# Using Smart Breakers for Demand Side Management in Smart Grids

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*Abstract*—The electrical energy system is handled as the largest machine humankind built, which is very understandable if one imagines the changes currently happening. It is rapidly leaving behind its centralized roots with "the" power plants generating energy for all loads connected to it via copper wires. Year after year, new records are reported of integrating more percentages of sustainable renewable generation at every conceivable decentralized point. This rise of uncontrollable, fluctuating production, combined with the increase of loads, is taking away flexibilities needed to keep the power grid stable at every point in time. This paper describes a mechanism called demand response, which is an aspect of demand-side management, to increase this fleeting flexibility again on the load side, by using newly developed smart actuator components. Field tested results show domain specific gains of annual consumption reduction from six to 33 percent.

I. Introduction

The ongoing transformation from our traditional energy distribution grid to a Smart Grid provides new opportunities to connect prosumers to energy providers and distribution system operators (DSO). The work at hand presents a prototypical implementation that takes advantage of these new cross-domain communication capabilities ...

... test section will then outline concrete use cases that have been implemented on a realistic field testing site and present the results produced during the testing period. These results will include an overview of the successfully tested functionalities, especially concerning the usage scenarios introduced at the beginning of the paper. Afterwards, we discuss the quantitative changes in energy consumption provided by the new system. The final section of this work will present our conclusions based on these results and provide a quick outlook on possible follow up work.

II. State of the Art

The following subsections will introduce some general concepts that are relevant to the work at hand. After this, we will give an overview of previous iniGrid related publications that contain more detailed information on the various aspects of the project.

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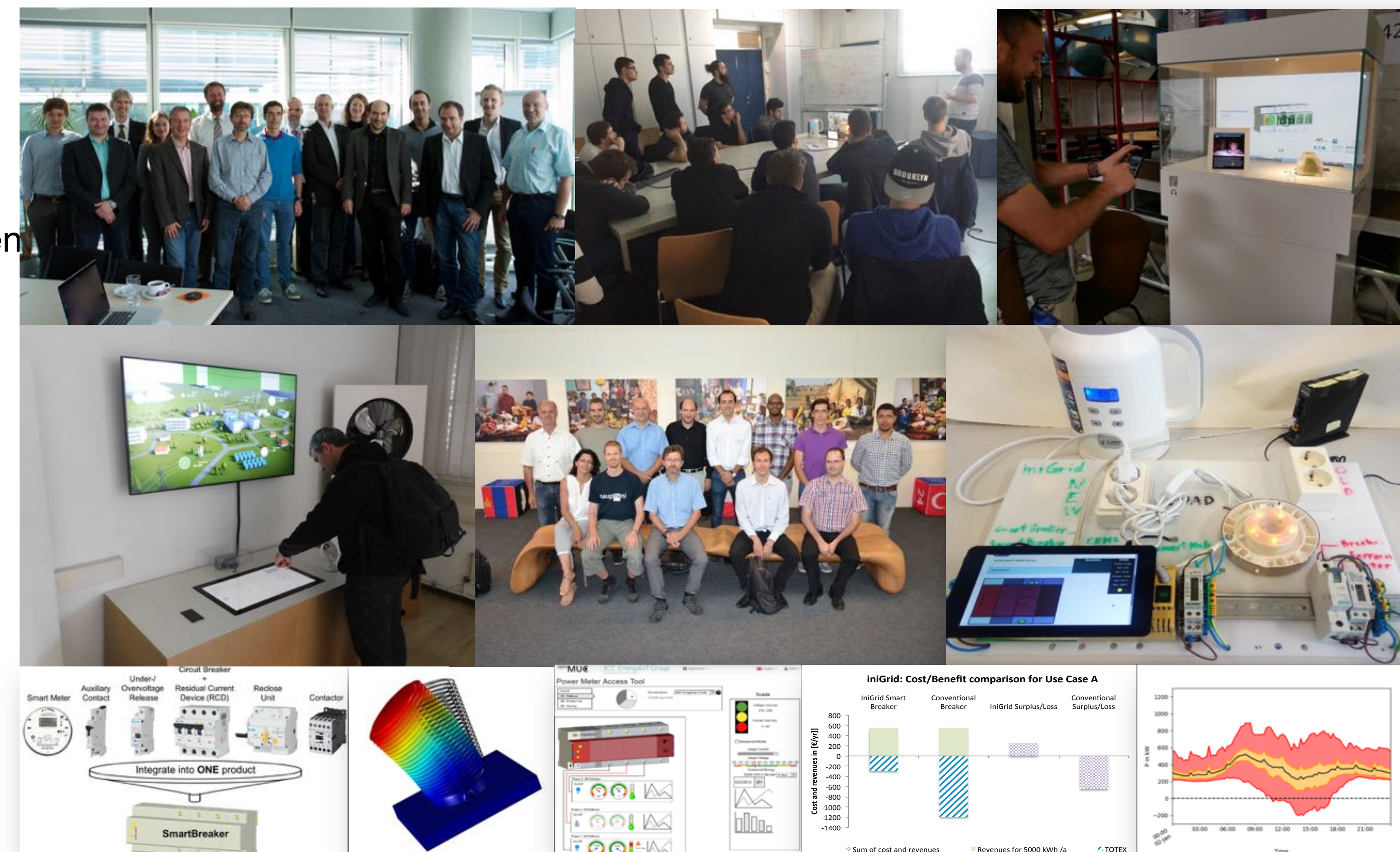
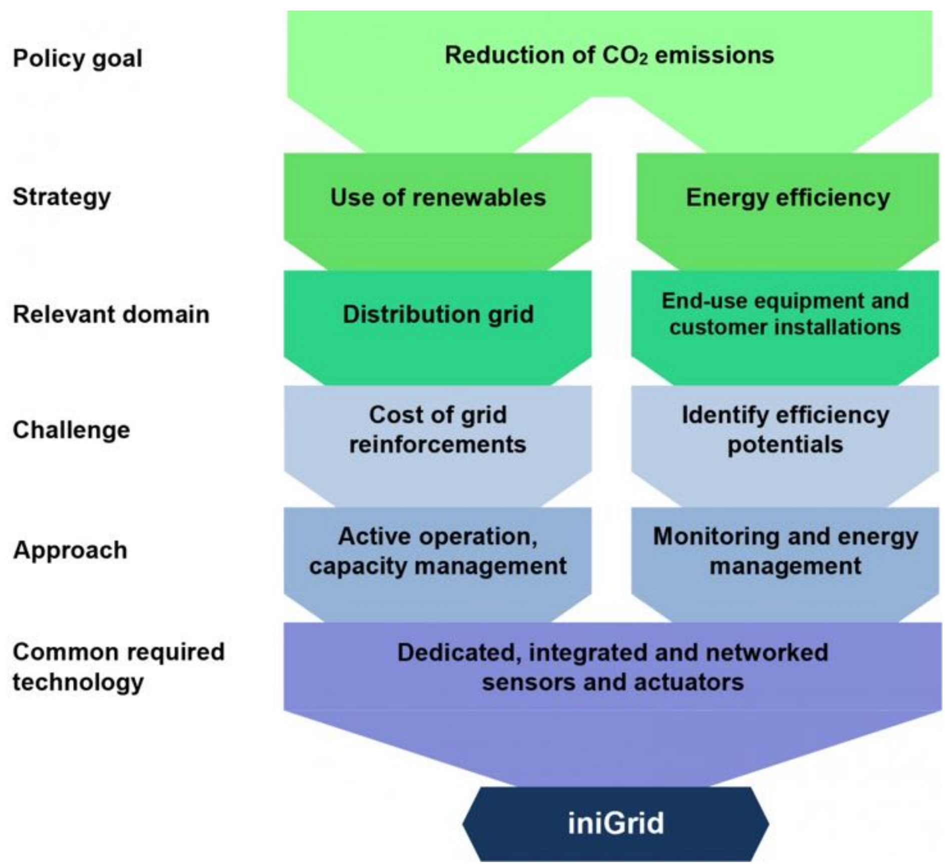
# iniGrid – Integration of Innovative Distributed Sensors and Actuators in Smart Grids

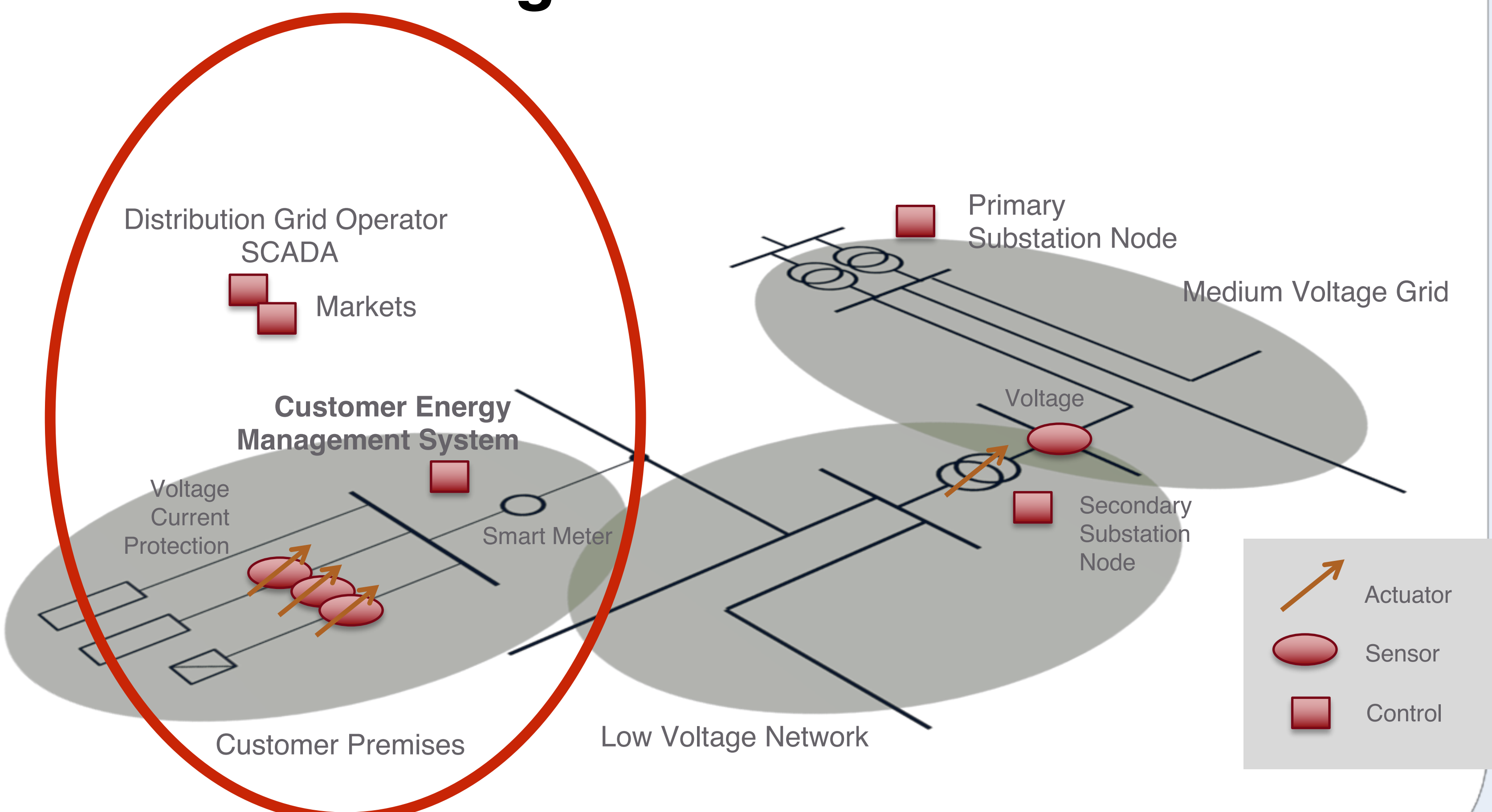
- Flagship project
  - RTI initiative, bmvit, FFG, Klima+Energie Fonds
  - e!MISSION.at – 4th call for proposals
- Funding & Duration
  - 4.1 Mio € costs (2.3 Mio funded)
  - 2014-2018, 42 months
- Diverse consortium
  - Institute of Computertechnology, TU Wien
  - Austrian Institute of Technology GmbH
  - Eaton Industries (Austria) GmbH
  - Infineon Technologies Austria AG
  - Zelisko GmbH
  - Sprecher Automation GmbH
  - Fachhochschule Oberösterreich
  - Linz Strom Netz GmbH
  - MOOSMOAR Energies OG



# iniGrid - Goals

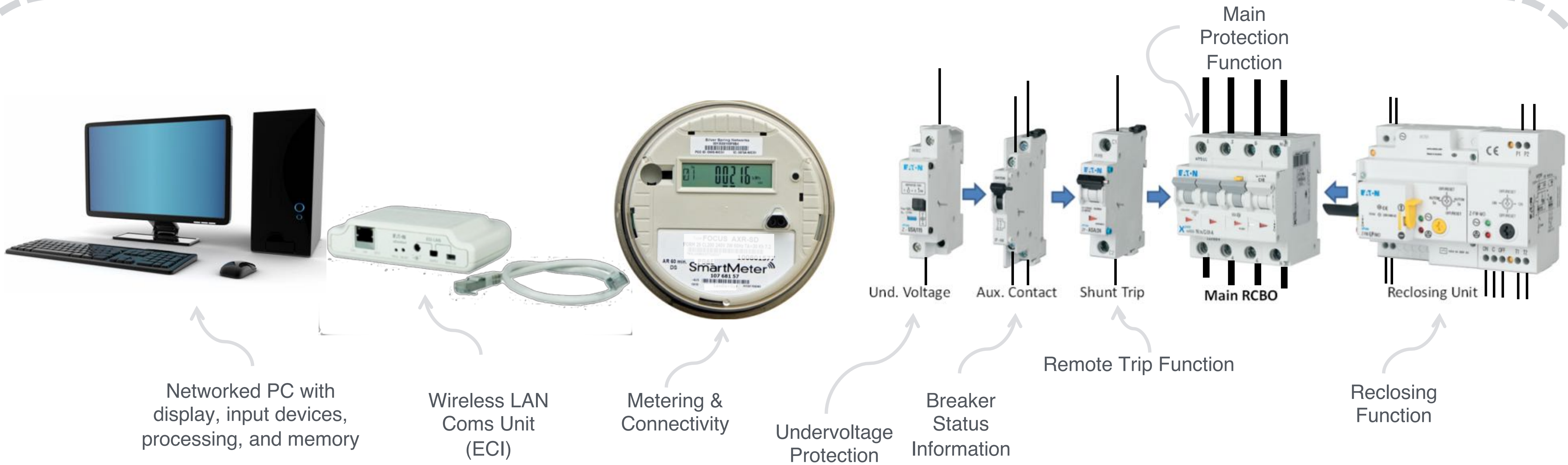
- **A) Energy Management on Prosumer Level** (focus of this work)
- B) Low Voltage Network Optimisation
- C) Medium Voltage Network Optimisation on Substation Level
- D) Medium Voltage Network Optimisation on Management System Level
- **E) Distribution Optimisation across Voltage Levels**



# Hybrid Switching Smart Breakers

## Active components and sensors with existing devices

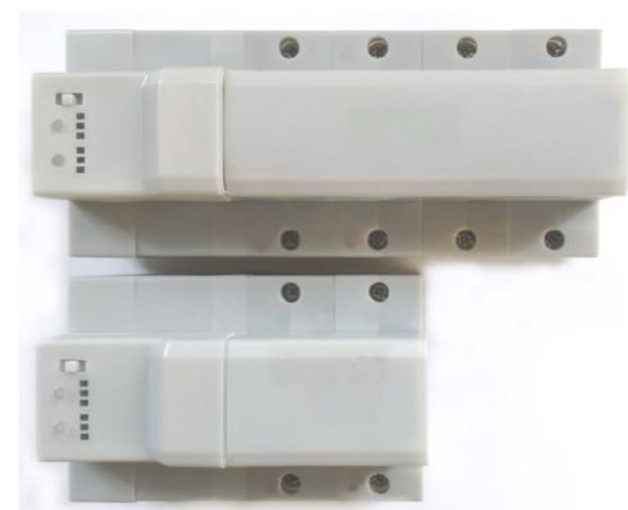



Integrate into Smart Device → **Smart Breaker**

First technical proof of concept validation prototype

Final Demonstrator-1 samples

(4 phases and 2 phases)



# Functionality Requirement – Customer Energy Management System (CEMS)

- main customer benefit on different levels
  - installations in residential/**commercial/industrial** segment
  - installations of 10-100s Smart Breaker switchable loads
- four smart grid functionalities for Smart Breakers (SB)
  - **fail safe**: providing limits to SB ahead of communication loss
  - **priority list**: configuring importance of switched devices for soft start after shutdown or blackout
  - **self consumption**: algorithms optimizing reliable self consumption using local switchable battery storages and generation
  - **switch patterns**: SB-network operator (eg. SCADA) learn / build knowledgebase of successful patterns of switch-states & communicate them as emergency plans (in different granularization hour/day/week)

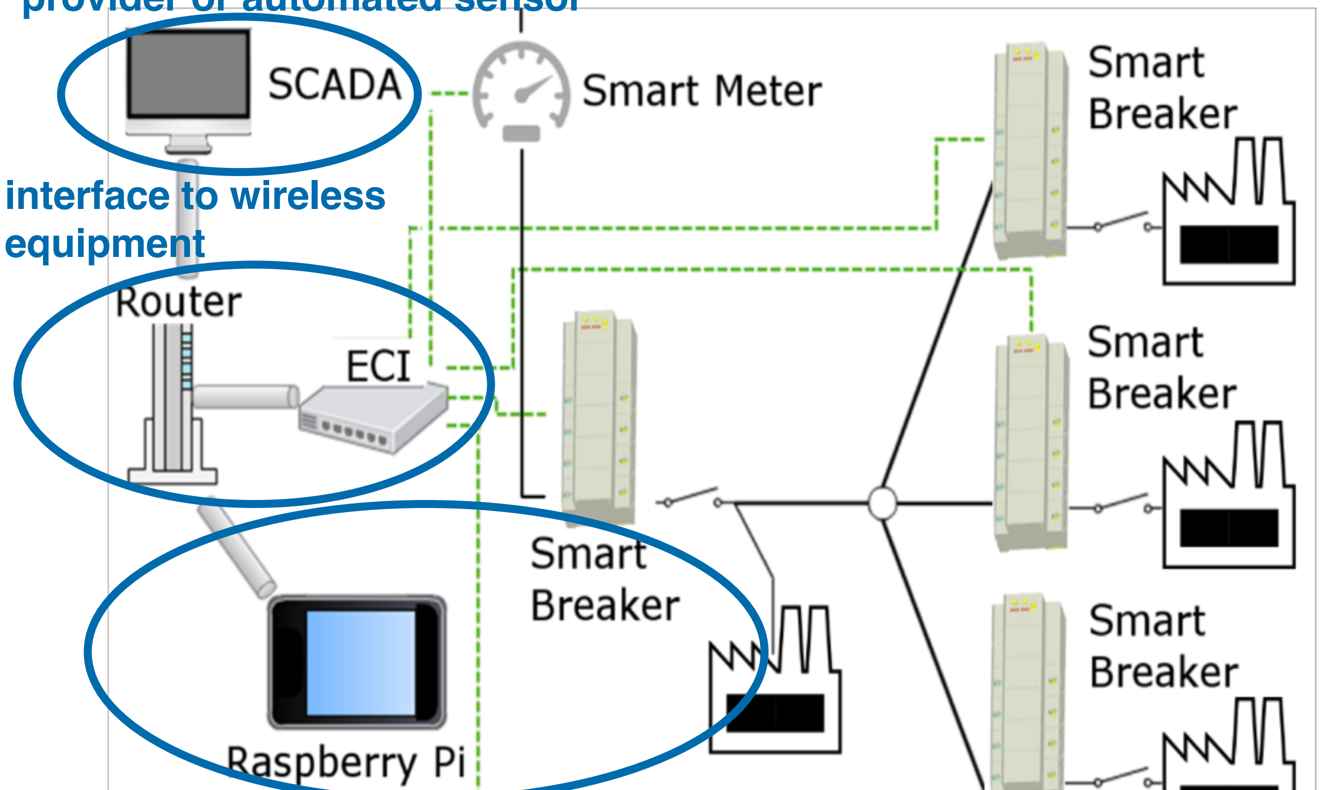
SCADA: Supervisory Control and Data Acquisition

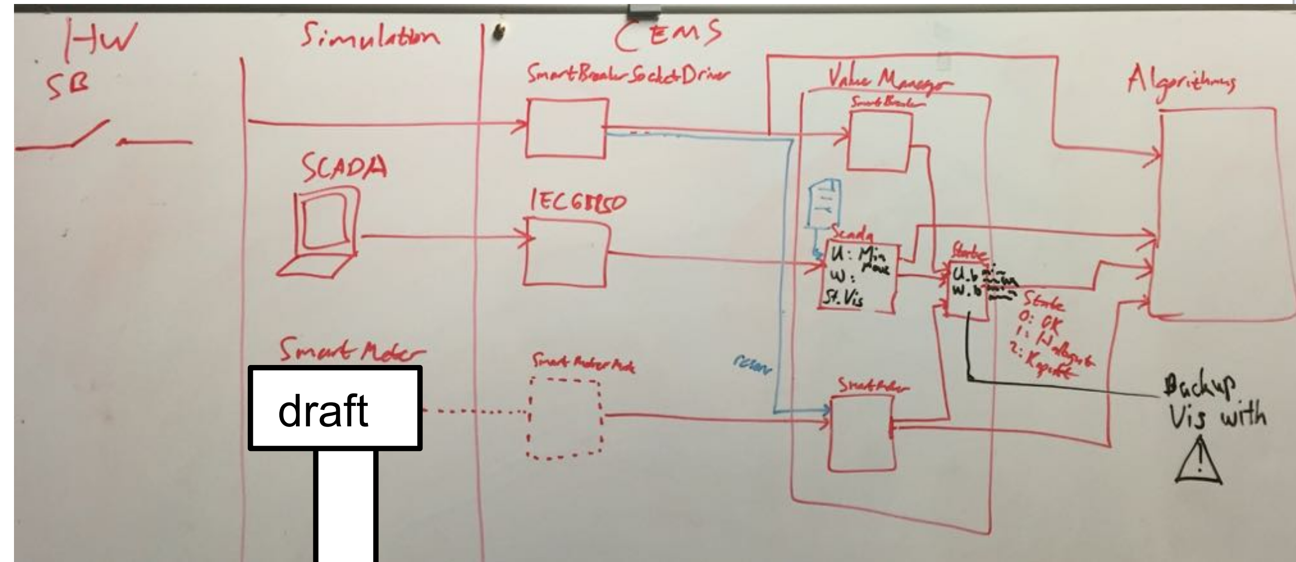
# PoC – Process

simulate distribution system, provider or automated sensor

interface to wireless equipment

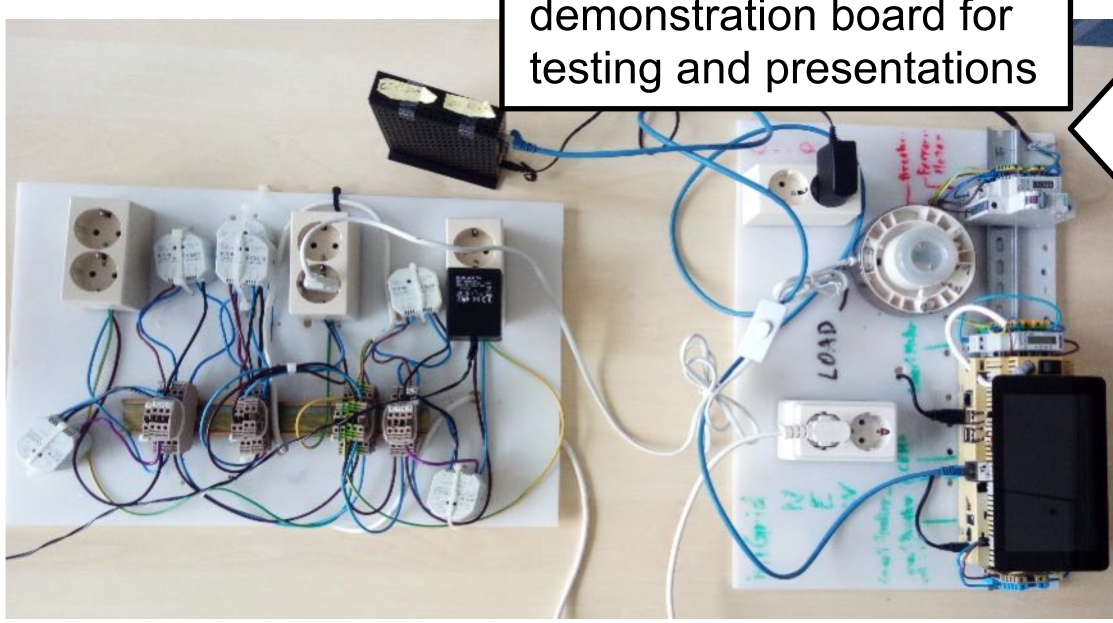
housing communication, actors, and intelligence



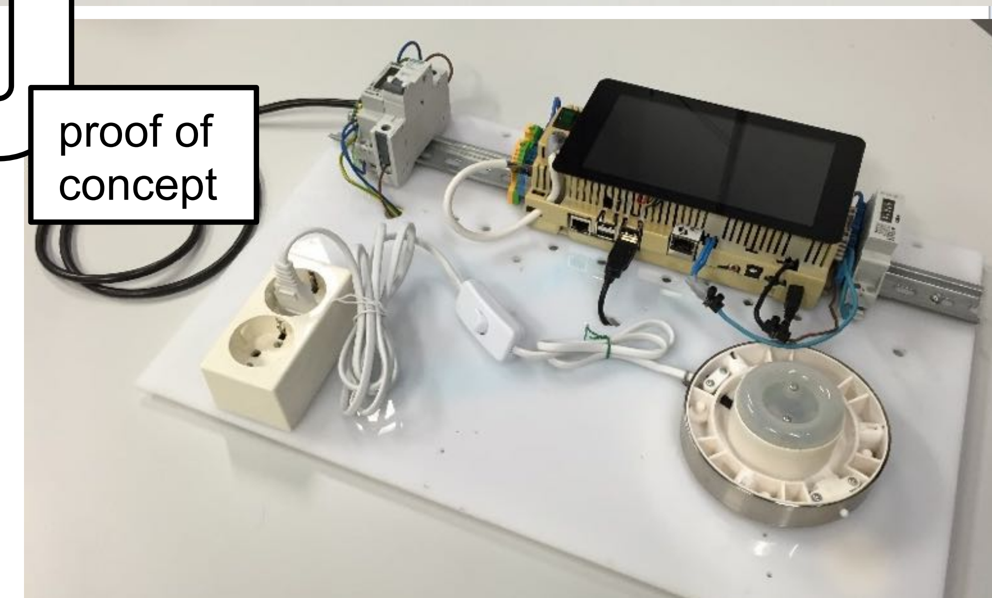

draft

demonstration board for testing and presentations



development stages

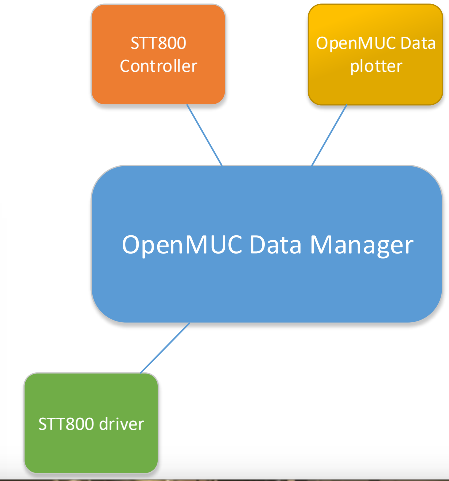
proof of concept



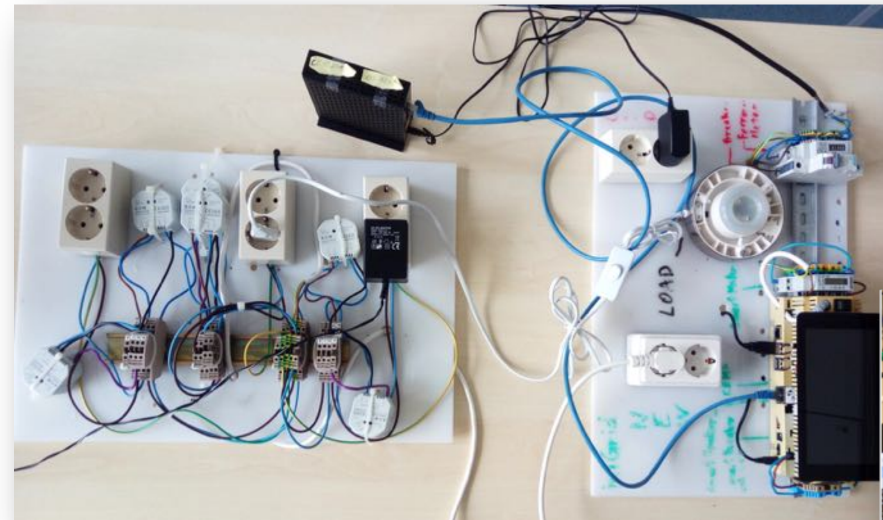
SCADA: Supervisory Control and Data Acquisition

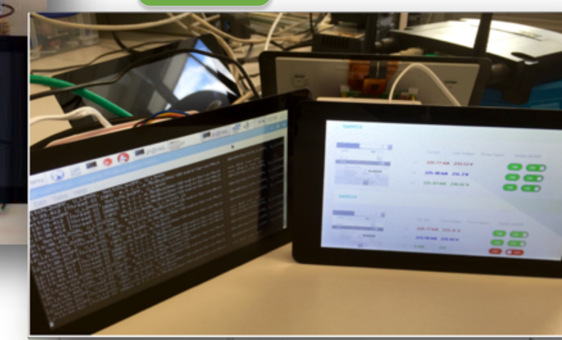
PoC: Proof of Concept

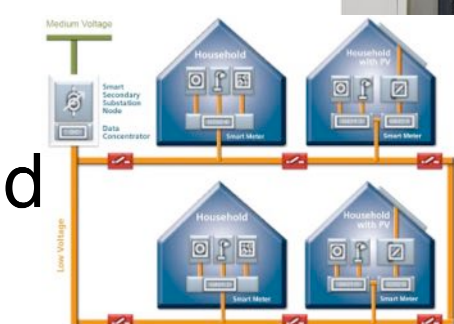
# Experimental PoC: Customer Energy Management System (CEMS)

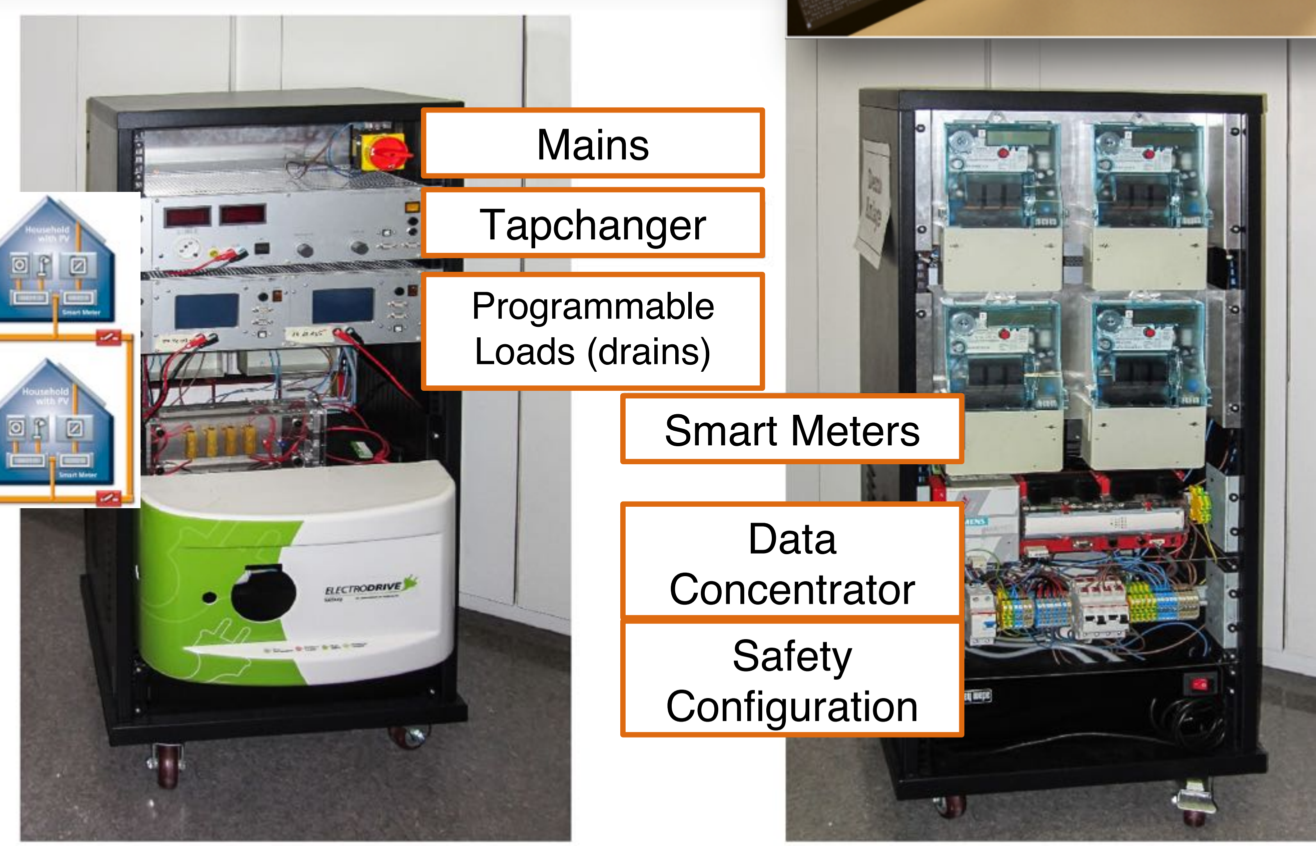



- deployable on affordable off-the-shelf hardware (Raspberry Pi 3)
  - switches+meters, display, input, CEMS, GUI
  - open communication framework OpenMUC for accessing the hardware, testbed board
  - secure communication by VHPready, SSH tunnels, IEC 62351 and IEC 61850
- communication failure testbed
  - hardware setup
  - Charles proxy
- emulation of low voltage grid
  - tapchanger transformer
  - continuous testing of communication mocks
  - STT800 controller, IEC 61850 & Modbus drivers
  - Wireshark communication records for security analysis





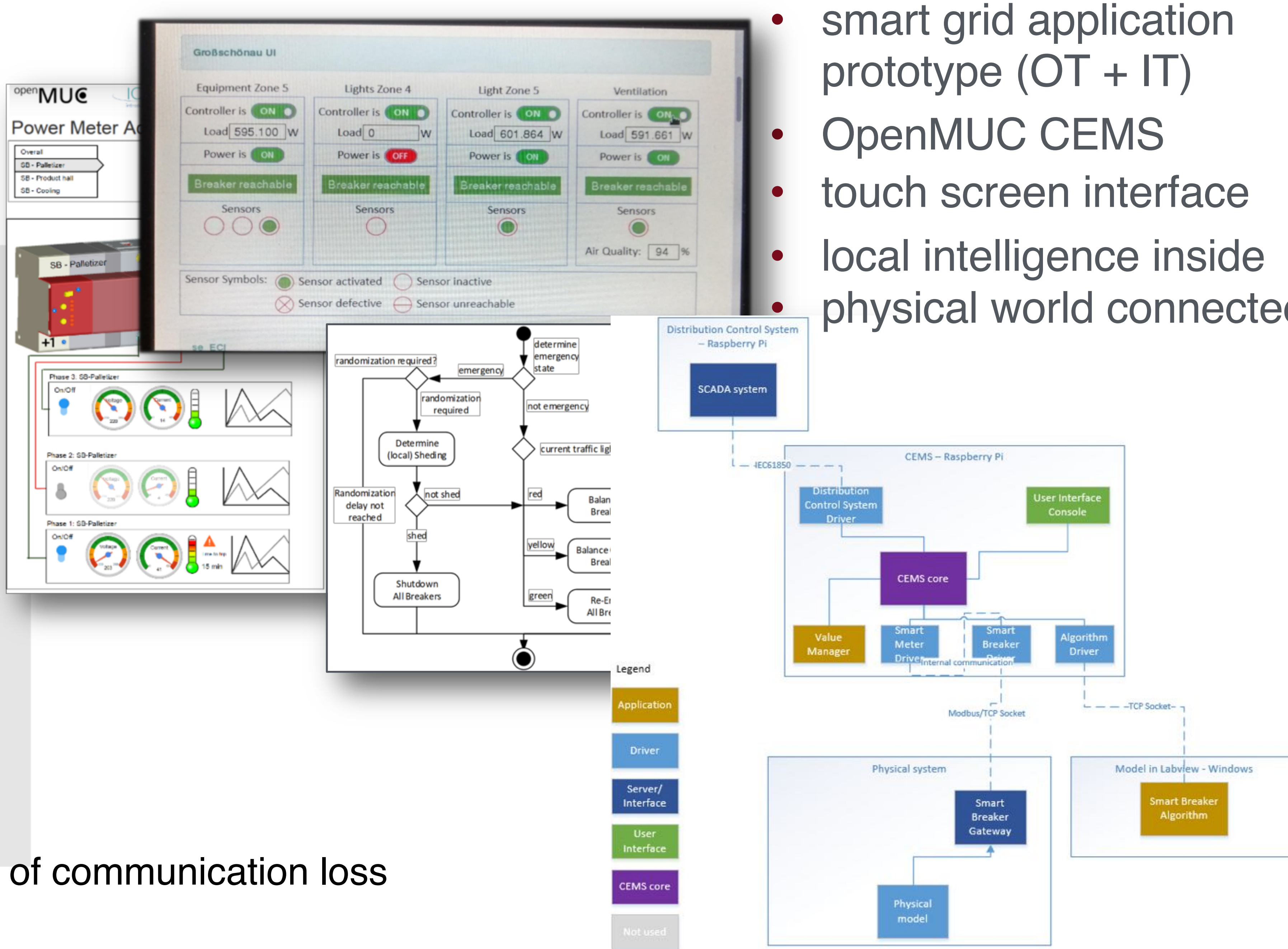




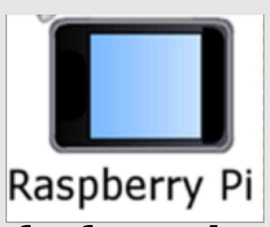

PoC: Proof of Concept GUI: Graphical User Interface

# PoC – RaspberryPi

the right tool for the job




- smart grid application prototype (OT + IT)
- OpenMUC CEMS
- touch screen interface
- local intelligence inside
- physical world connected

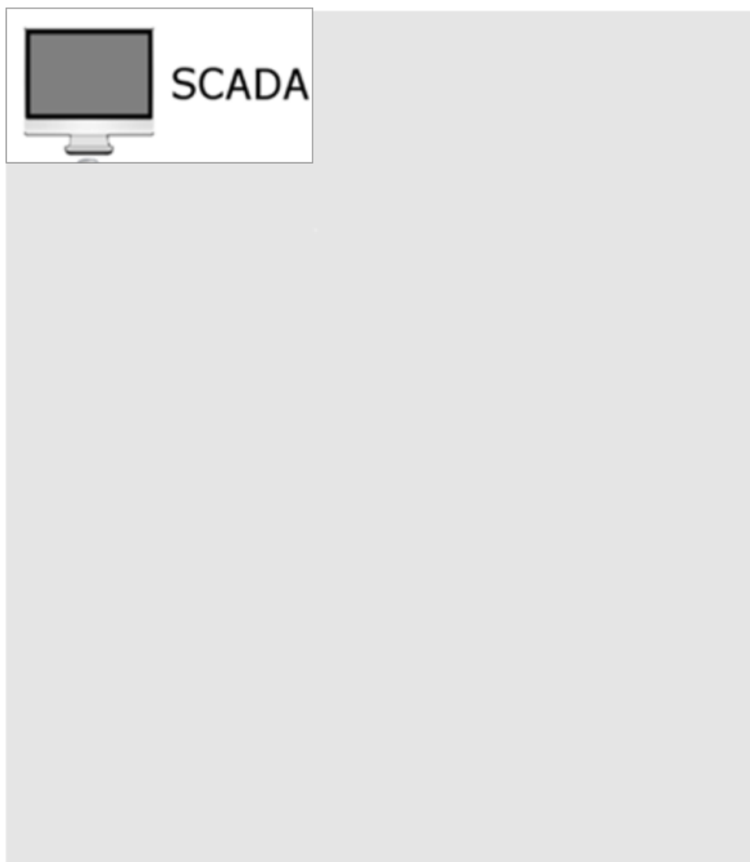



- **fail safe functionality**
  limits for smart breakers ahead of communication loss
- **priority list functionality**
  configuring importance of switched loads for soft start after shutdown or pre-blackout critical emergency states
- **self consumption functionality (FHOE partner cooperation)**
  optimizing usage of local renewable generation and battery storage systems (3rd party algorithms)

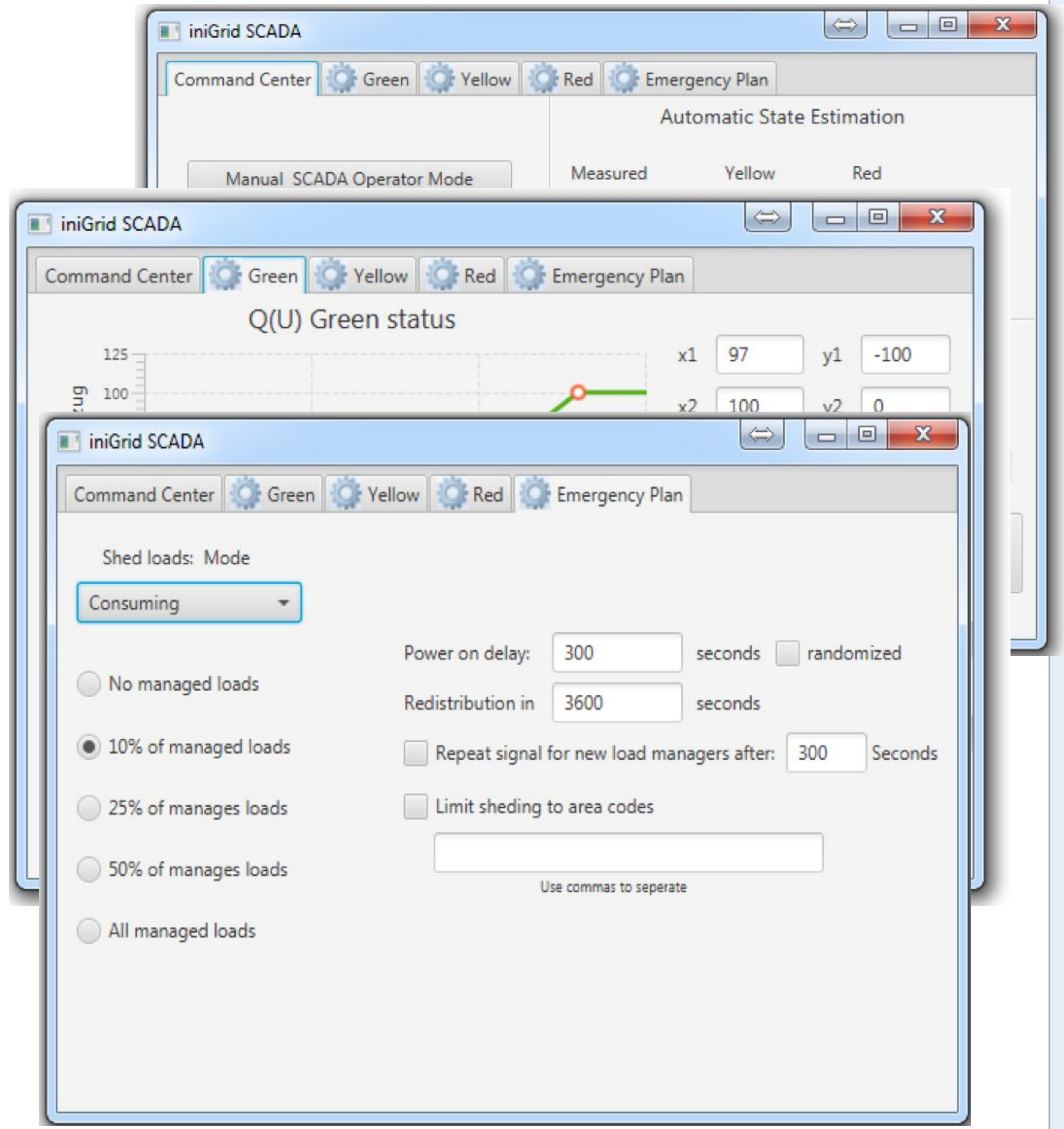
PoC: Proof of Concept OT: Operational Technology IT: Information Technology

# PoC - SCADA

- the right tool for the job



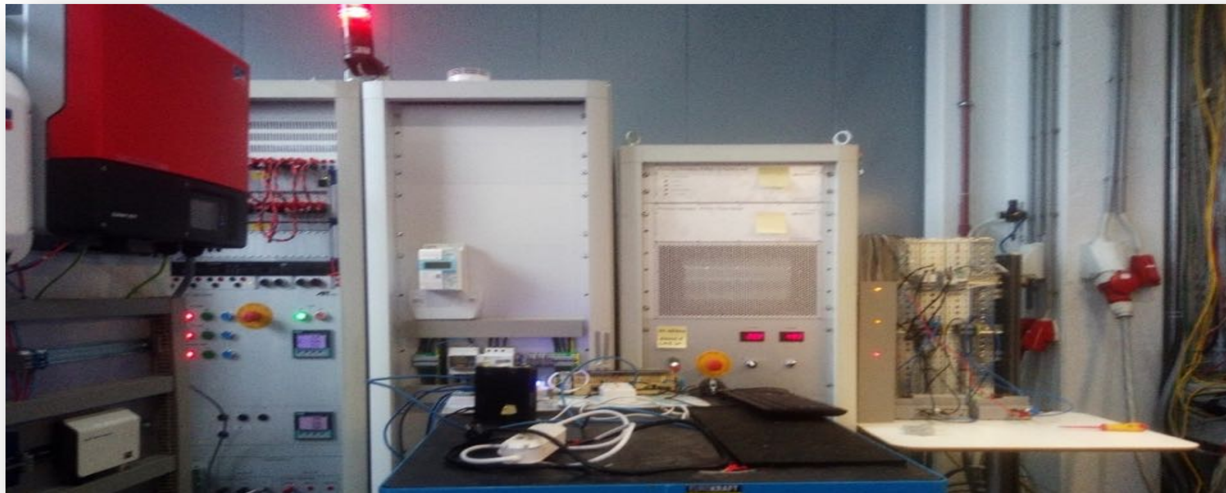

**switch patterns functionality**
allows distribution optimization across voltage levels, increases predictability, and allows configurable emergency behaviors

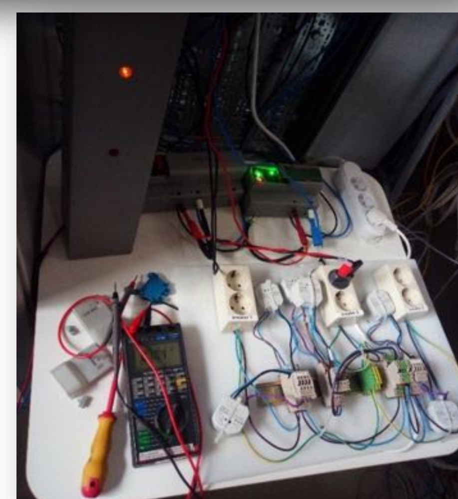



- emergency shedding for crisis simulation
- adjustable shedding percentage (**switch patterns**)
- uni-directional communication (SCADA → CEMS)

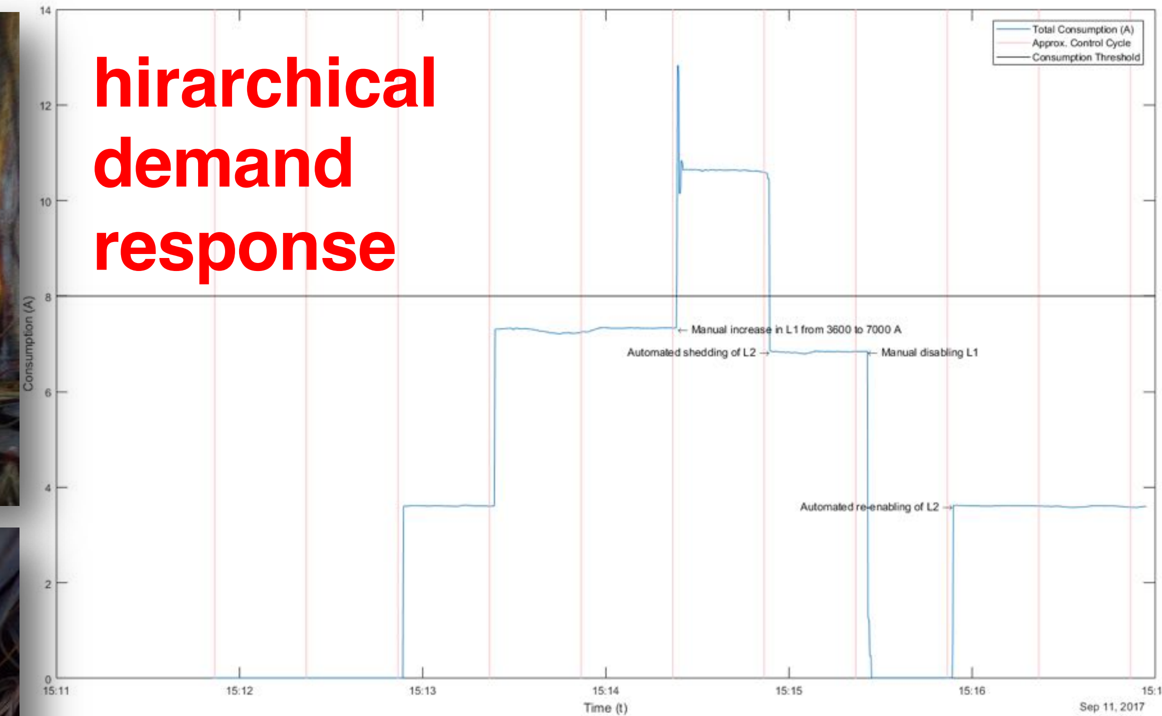
PoC: Proof of Concept

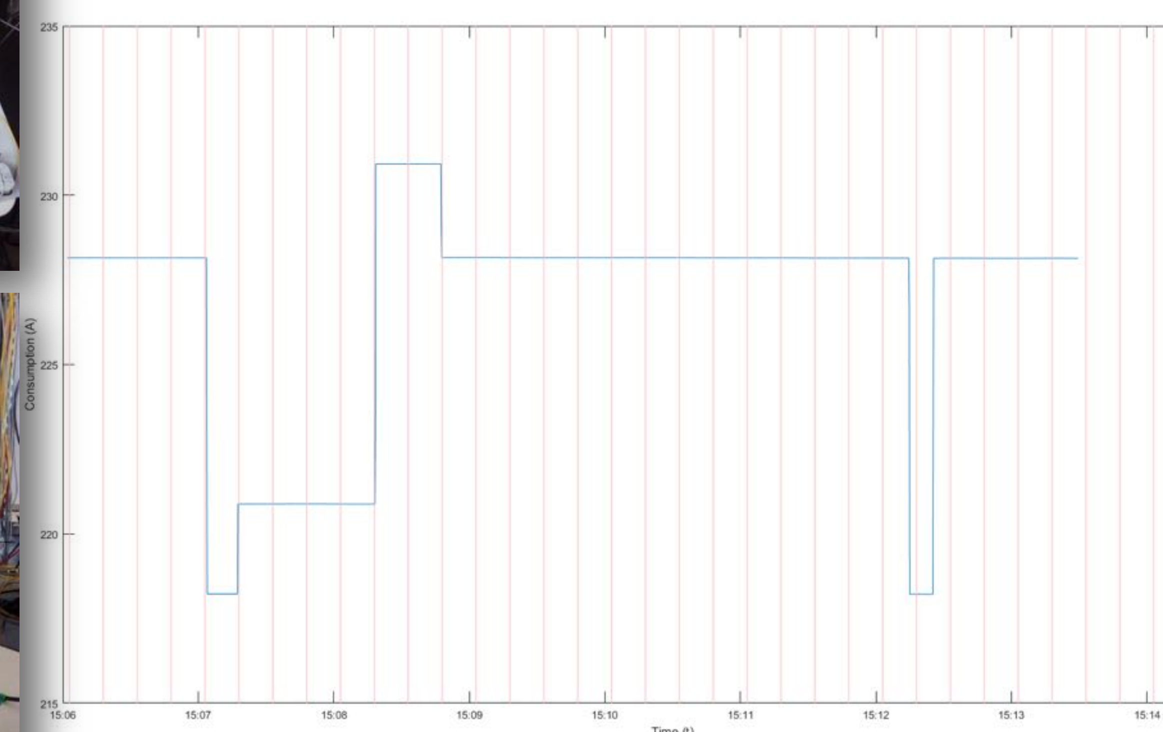
# Function proof with PoC at AIT SmartEST Laboratory





- use case (A-E) based usage scenarios
- grid simulator
- switching of (more) realistic loads
- successfull validation of various concepts




PoC: Proof of Concept

# Field Test Location

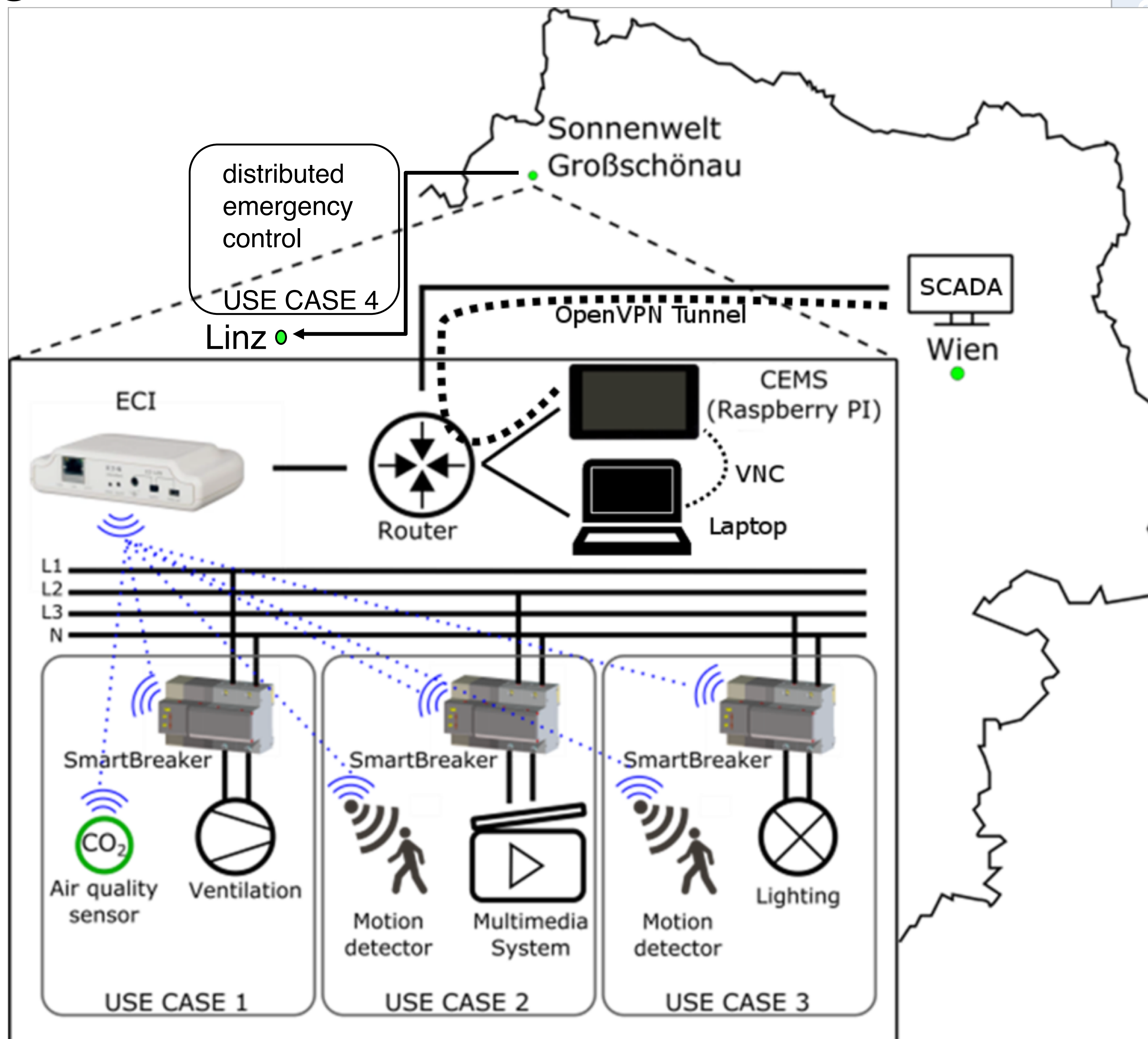
- deployment at active museum in Lower Austria
- approx. 30000 visitors / year
- approx. 45000 – 48000 kWh yearly total consumption (we only control a small part of that)
- local PV system with 82 kWp
- centralized ventilation system
- flexible exhibition setup


# Field Test Use Cases

- use case 1: multimedia (MM)
  - control various MM equipment with varying bootup times
  - based on movement sensors in adjacent rooms
- use case 2: ventilation
  - multicriteria decision: air quality, regular intervals, manual triggers
  - marked as “optional equipment” for use case 4
- use case 3: lights
  - triggered by movement sensors
  - multiple entries and exits
- use case 4: demand response communication
  - simulated grid stress
  - attempt remote active grid stabilization

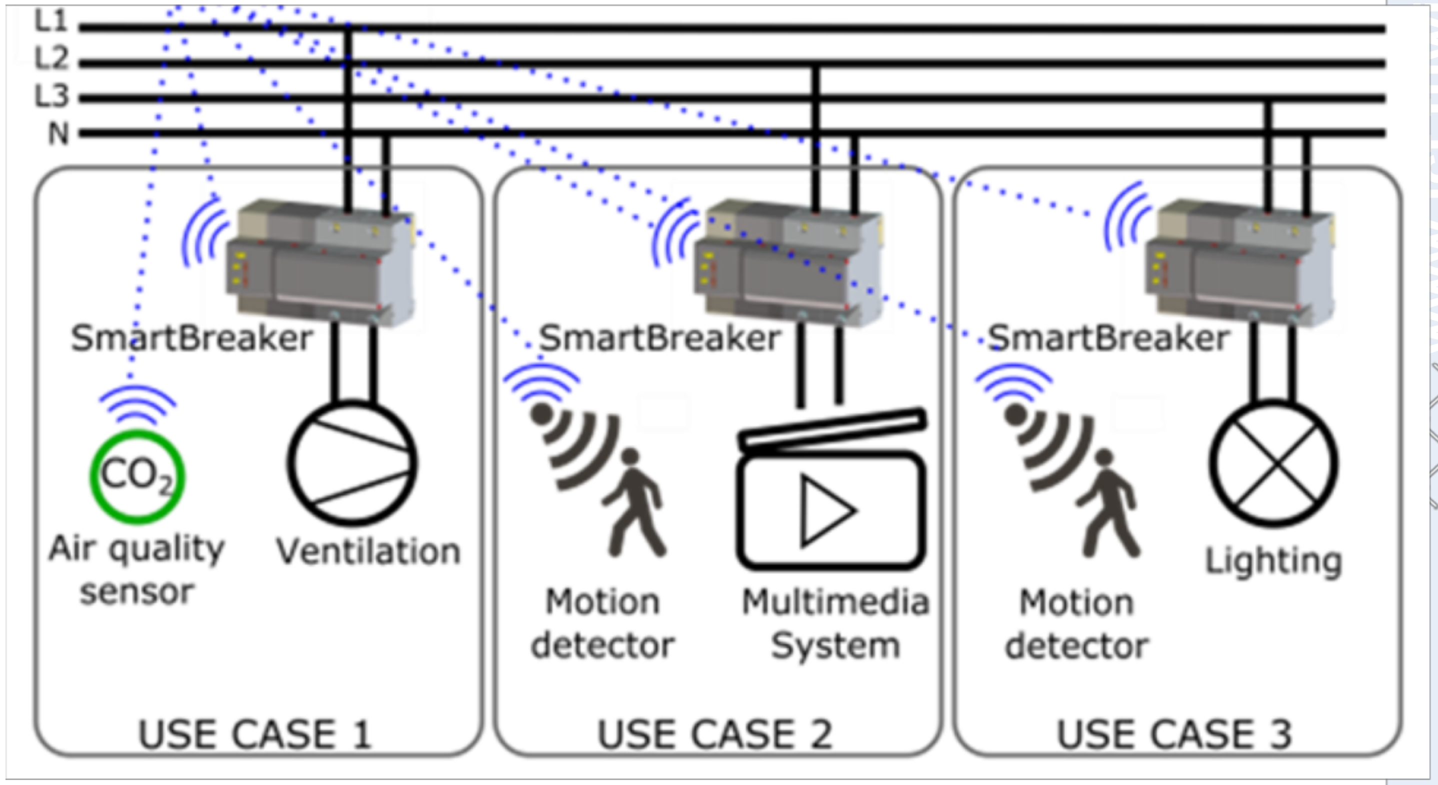
# Field Test Setup

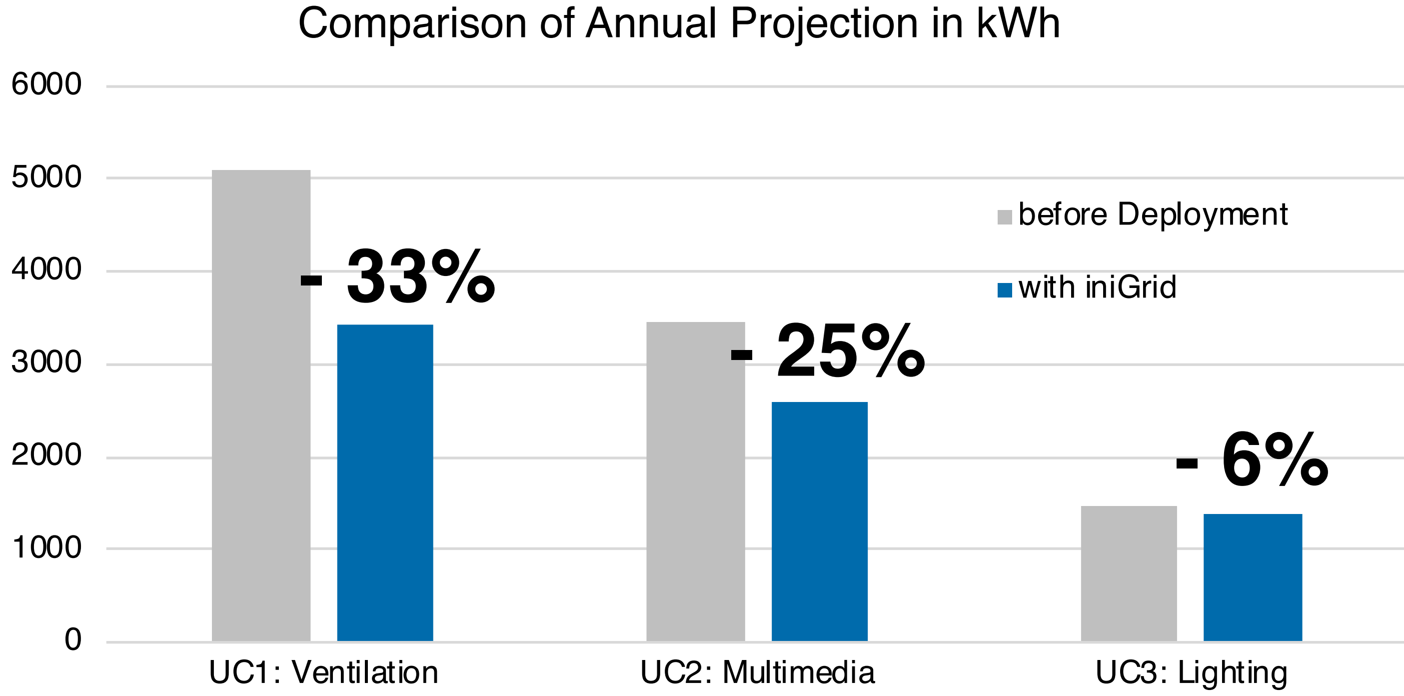
- local deployment
  - two stage deployment using laptop and Pi
  - CEMS measurements
- local optimization
- remote interaction via secure tunnel
- total deployed hardware
  - 1x Rasperry Pi 3 incl. touch LCD
  - 1x ethernet switch
  - 1x ethernet communication interface
  - 4x smart breakers
  - 2x switch cabinets
  - 4x binary input, xComfort
  - 1x analog input, xComfort
  - 1x air quality sensor, xComfort
  - 4x movement sensors, xComfort



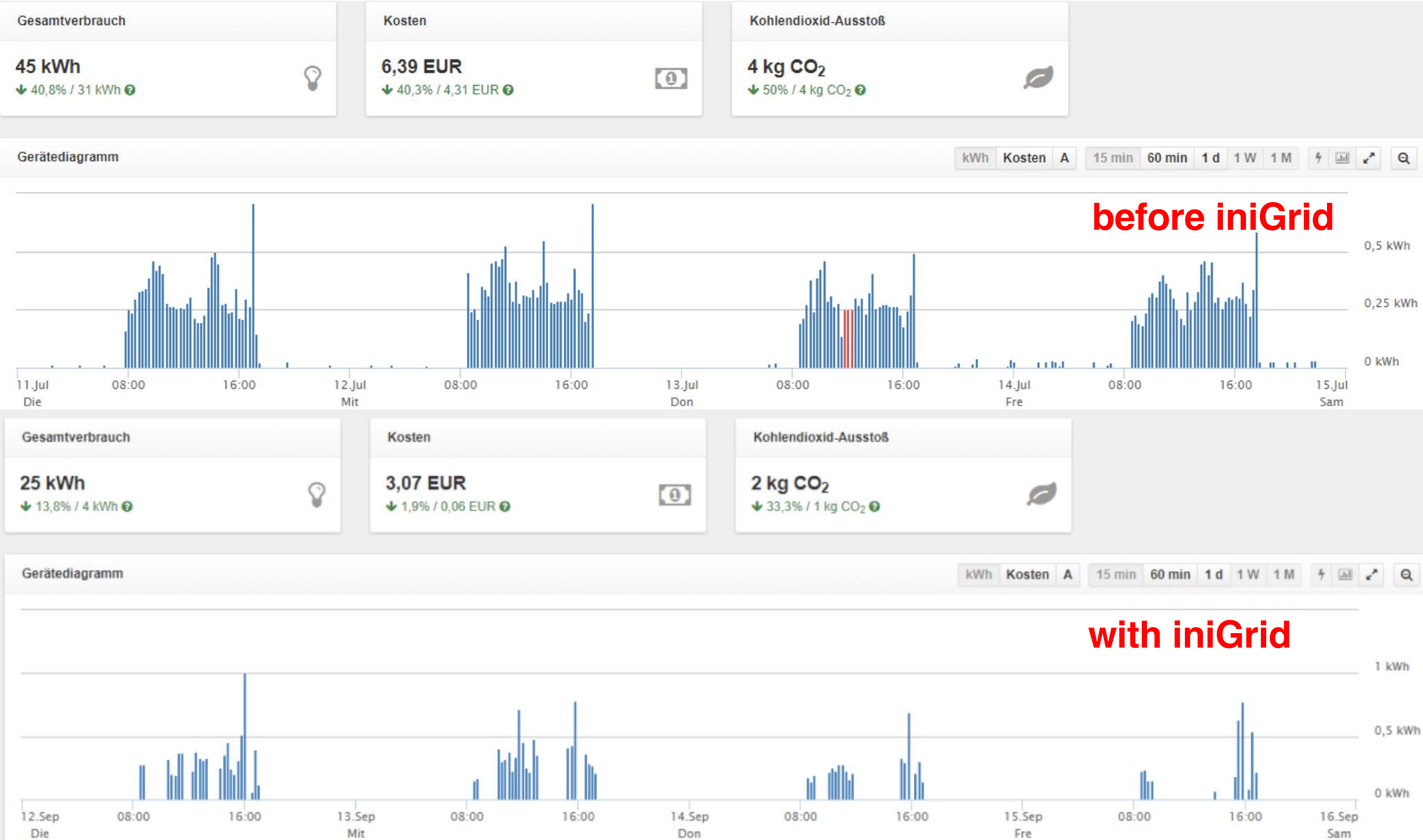
# Field Test Data Results

- validated concepts
  - commanding limits of power/voltage successfully
  - emergency shedding possible
  - according to security standard VHPready
  - centralized installation and by-power-line control feasable
- consumption impact
  - 1 month baseline, 8 operational
  - significant improvements for ventilation and multimedia equipment
  - meeting commercial baseline for lighting



# Results – Multimedia Details (UC2 example)

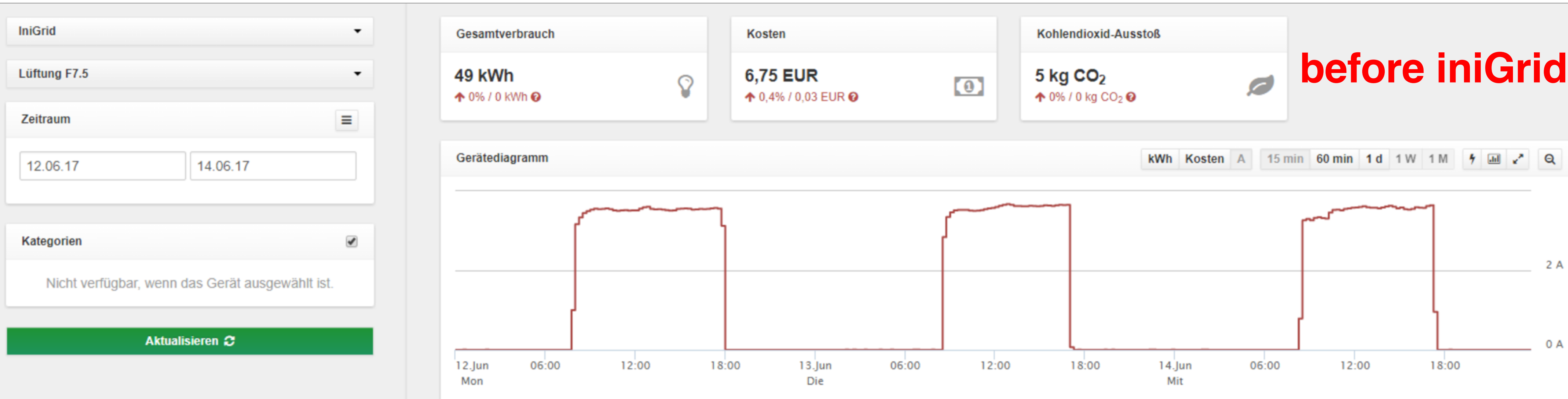


# Results Ventilation Details (UC1 example)

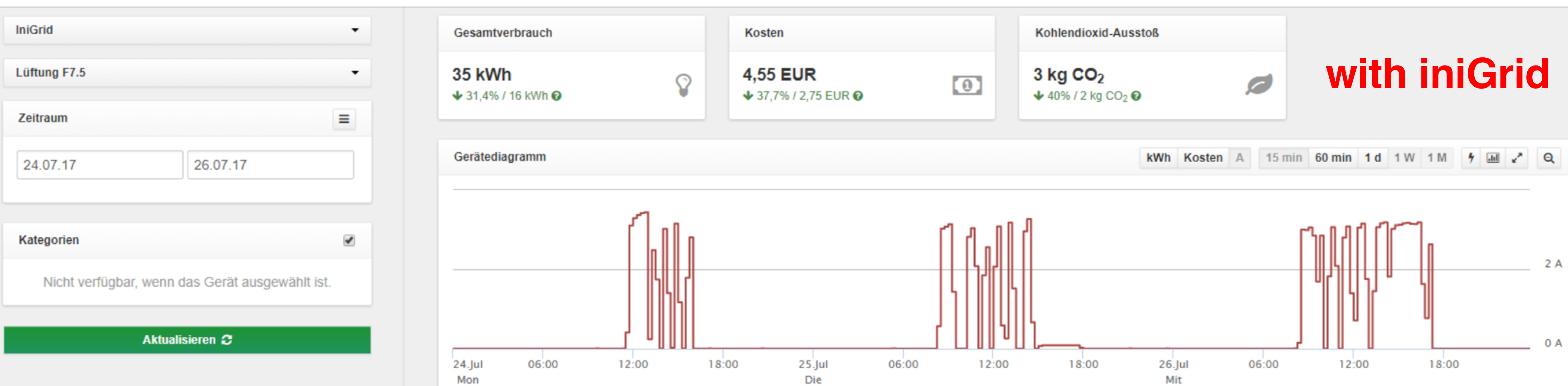
massive changes (challenges):

- increased volatility on device level
- frequent switching events
- changing operation levles
- not deterministic

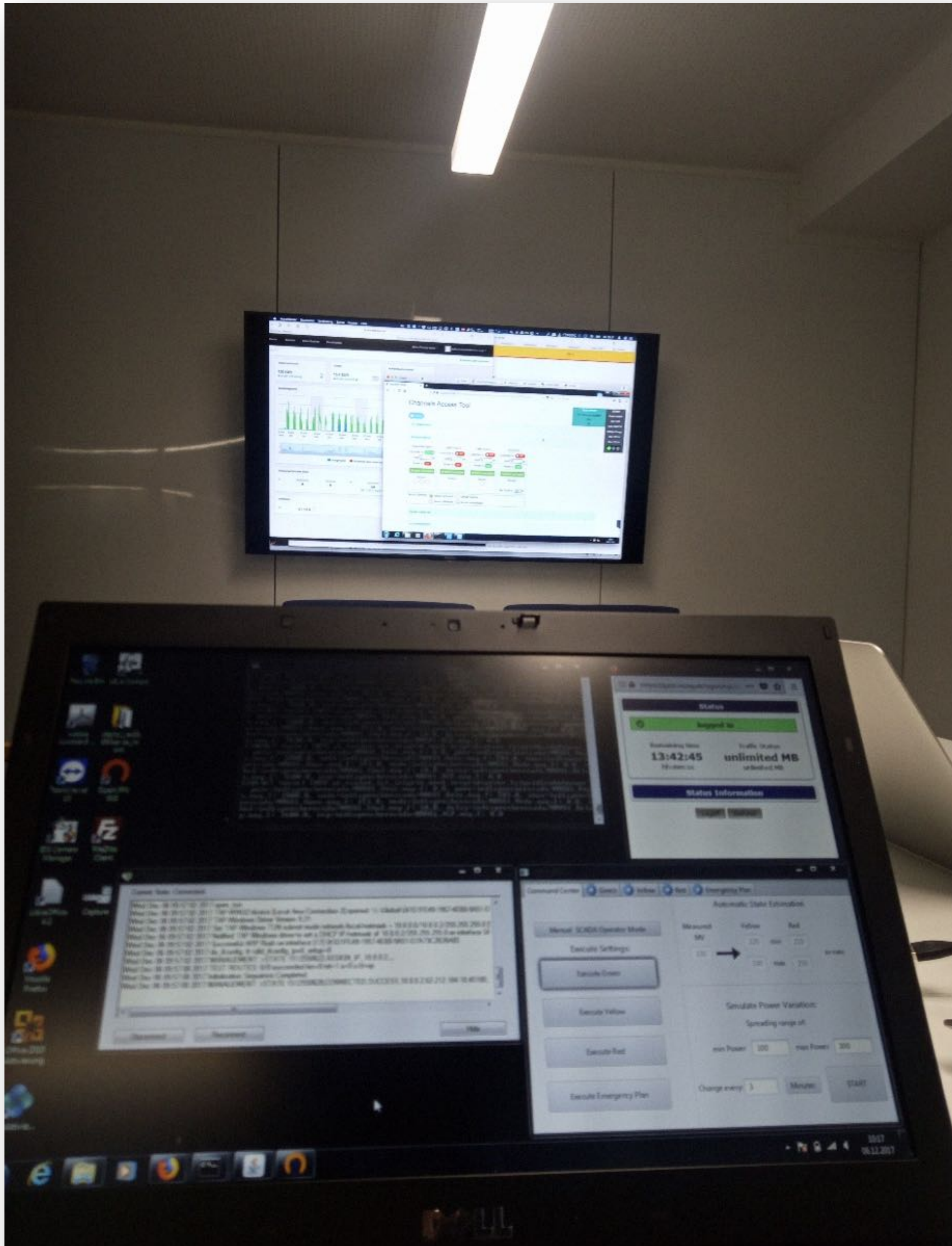
**before iniGrid**



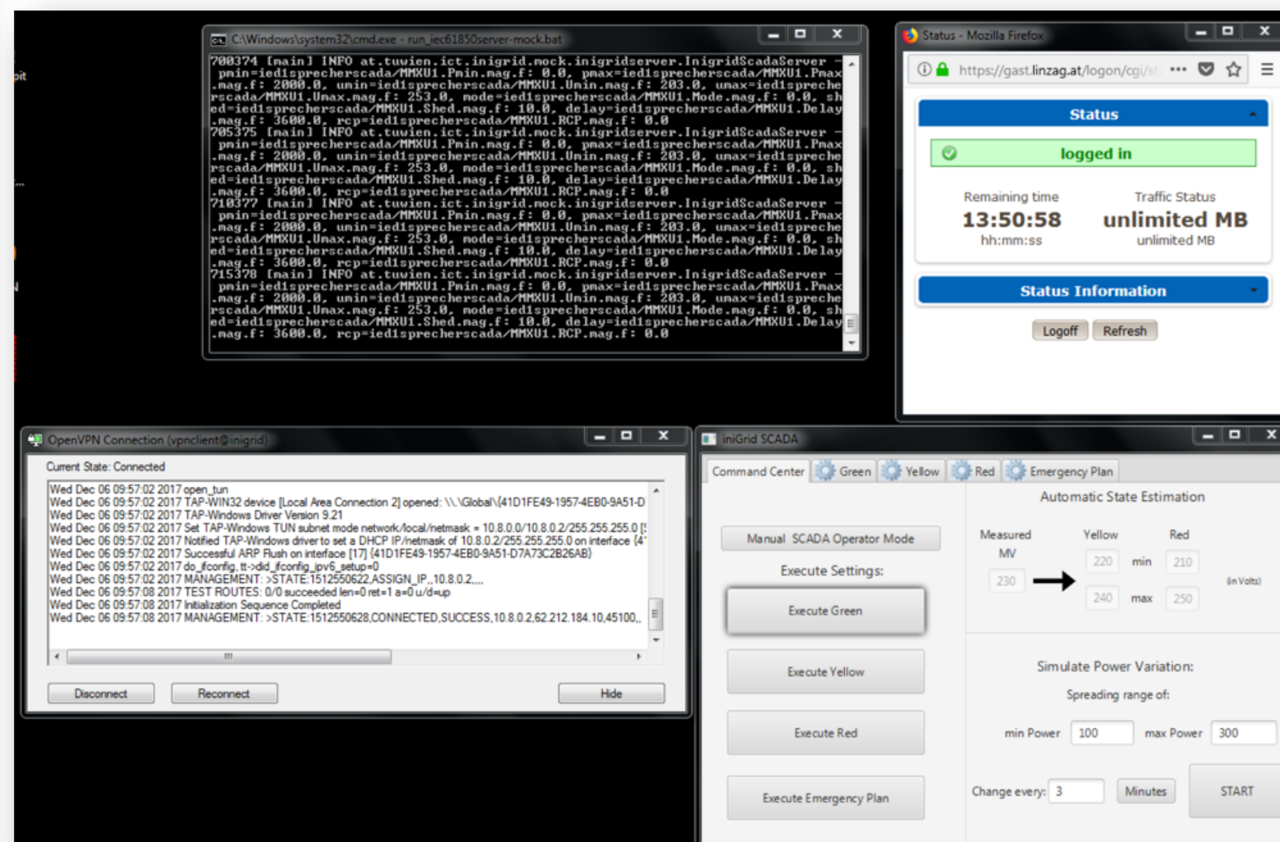

**with iniGrid**



# Distributed Control Test Results (UC 4 example)



- on-Site at Linz Strom Netz
- secure communication in accordance to VHPready IEC 62351, IEC 61850
- succesfull state communication
- succesfull load shedding



# Field Test Summary

- **using smart breaers for DSM validated -> new challenges**
- **traditional building automation & hybrid breakers (goal A)**
  - local centralized setup w/ less switches & central access
  - modular framework for control algorithms
    - closed loop eg.: for movement and air-quality
    - open loop eg.: for regular venting and exhibition hours
    - allows integration of sophisticated 3rd party algorithms

- **validating dynamic reaction to grid (goal E)**
  - disabling non-essential components on demand (ventilation)
  - encrypted communication in secure tunnel (security)
  - uni-directional communication (privacy … and security)

www.inigrid.at

DSM: Demand Side Management

# Thank you!

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