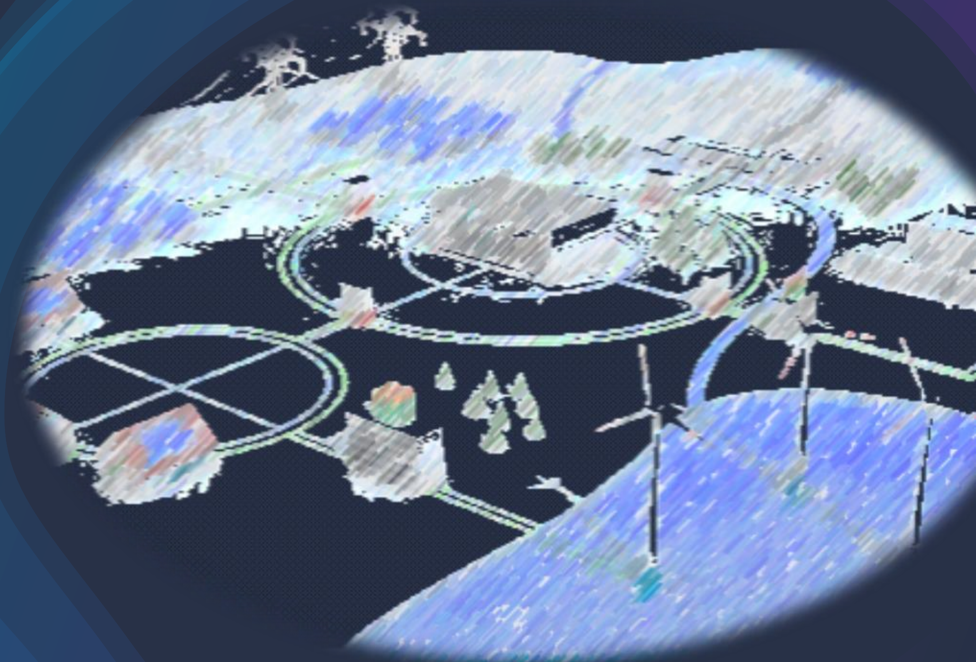
PV **self-consumption** at its **economic** optimum

managing heat pumps and electric vehicles



Andreas Hutter, CSEM
Alain Aerni, Soleco

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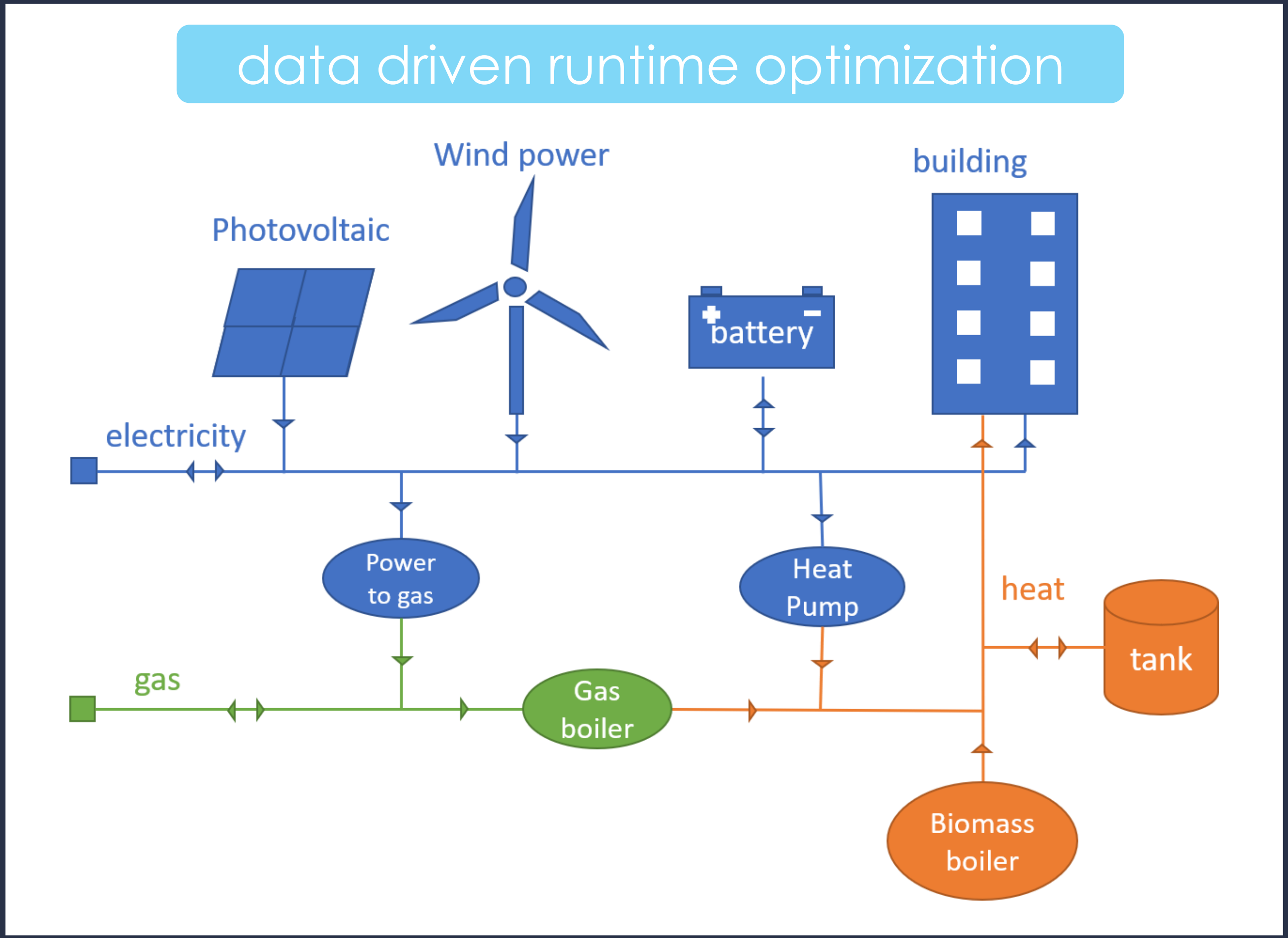
Optimized coupling of multifluid networks via Smart Control

Solution to efficiently couple energy production and consumption units with various shifting potential on different time horizons for

- electric,
- thermal and
- gas

components and storage.



EC project PENTAGON, *Unlocking local flexibility at district level*, grant agreement no. 731125, Dec. 2016 to Nov. 2019

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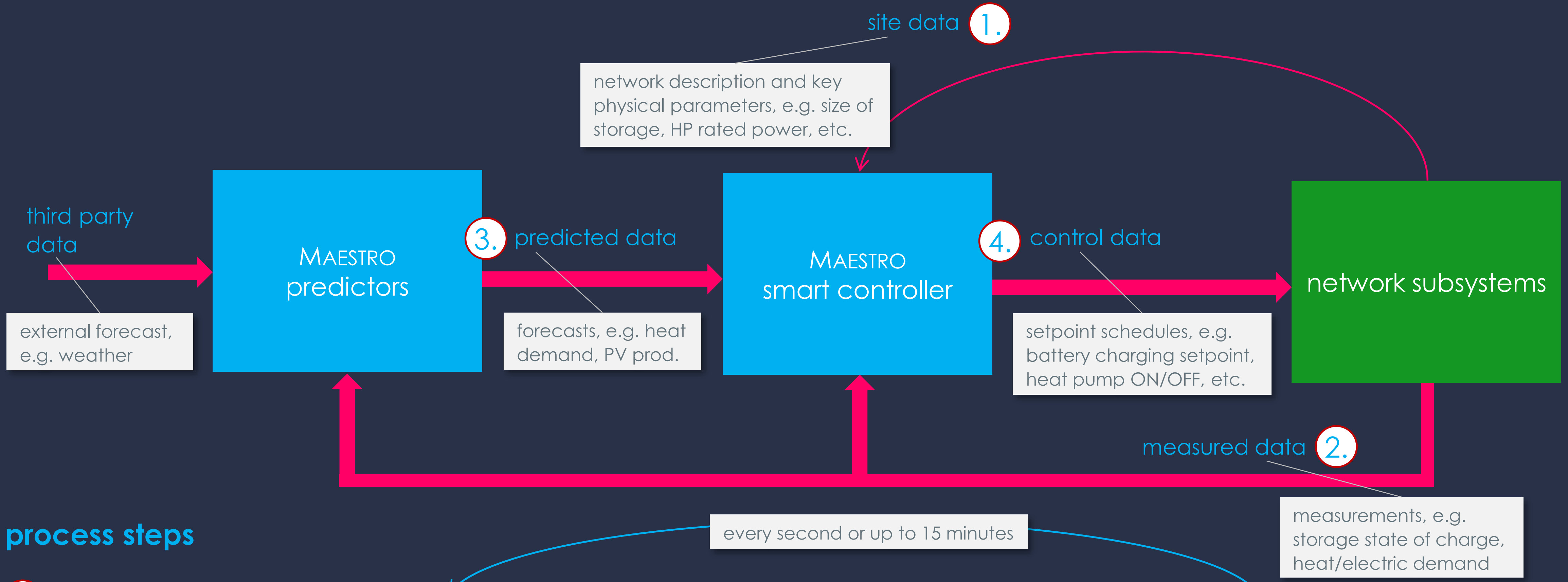
Working principle of the MAESTRO framework

model predictive control
MILP-based optimization



process steps

1. configuration

provision of multi-energy network data and details (offline preparation)

2. network state update

automatic acquisition of measurements and information from the network

3. prediction of evolution

determination of forecasts based on learned statistics (continuous update) and external data

4. optimized control

automatic determination of optimized schedules based on internal physical model and global cost optimization

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Models and parameters

Based on linear models capturing the main characteristics

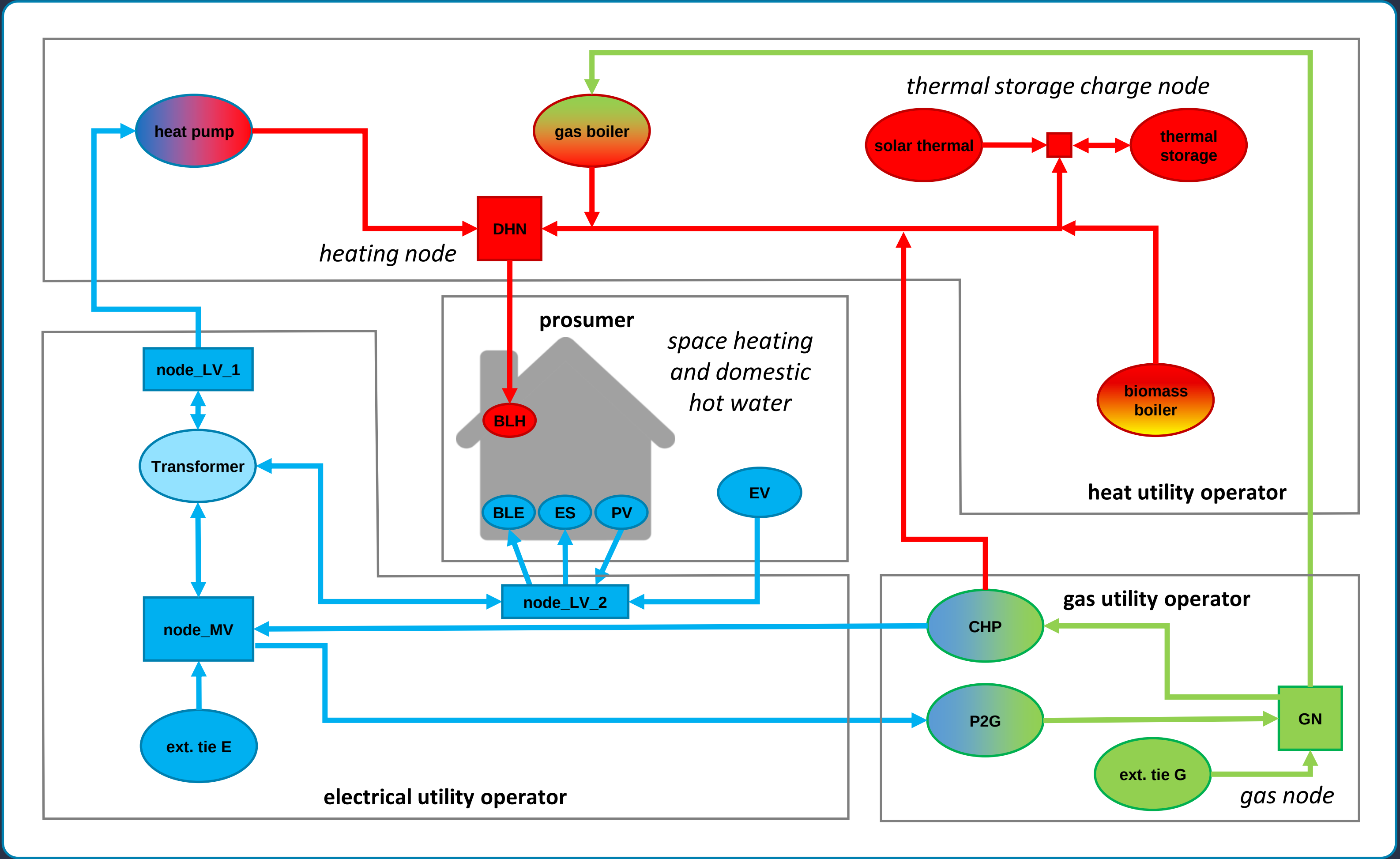
- simple model configuration
- including variable tariffs
- easily extendable

Optimization name	Type	Symbol	Description
energyType	configuration	-	Energy type of the consumer (electrical or heating)
isSheddable	configuration	-	Boolean value
loadSheddingPriceProfile	sensor	$f^{shedding}(\tau)$	The price of shedding the load profile
forecastedActivePowerProfile	sensor	$P^{forecast}(\tau)$	Forecasted power profile provided by PENTAGON forecasting framework
powerConsumptionProfile	actuator	$P_{BL}(\tau)$	Optimized power consumption of the consumer

E … electric network H … heat network G … gas network

Component	Network	Level	Model
Baseline Load (BL)	E | H	Building/District	Consumer
Photo-voltaic (PV)	E	Building/District	Renewable generator
Solar thermal	H	Building/District	Renewable generator
Wind turbines	E	District	Renewable generator
Electrical utility | Gas utility	G | E	District	External tie
Power-to-Gas (P2G)	E,G	District	Converter
Heat-pump (Power-to-Heat, P2H)	E,H	Building/District	Converter
Gas boiler (GB)	G,H	Building/District	Converter
Electrical boiler (EB)	E,H	Building	Converter
Biomass boiler (BB)	H	District	Generator
Gas CHP	E,H,G	District	Cogenerator
Electric battery	E	Building/District	Battery energy storage system
Water tank (Pool, thermal storage)	H	Building/District	Thermal storage
Space heating (SH)	H	Building	Thermal storage

Technology validation



Parameter	value
Boiler max. power	30 kW
Boiler min. power	5 kW
P2G min. elec. pow.	5 kW
P2G max. elec. power	10 kW
P2G conversion efficiency	0.75
Biomass Boiler max. pow.	10 kW
Thermal tank size	$2m^3$
Electricity buy price	0.2 €/kWh
Electricity sell price	0.04 €/kWh
Gas buy price	0.13 €/kWh
Biomass buy price	0.2 €/kWh
Elec. demand	2383 kWh
Heat demand	15354 kW
PV prod.	637 kWh
Wind power prod	3594 kWh

	w P2G	w/o P2G
SC ratio[%]	95.4	38.3

validated based on **hybrid approach** with **emulation** and **real assets** at CEA

Maestro: A Python library for multi-carrier energy district optimal control design*†

Tomasz T. Gorecki and William Martin‡

December 2, 2019

Abstract

This paper introduces the *Maestro* library. This library for Python focuses on the design of predictive controllers for small to medium-scale energy networks. It allows non-expert users to describe multi-carrier (electricity, heat, gas) energy networks with a range of energy production, conversion, and storage component classes; together with consumption patterns. Based on this description a predictive controller can be synthesized and tested in simulation. This controller manages the dispatch of energy in the network, making sure that the demands are met, while minimizing the total energy cost. Alternative objectives can be specified. The library uses a mixed-integer linear modelling framework to describe the network and can be used in stand-alone based on standardized input files or as part of the larger energy network control platform PENTAGON.

1 Introduction

The shift from centralized energy generation in few large plants to a more and more decentralized generation infrastructure with a growing penetration of intermittent renewables challenges the management logic of the grid in all its aspects: communication, data management, control [1, 2]. With the emergence of micro-grids and self-consumption communities, it is expected that local grid control strategies will play an important role in the management of the future power grids. In addition, with the electrification of transport, the increasing penetration of heat pump to serve heating and cooling needs and the emergence of new technology such as power-to-gas systems and fuel cells, power, gas and local heat energy grids are becoming more interconnected. This provides additional opportunities to improve the

*This project has received funding from the European Unions Horizon 2020 research and innovation programme under grant agreement No 731125

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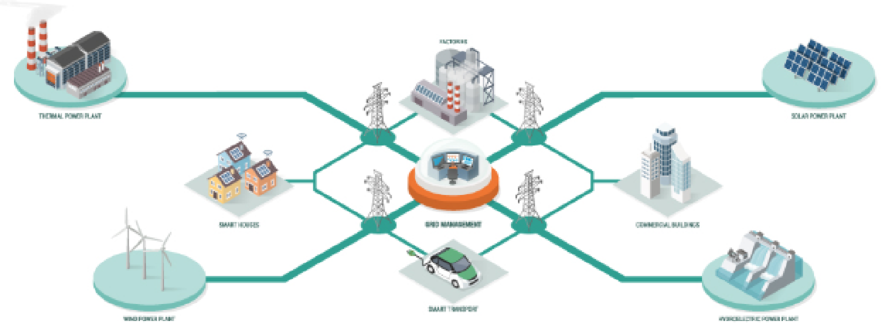
DISTRICT ENERGY SYSTEMS REAL-TIME PLANNING OPTIMIZATION

online simulator

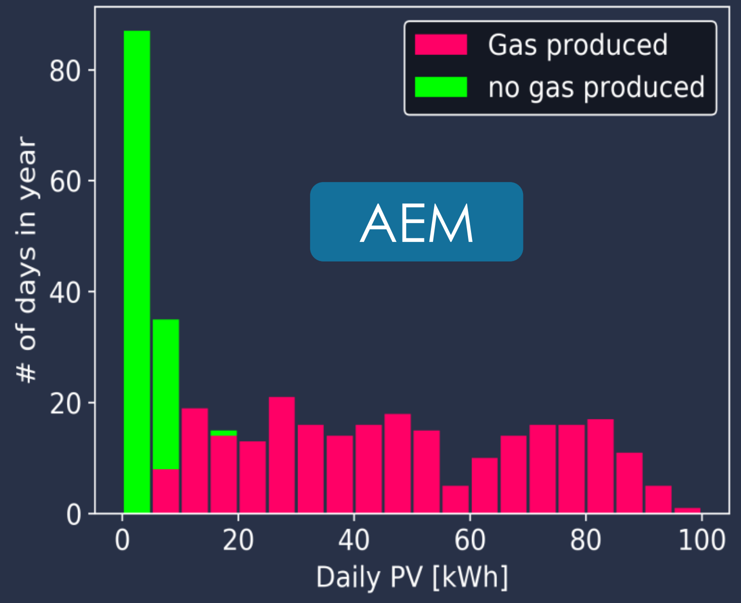
With the installation of distributed energy production assets, energy storage systems and the electrification of transport and heat production through heat pump, energy networks and micro-grids are becoming increasingly difficult to manage.

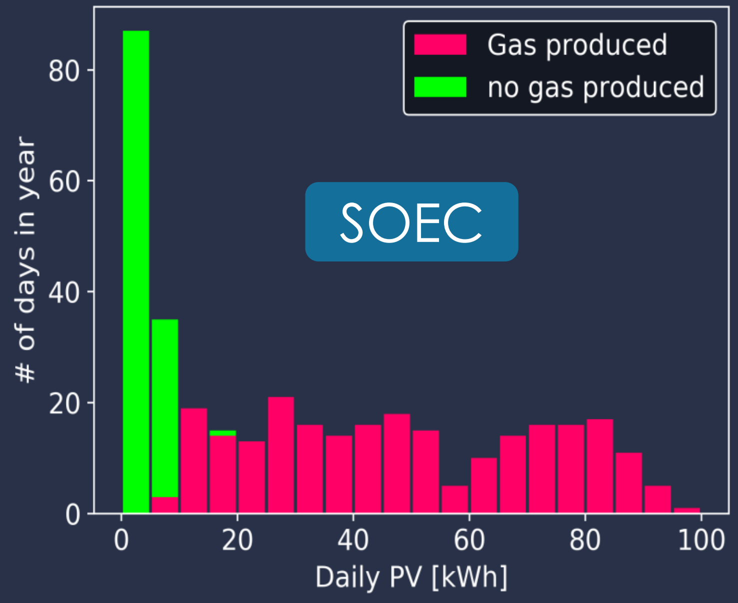


A coordinated and intelligent use of all these resources is needed to reduce energy costs, secure return on investment on energy assets, mitigate power fees. With our control planning software, non-

Technology comparison for power2gas application

Param.	AEM	SOEC
P_{max}^{on}	9.2 kW	
P_{min}^{on}	$0.2P_{max}^{on}$	$0.2P_{max}^{on}$
P^{warmup}	0	$0.1P_{max}^{on}$
P^{hot}	0	$0.01P_{max}^{on}$
η	58%	70%
$T_{off2hot}$	3 min.	2 h
$T_{hot2off}$	3 min.	1 h





Case	Revenue [CHF/y]	Increase [%]	SC ratio [%]	Gas [MWh]
No P2G	491	n.a.	0	0
P2G - AEM	707	45.3	89.8	6.4
P2G - SOEC	808	64.7	89.7	7.4

Potential of SOEC technology confirmed

P2G for dom. appl. not yet economic

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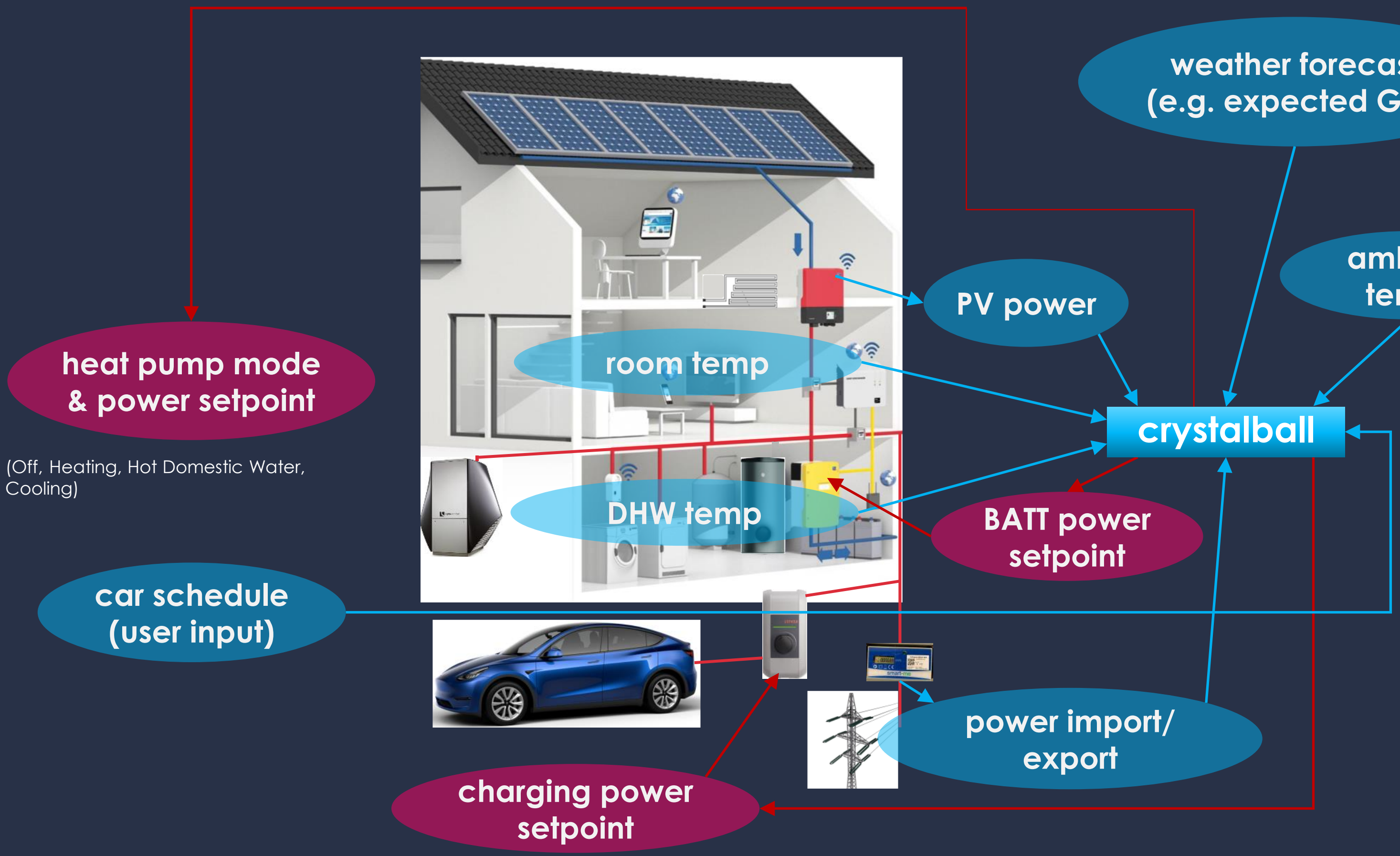
Successful industry transfer → crystalball energy manager



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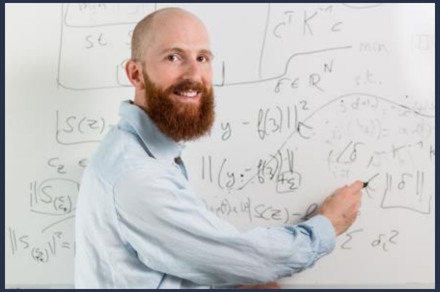
- 25% energy cost savings
- 35% self-consumption increase
- no increase of overall energy

➔ validated in practice!

energy	cost [CHF]	bought [MWh]	sold [MWh]	heating [MWh]	SC [%]
PID	**1’957**	6.8	13.0	3.2	**26.0**
MPC	**1’496**	4.7	11.4	2.8	**35.2**



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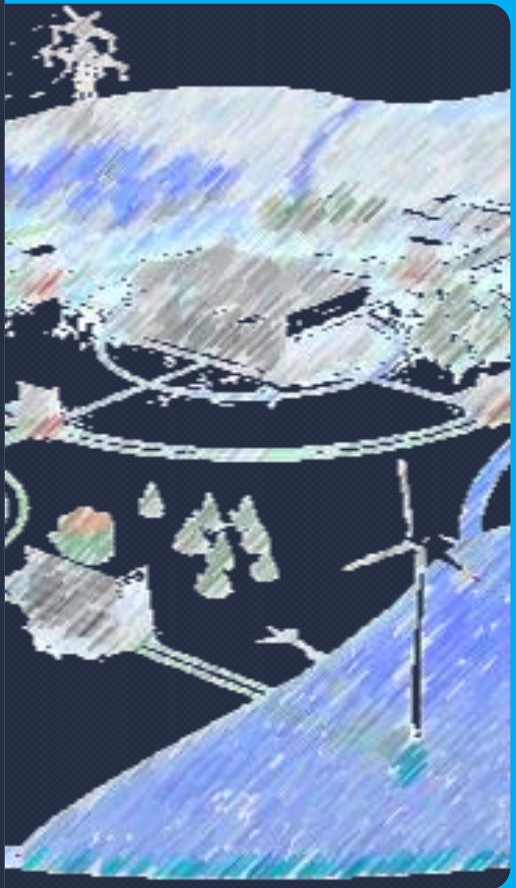


Crystalball

November 2020

Agenda

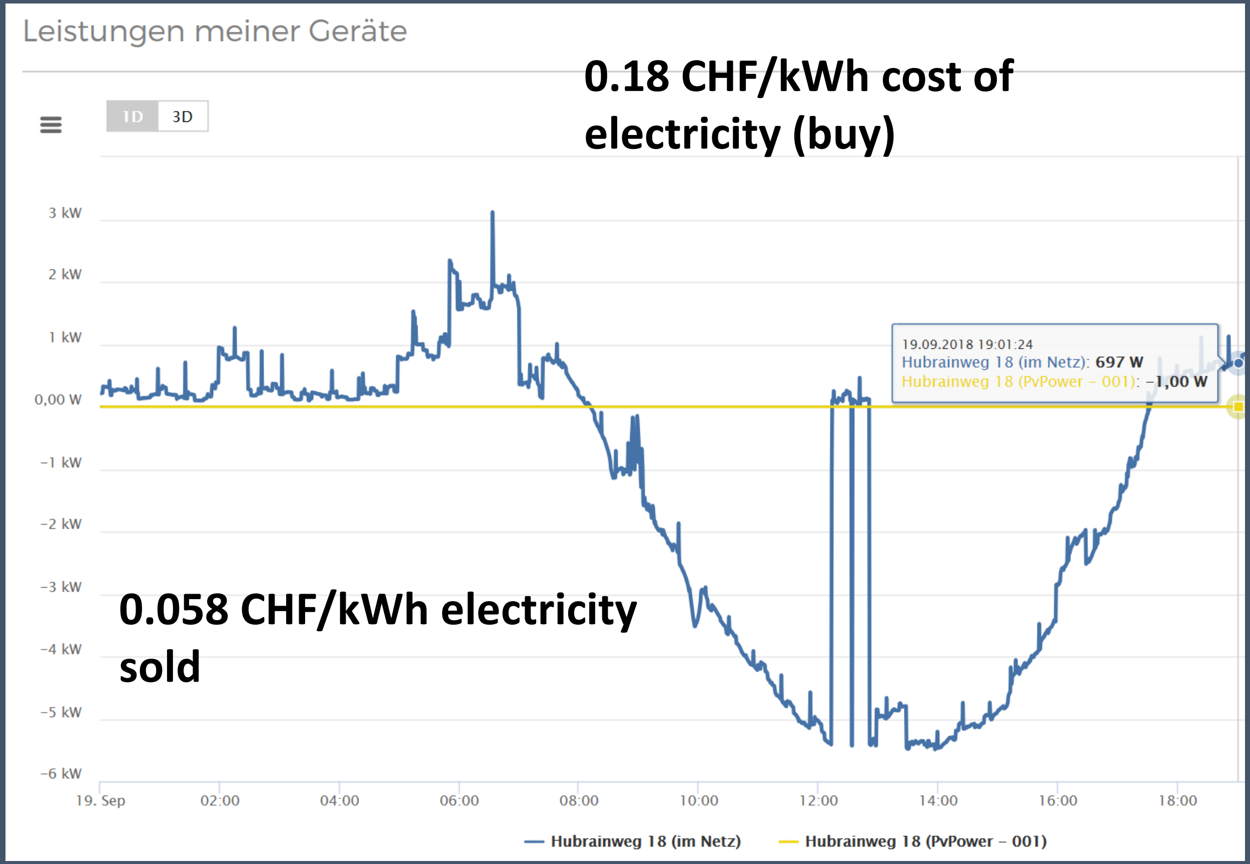
The challenge

Crystalball and the way to it

Next steps

An Integrated and Smart Controller

- Develop and validate a low cost easy to use ISC
  - Based on a Digital Twin
  - Enhanced economic optimisation
- The ISC will control the individual power and heat demand
  - local system controllers and sensors
  - intelligence in the cloud



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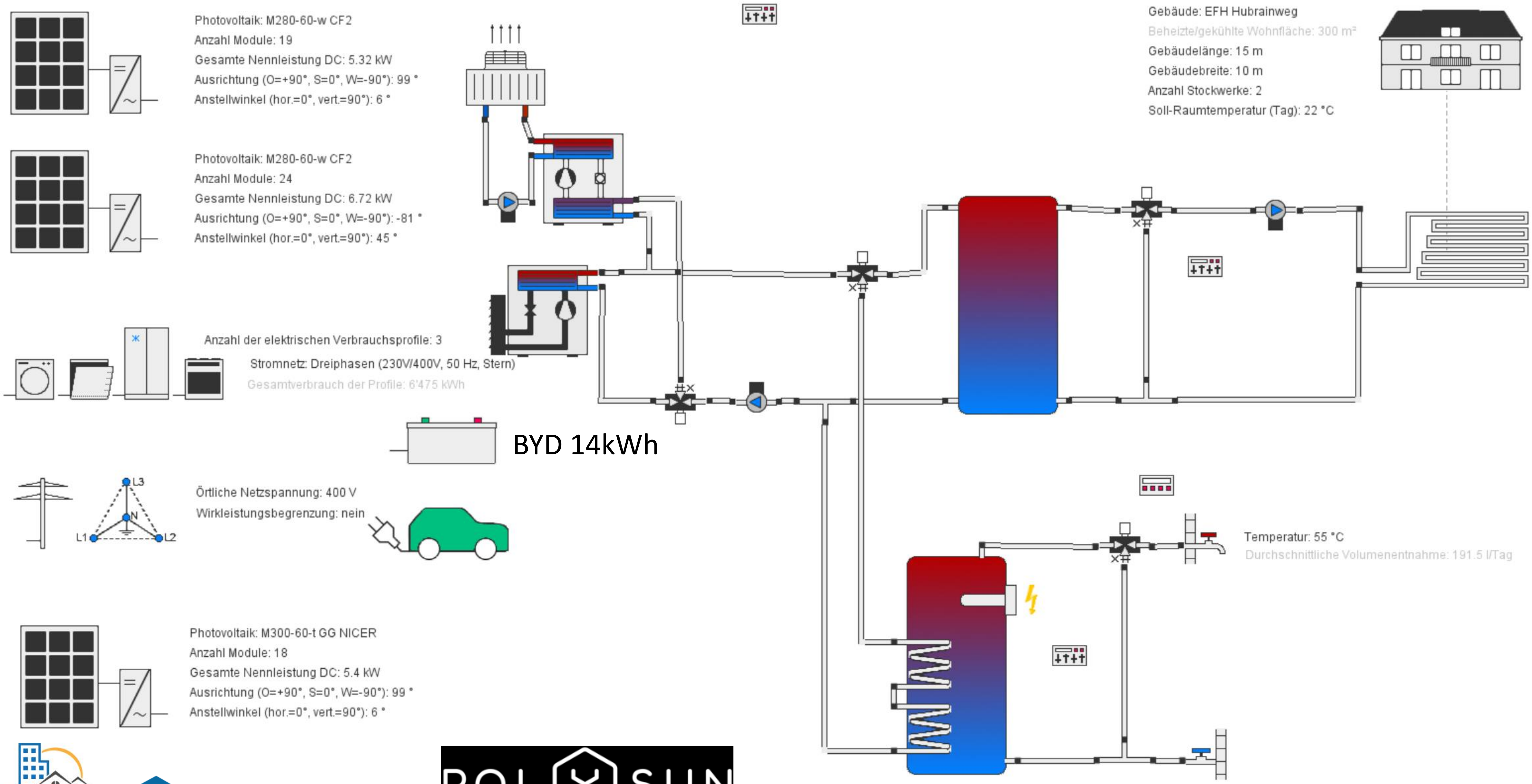
Projekt Hubrainweg 18_ist - Variante MODEL_01_BASE_V00 (Referenz)



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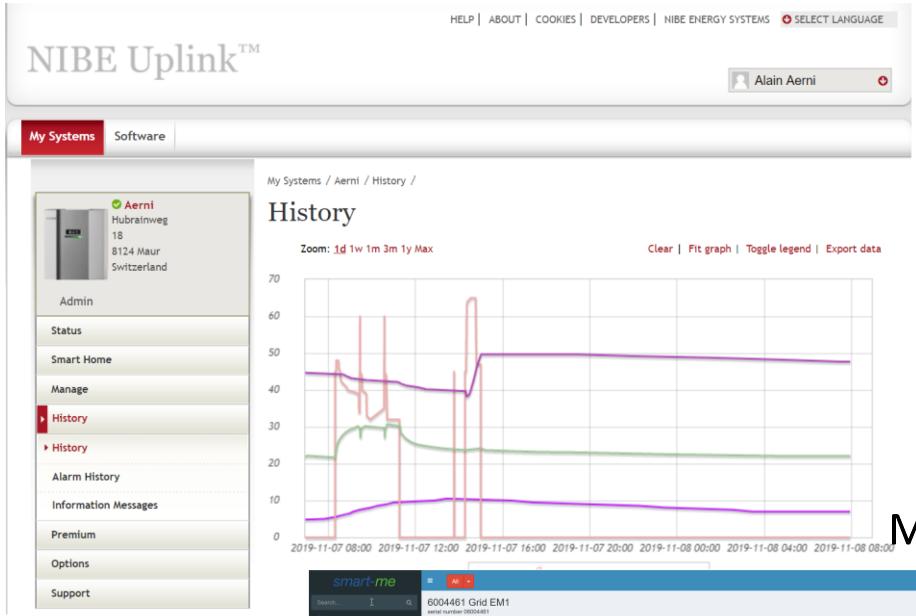
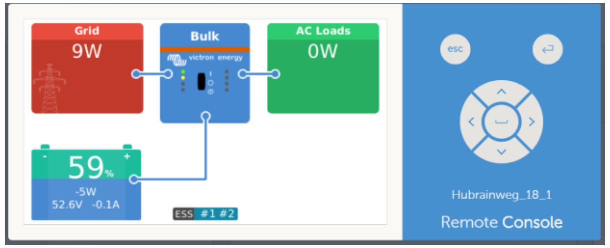
A lot of apps! But……

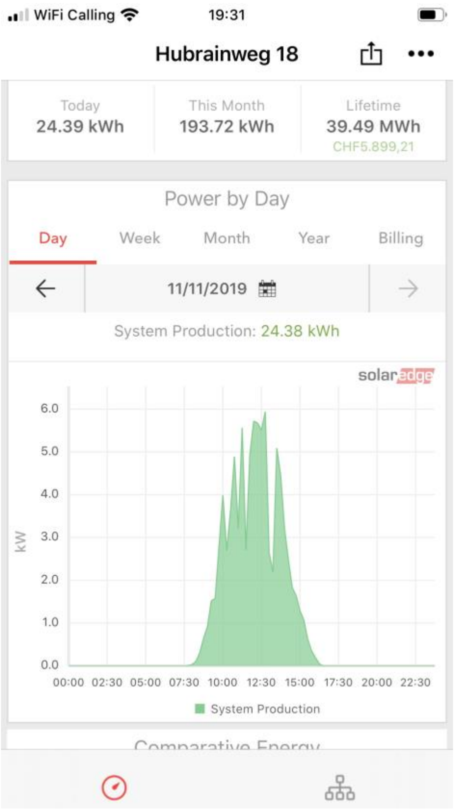
Heat Pump



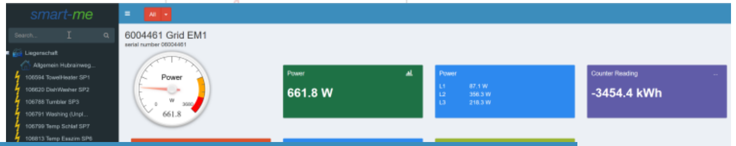
Battery with Venus GX



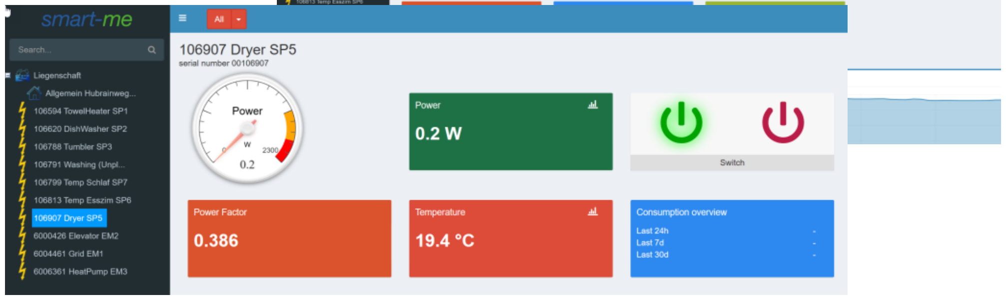
Solar edge

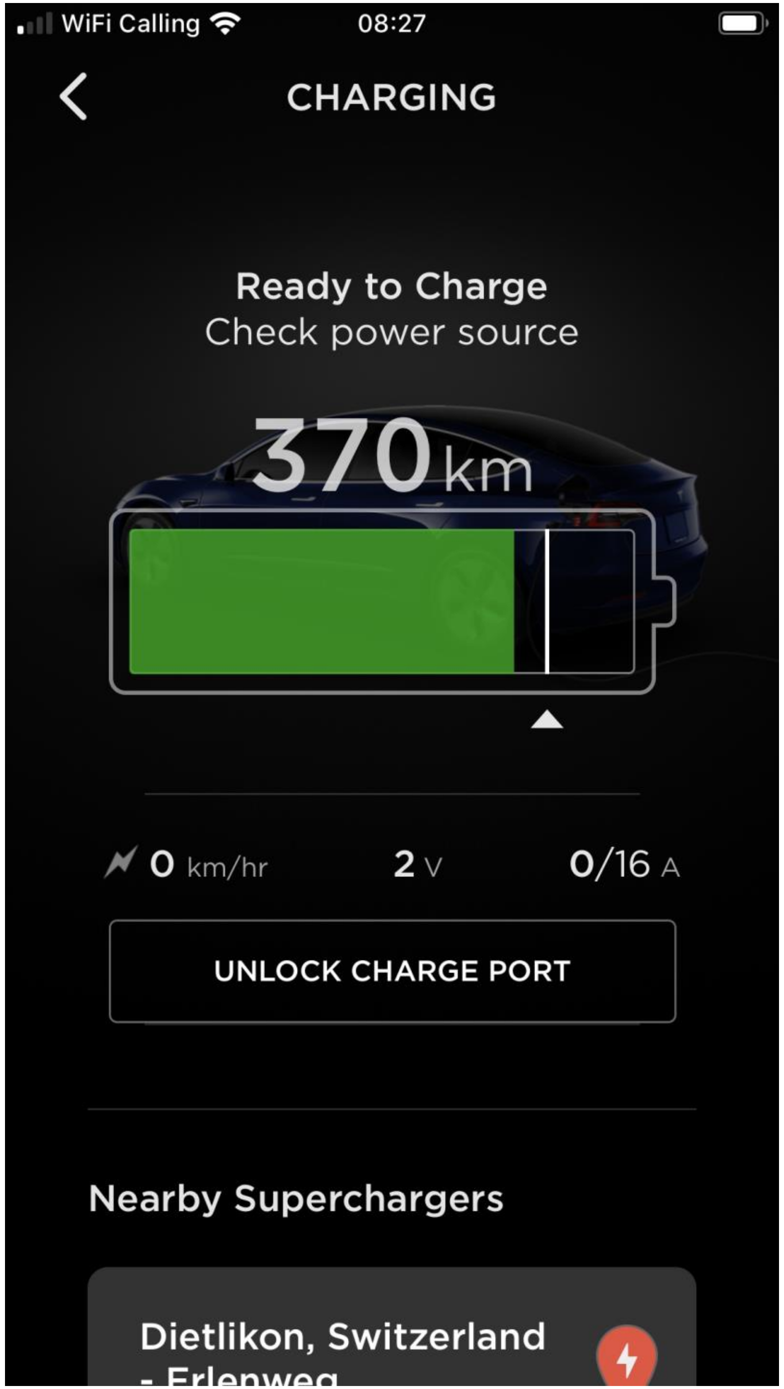


Meters



Smart-me plugs





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Agenda

The challenge

Crystalball and the way to it

Next steps

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Our journey

Major Challenges

- Connectivity
- Integration
- Orchestration
- Forecasting
- Optimizing to cost
- Visualize
- Easy to use

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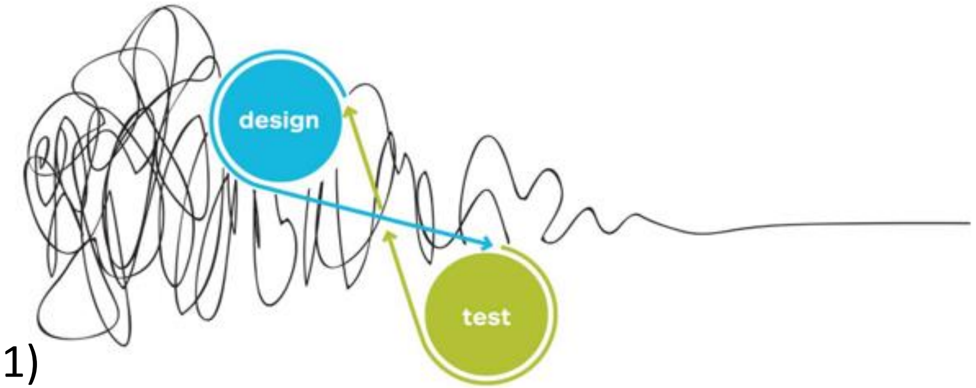


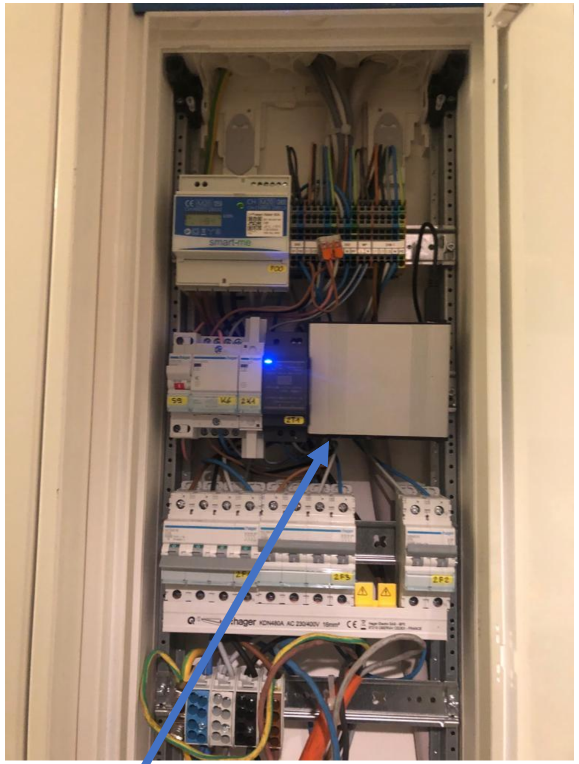
1)

+

Guide
Helpful and friendly
Knowledgeable
Creative
Resourceful

=

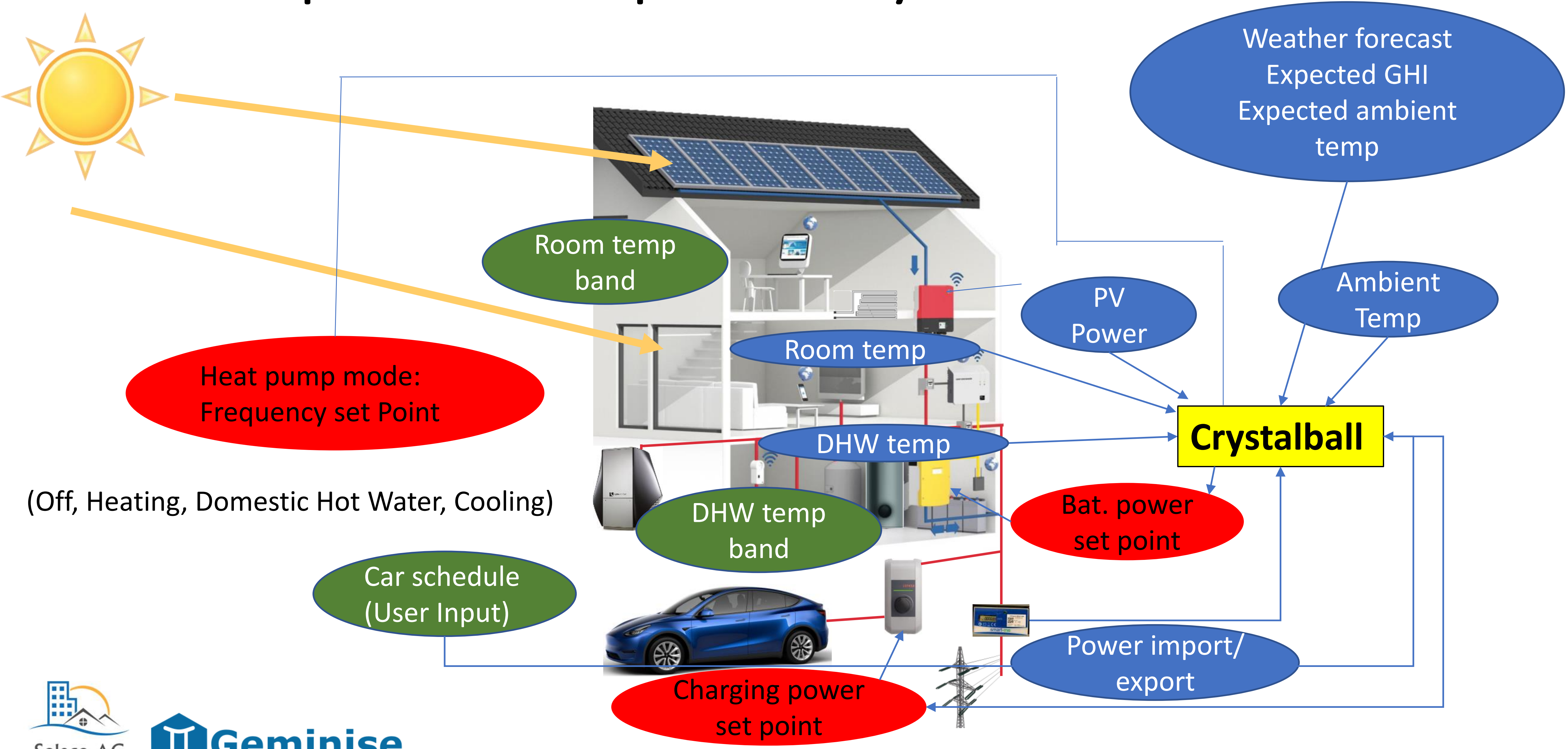
MPC/AI control



Crystalball and a great team

1)Source: Osterwalder; Value Proposition Design

Main inputs and outputs of Crystalball



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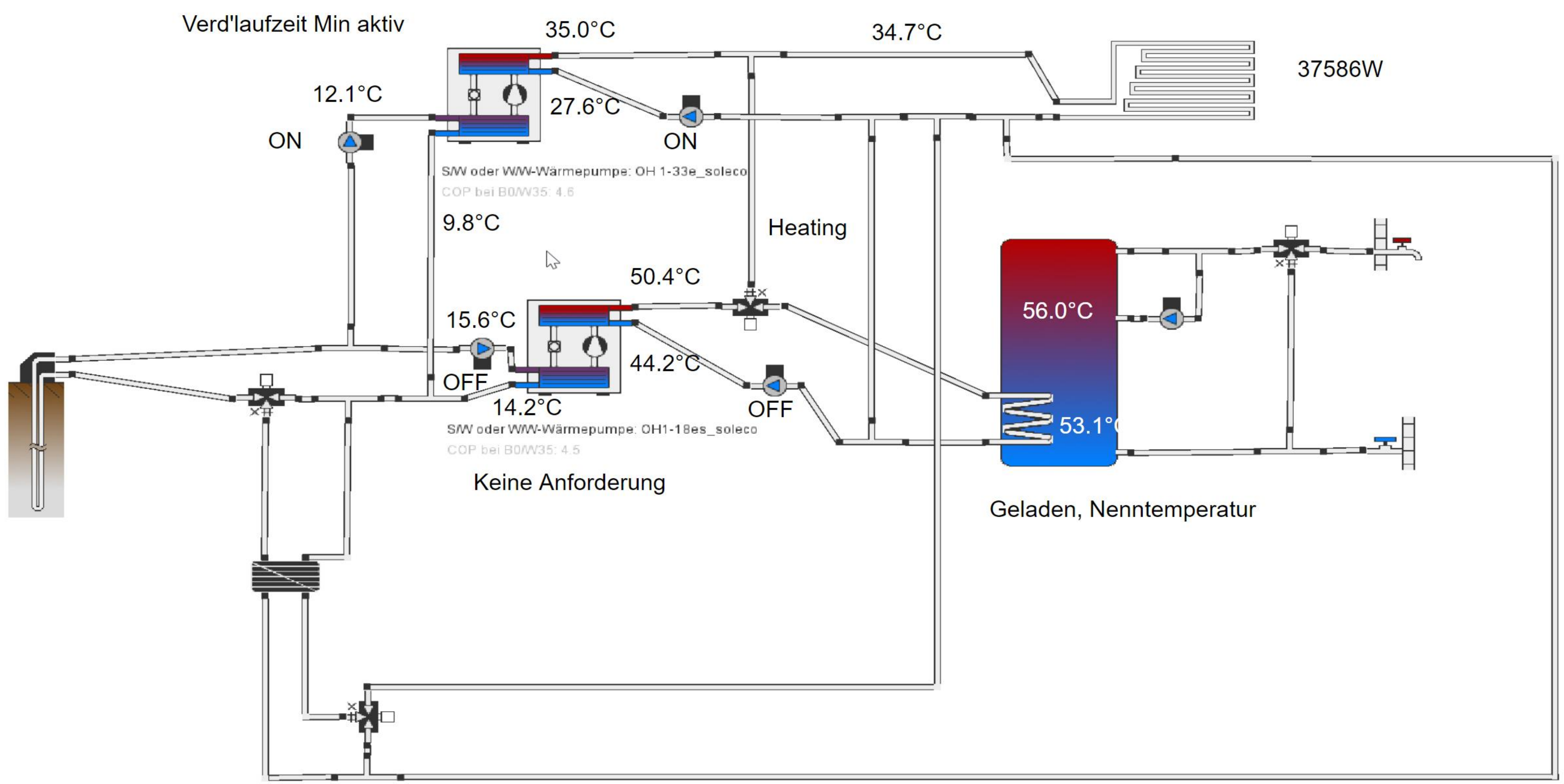
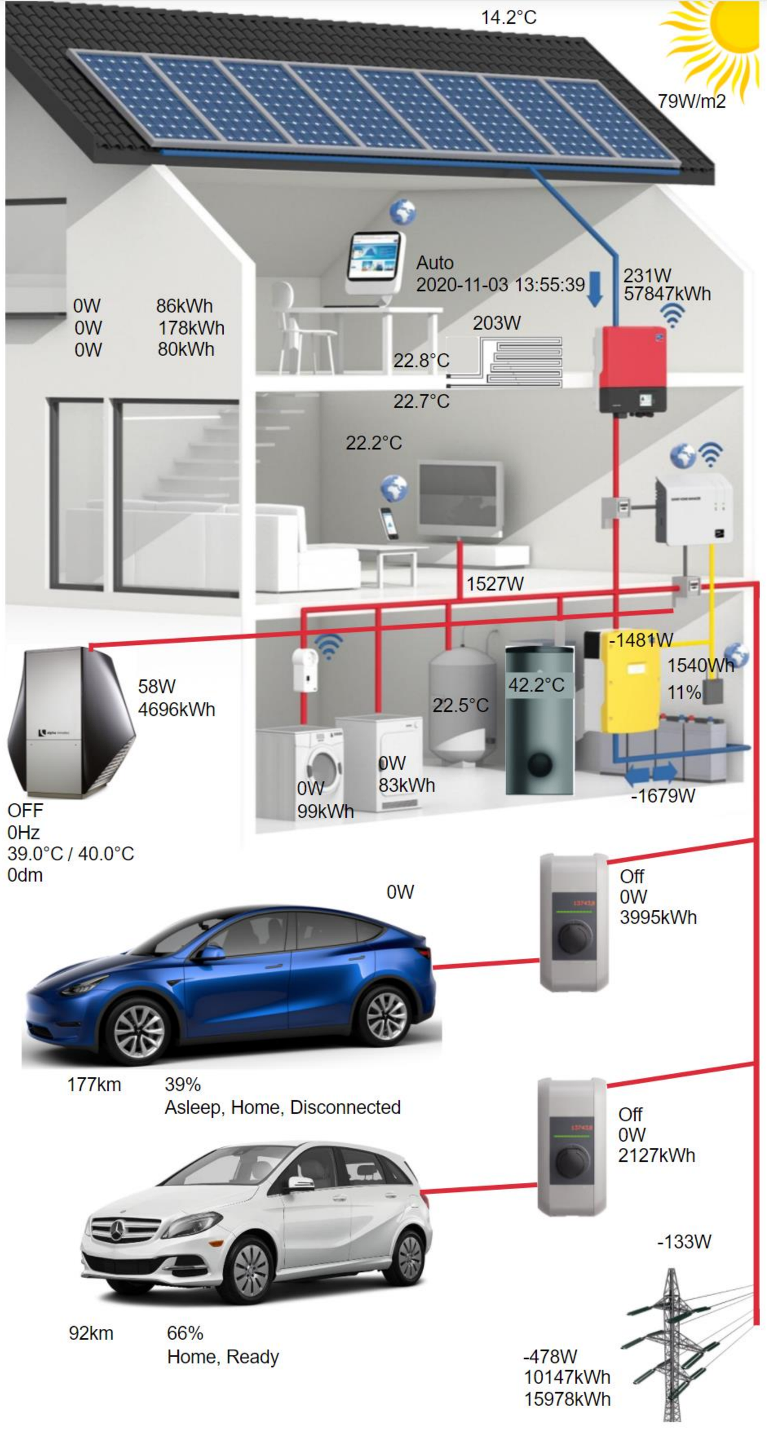
GUI overview

9.5°C

24.1°C	23.7°C	
23.6°C	23.3°C	23.7°C
23.8°C	23.0°C	24.5°C





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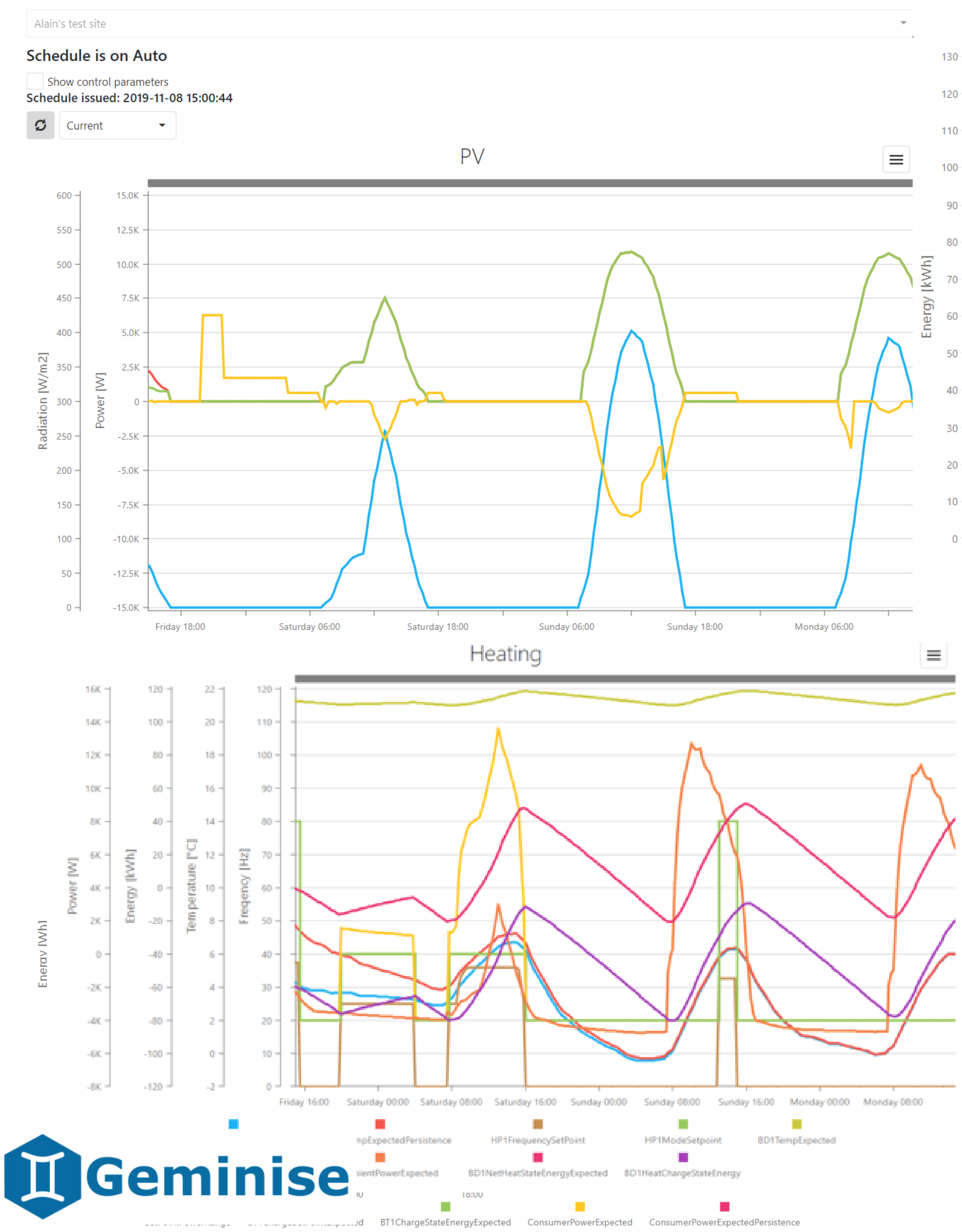

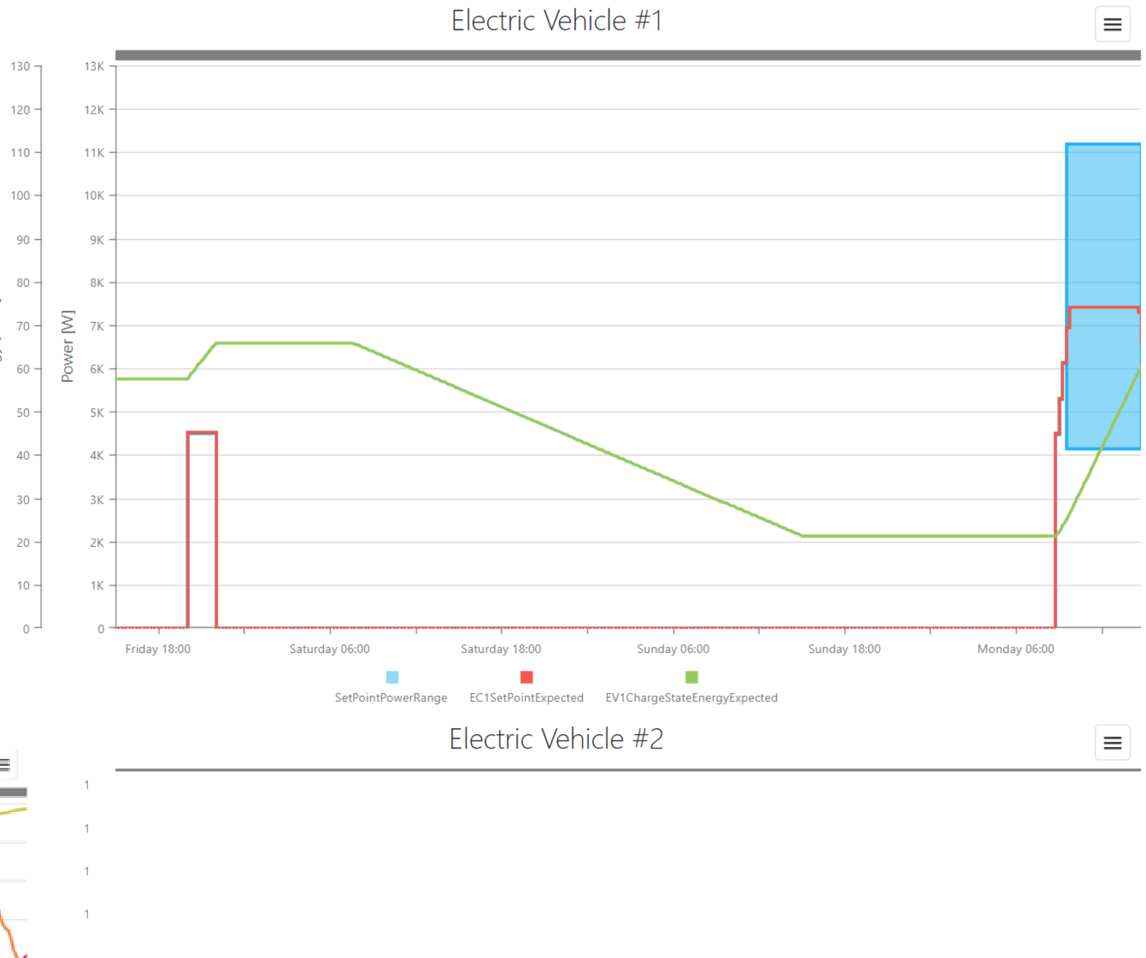

Minimizing energy cost over a 3 days forecast period with user constraints

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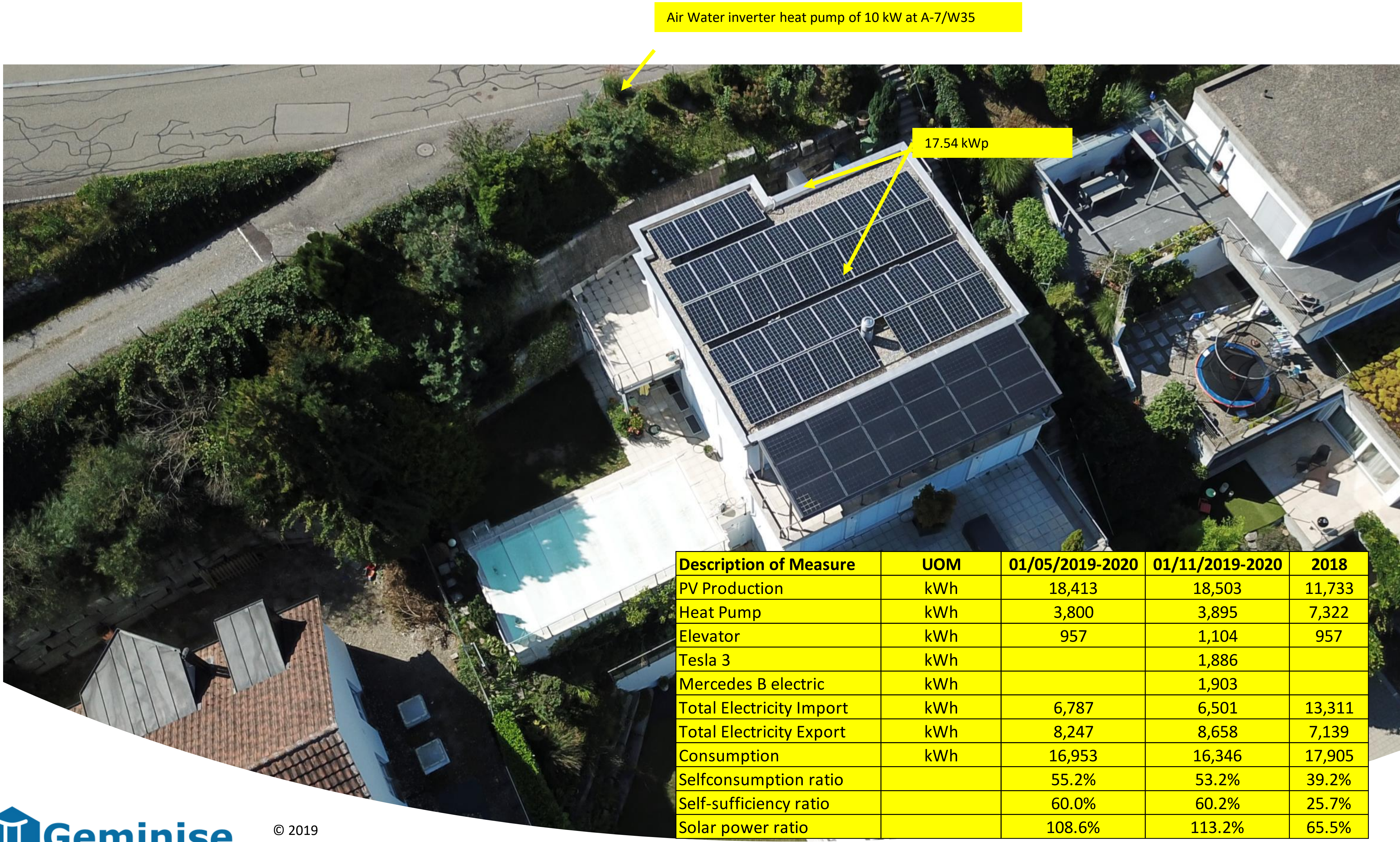

Description of Measure	UOM	01/05/2019-2020	01/11/2019-2020	2018
PV Production	kWh	18,413	18,503	11,733
Heat Pump	kWh	3,800	3,895	7,322
Elevator	kWh	957	1,104	957
Tesla 3	kWh		1,886	
Mercedes B electric	kWh		1,903	
Total Electricity Import	kWh	6,787	6,501	13,311
Total Electricity Export	kWh	8,247	8,658	7,139
Consumption	kWh	16,953	16,346	17,905
Selfconsumption ratio		55.2%	53.2%	39.2%
Self-sufficiency ratio		60.0%	60.2%	25.7%
Solar power ratio		108.6%	113.2%	65.5%

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Agenda

The challenge

Crystalball and the way to it

Next steps

Status and next steps

- Crystalball is live at 6 sites. It is also deployed on each new project of Soleco AG
- Further validate benefits (Quantitative and user convenience)
- Get further lead customers to validate scalability
- Further technical improvements for: (Human Interface, cost, more connections and control of devices)
- Develop sales and delivery channel
- Search for Investor(s) and/or Partners

Contact

So

Thank you

Please contact us per mail for a demo or for…….

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