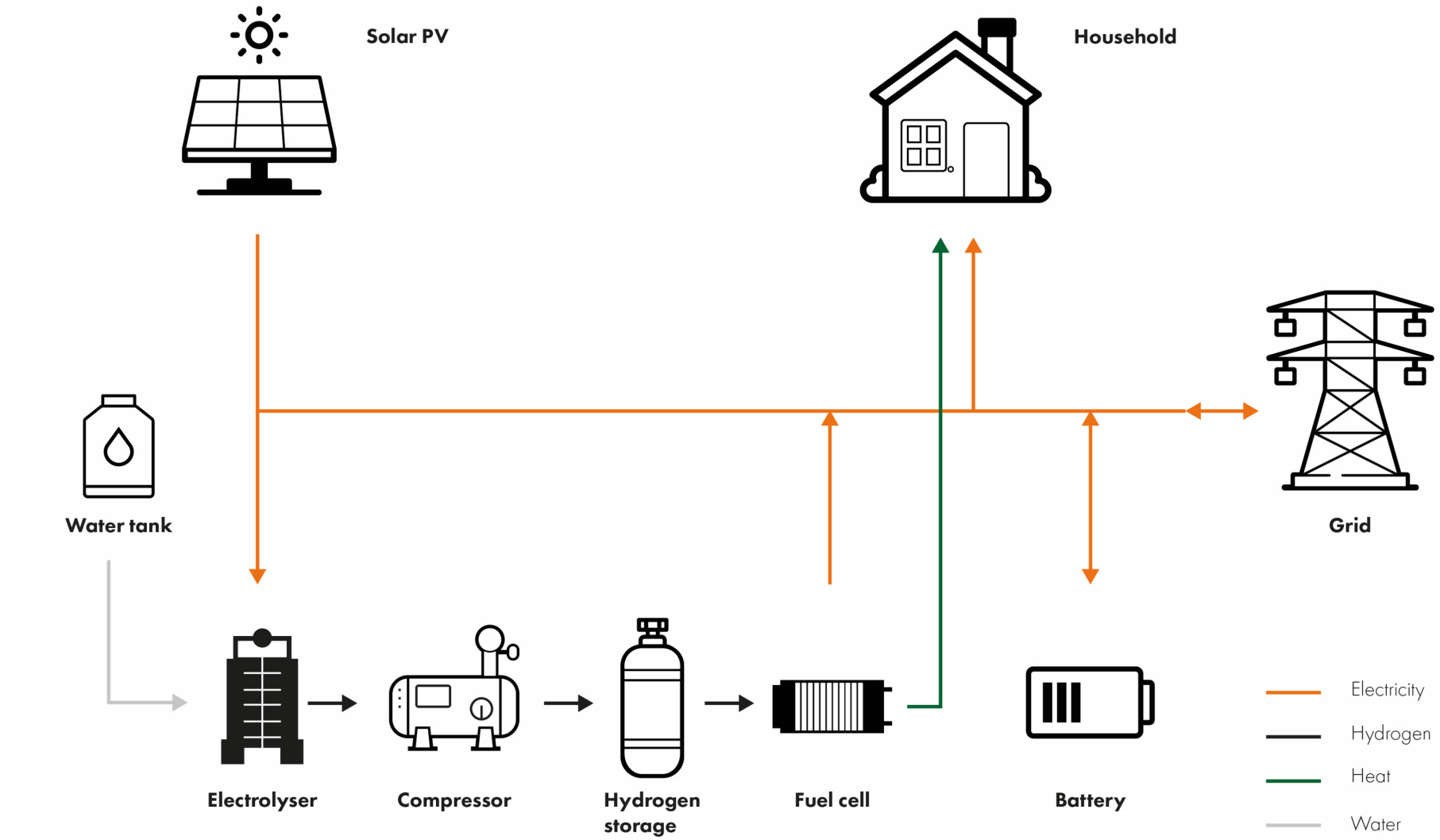
- Fully self-sufficient energy system
- Generation, storage and supply of 100% renewable energy
- Battery - Hydrogen hybrid
- Solar power only source of energy for current system
  - Adding other RES highly feasible
- Phase 1 - demonstration

THE GREEN VILLAGE

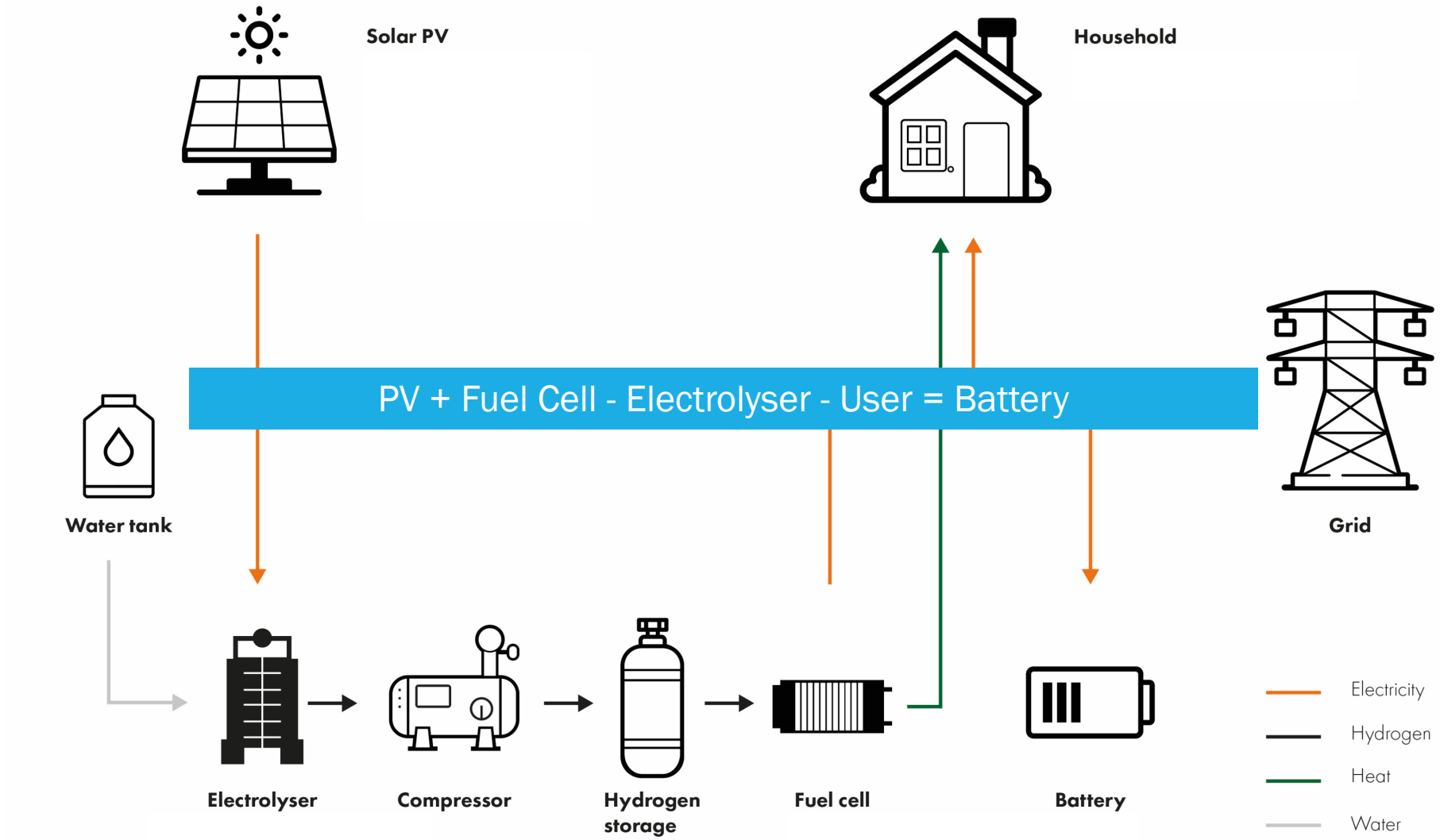
DESIGN BACKGROUND

- Hydrogen storage
  - High storage capacity
  - Location independent
  - Low resource use
  - Poor round-trip efficiency
  - Small battery needed for short-term balancing
- Built environment design anchor: yearly consumption

AUTONOMOUS ENERGY SYSTEM OVERVIEW



AUTONOMOUS ENERGY SYSTEM OVERVIEW

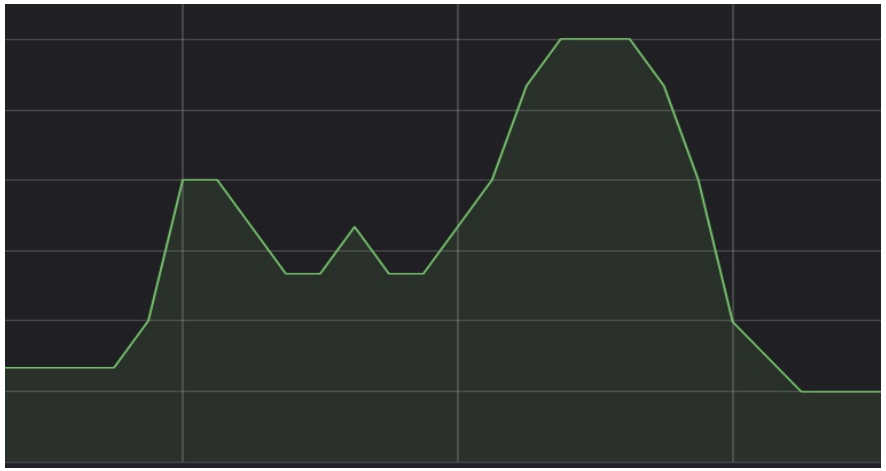


DESIGN BACKGROUND AND CHALLENGES

- For a given yearly consumption:
  - How to determine size of components?
    - PV, electrolyser, fuel cell, battery
  - How much storage is needed?
- Electrolyser and battery interaction with PV
  - When should the electrolyser run? For how long?

SIMULATION BACKGROUND

- Input
  - EU PVGIS PV data for the Netherlands, 2005-2016
  - Generalized domestic consumption profile
- Desired output
  - Hydrogen storage capacity
  - Component capacities – fuel cell, electrolyser, PV, battery



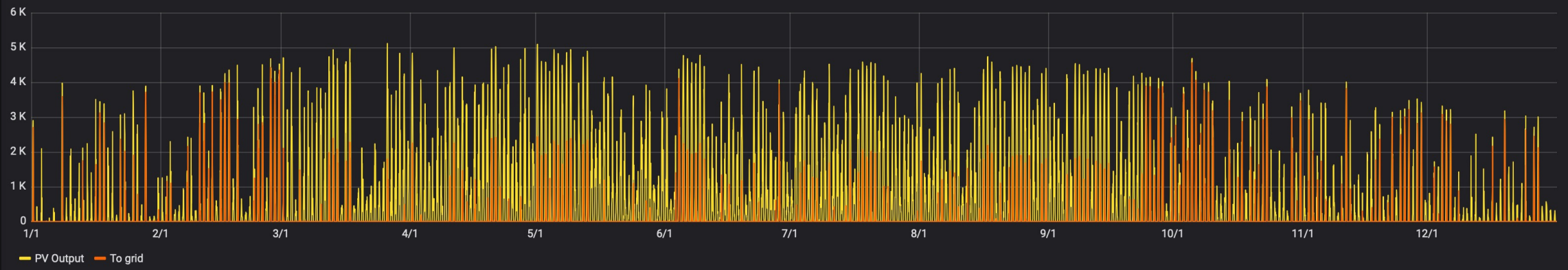
Generic domestic consumption profile

SIMULATION PROCESS

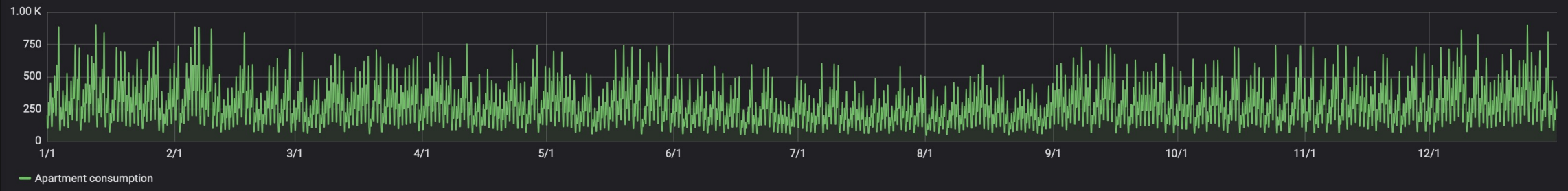
- Minute-by-minute decision making
  - PV input
  - User consumption
  - Battery SOC
  - Dates / time of year
- Parameters controlled
  - Is the electrolyser running? Turn on/off?
  - Is the fuel cell running? Turn on/off?
- Battery balances sources and sinks
- Successful when hydrogen never runs out

SIMULATION OUTCOME

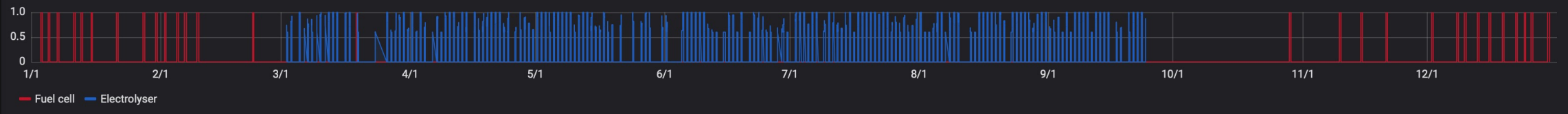
PV Output // Grid delivery



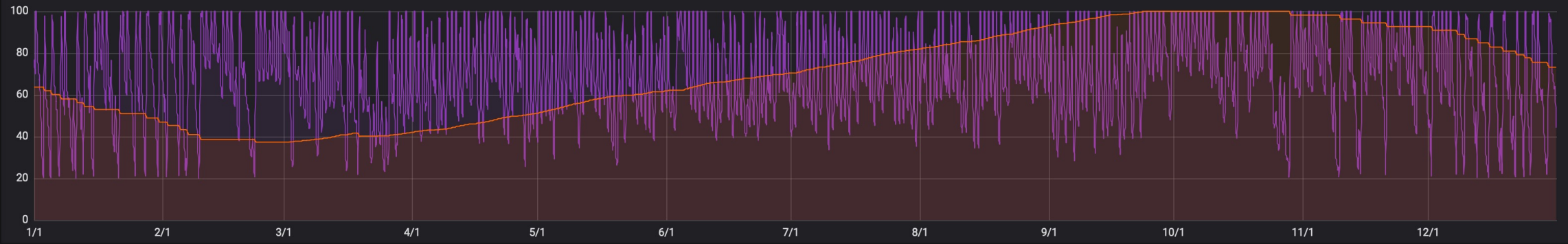
Apartment consumption



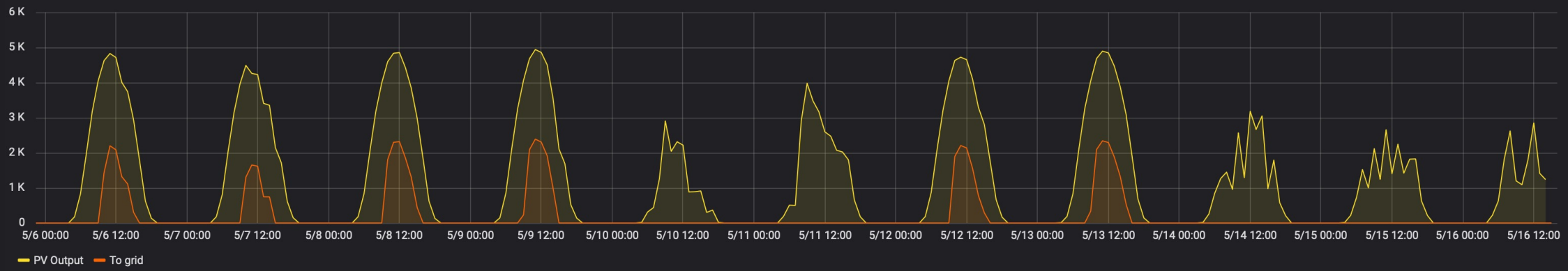
Fuel cell // Electrolyser



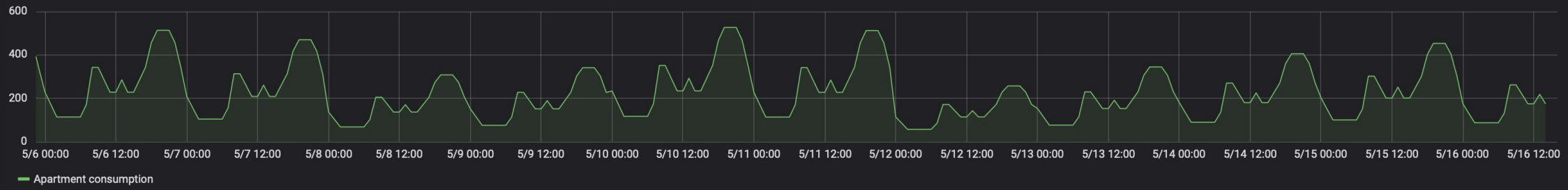
Battery // Hydrogen



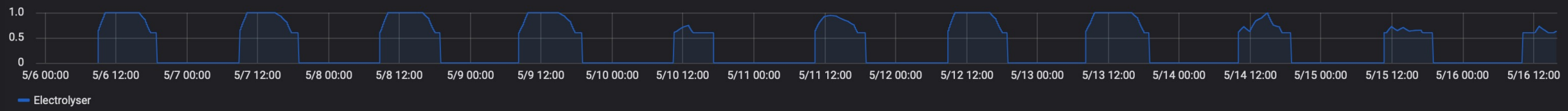
PV Output // Grid delivery



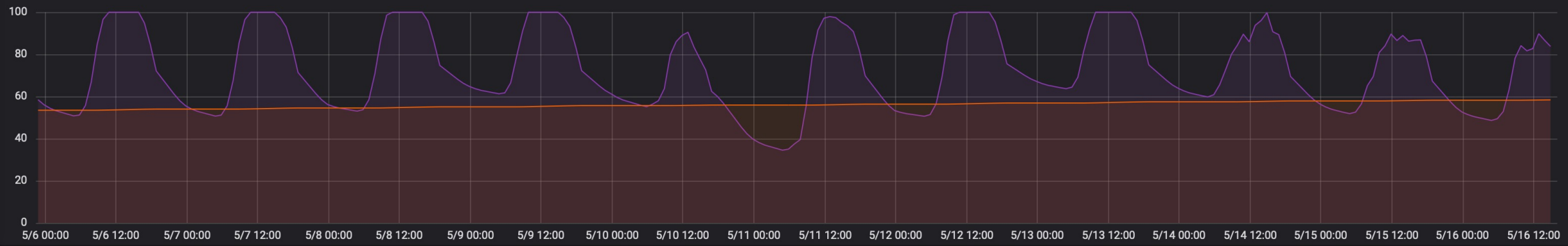
Apartment consumption



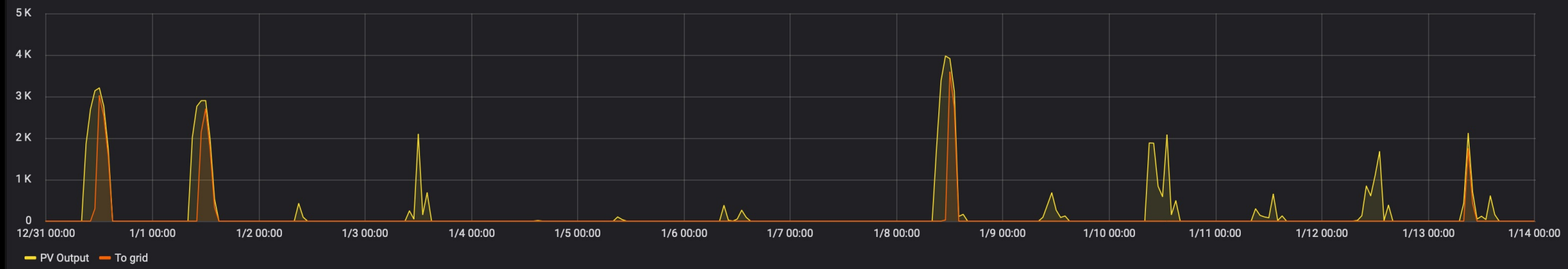
Fuel cell // Electrolyser



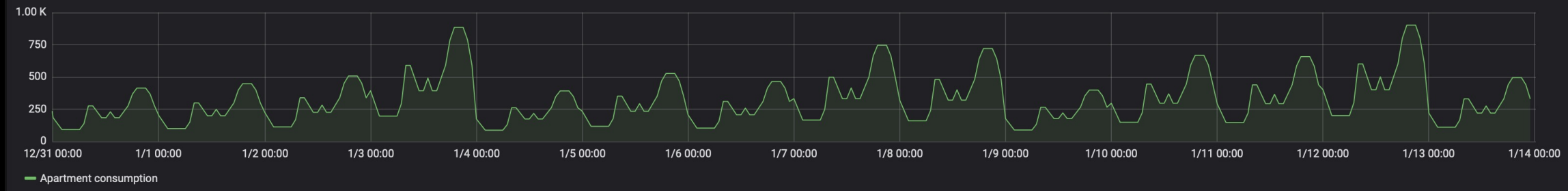
Battery // Hydrogen



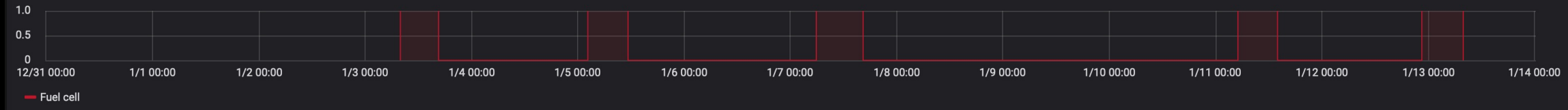
PV Output // Grid delivery



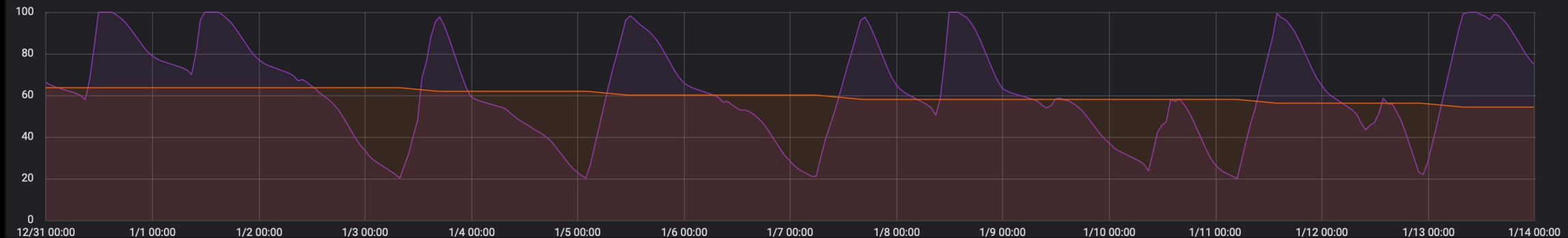
Apartment consumption



Fuel cell // Electrolyser



Battery // Hydrogen




PV Output // Grid delivery
6 K
5 K
4 K
3 K
2 K
1 K
0
2005-1
2006-1
2007-1
2008-1
2009-1
2010-1
2011-1
2012-1
2013-1
2014-1
2015-1
2016-1
2017-1
PV Output
To grid
Apartment consumption
1.00 K
750
500
250
0
Apartment consumption
Fuel cell // Electrolyser
1.0
0.5
0
Fuel cell
Electrolyser
Battery // Hydrogen
100
80
60
40
20
0

SIMULATION LEARNINGS

- Everything is connected
  - Electrolyser capacity tied to buffer size
  - Buffer size tied to user consumption
  - Large battery adds stability
  - Large PV also adds stability
  - Only Fuel Cell remains flexible
- Conclusion: Full system decided by solar availability and user consumption
  - Note: Adding a car, electric or H2, requires additional capacity

SIMULATION LEARNINGS

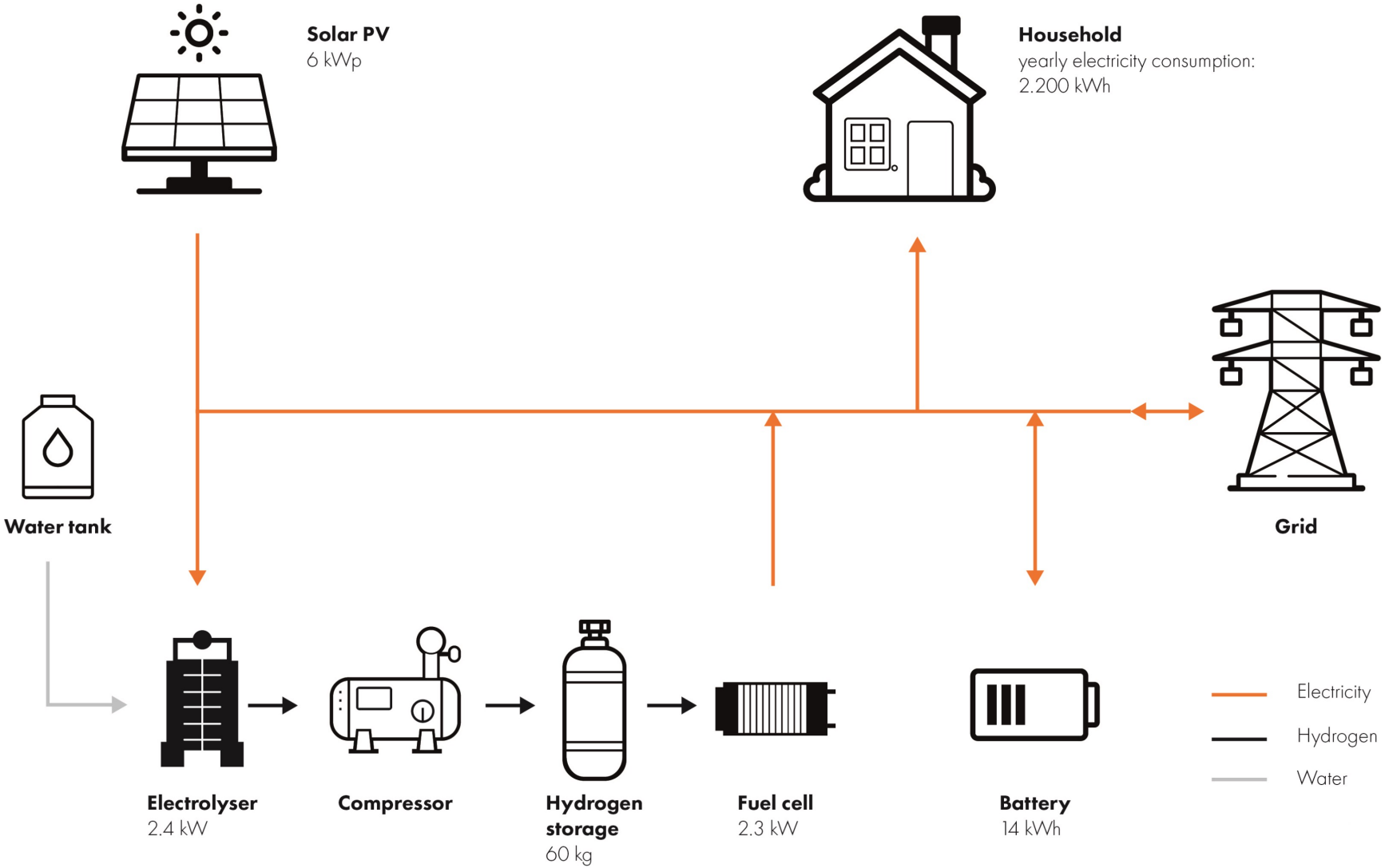
- Rough control parameters determined
- Electrolyser runs from beginning of March to mid-October
  - On and off determined by battery SOC
  - Using prediction can open up the production period and optimize utilization
- Fuel cell always available
  - Also controlled by battery SOC
  - …but mostly only runs from Oct to March anyway

SIMULATION LEARNINGS

- Harvesting “excess” solar energy is difficult
  - Adding more electrolyser power is easy, but…
  - Adding a larger battery is also easy, but…
  - Do we adapt storage to PV, or PV to storage?
- Improvements
  - Predictive control can likely improve utilization
  - Sell from battery during off-peak hours
- Solar availability from year to year stable, but does vary

THE GREEN VILLAGE

GREEN VILLAGE SYSTEM



GREEN VILLAGE SYSTEM SPECIFICS

- System remains grid connected
- Heat vented to ambient
  - Measured and logged for performance evaluation
  - Possible future upgrade: connect to TGV heat grid
- Control system under evaluation
  - Node-RED, OpenEMS, Enapter proprietary
- All data logged in TGV data platform
  - Energy generation, hydrogen buffer status, battery charge, etc.
  - Detailed consumption figures left out for privacy reasons

REFERENCE FIGURES

TGV System		Reference	
User electricity consumption	2.200 kWh/year	Apartment Town house Detached house	2.070 kWh/year 3.100 kWh/year 4.100 kWh/year
Battery	14 kWh	Tesla battery	100 kWh
Hydrogen capacity	60 kg	Hydrogen car tank capacity	~ 5 kg
PV System	6 kWp	Hydrogen energy content * 60 kg	33.3 kWh/kg 2000 kWh
PV System yearly yield	5.900 kWh/year	Hydrogen fuel cell energy contents (45% eff.) * 60 kg	15 kWh/kg 900 kWh

EXPECTED LEARNINGS

- Were the simulations correct?
  - Prediction: the hydrogen storage is oversized
- What did we miss – unknowns/errors in design process?
- Where to find points for optimization?
  - Efficiency
  - System cost

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