Karlsruhe Institute of Technology

Investigating energy futures: The KITTEN test facility for sustainable research infrastructures

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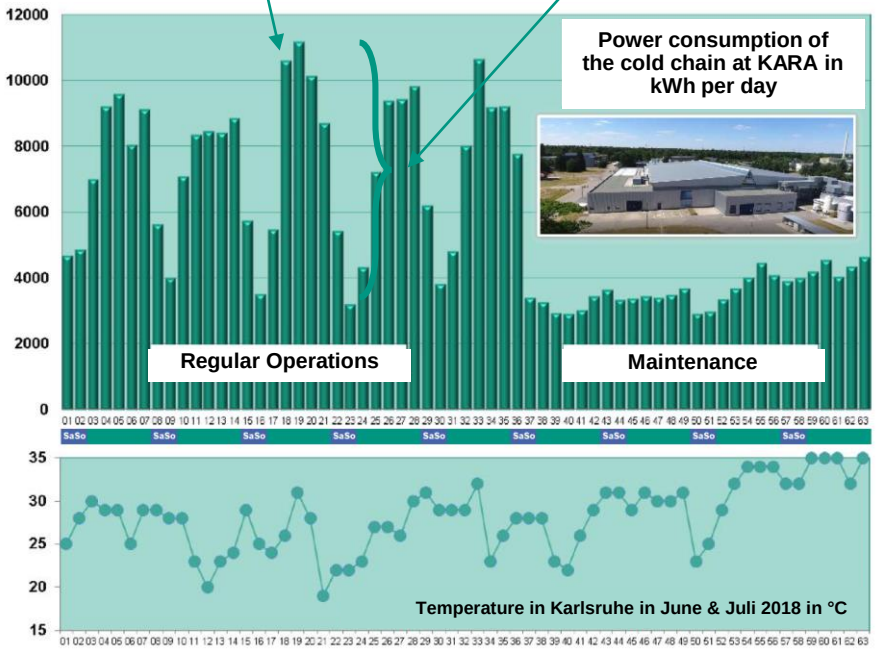
Karlsruhe Institute of Technology - 21/11/2022

The starting point

11GWh ≈ 10.000 citizens city

Variable consumption ≈ 8 MWh



X High power demand

X High carbon footprint

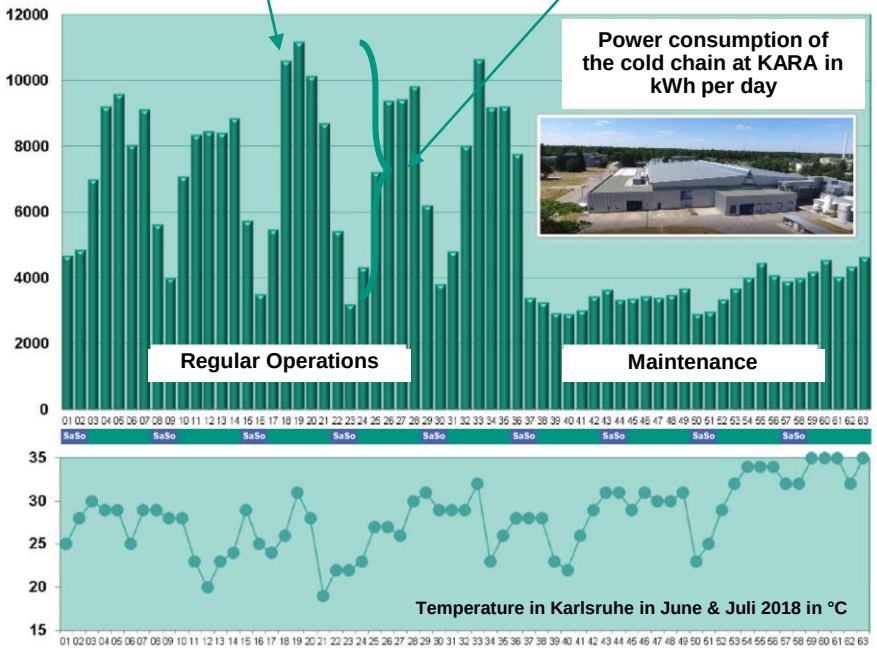
X Need for a stable grid

X High energy costs

The starting point

11GWh ≈ 10.000 citizens city

Variable consumption ≈ 8 MWh



✓ **Highly efficient**

✓ **Rely on green energy**

✓ **Flexible, offer services to the grid**

We need to propose new solutions for sustainable research infrastructures in a comprehensive and systematic way

KITTEN

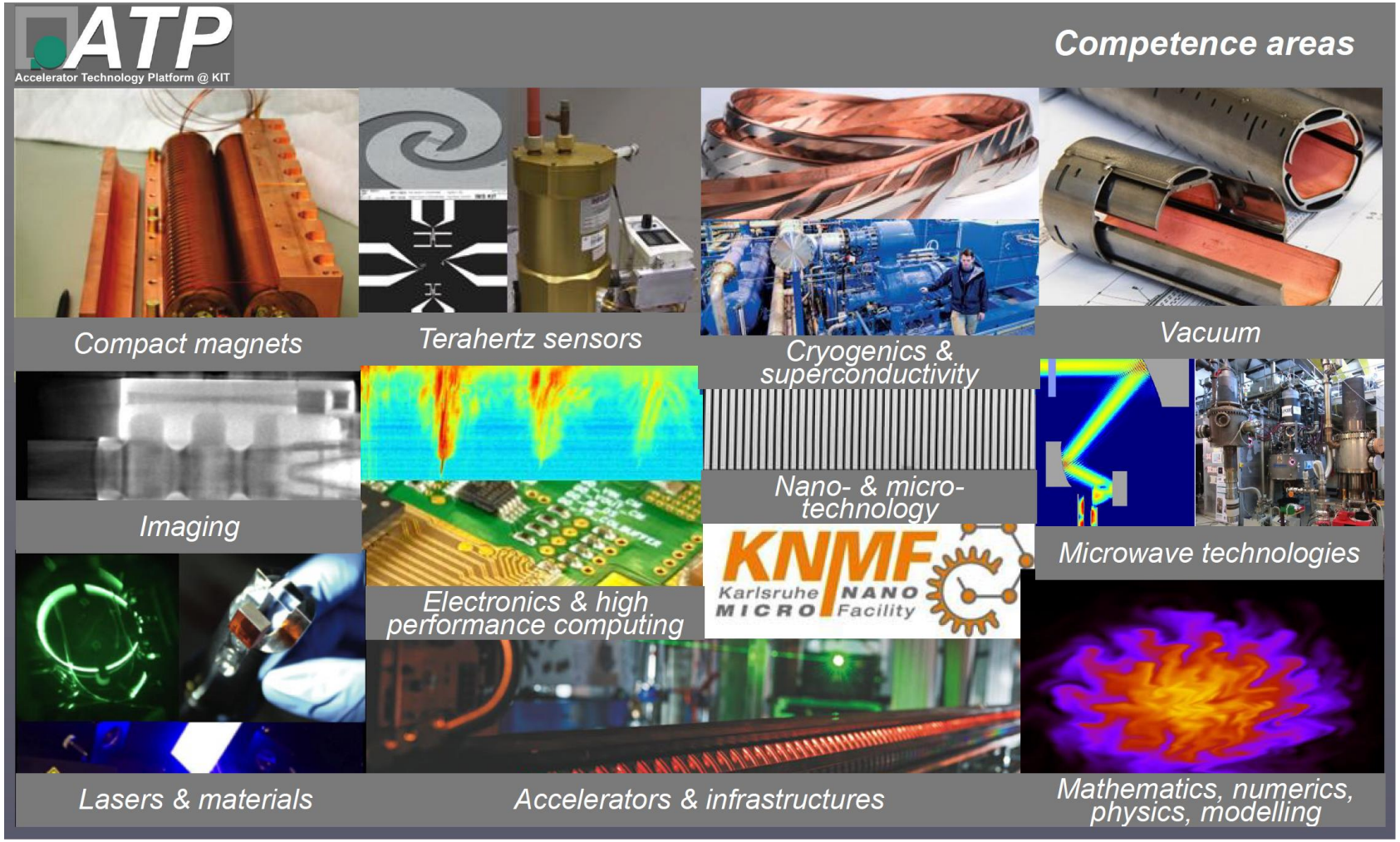
KIT Testfeld für Energieeffizienz und Netzstabilität in großen Forschungsinfrastrukturen

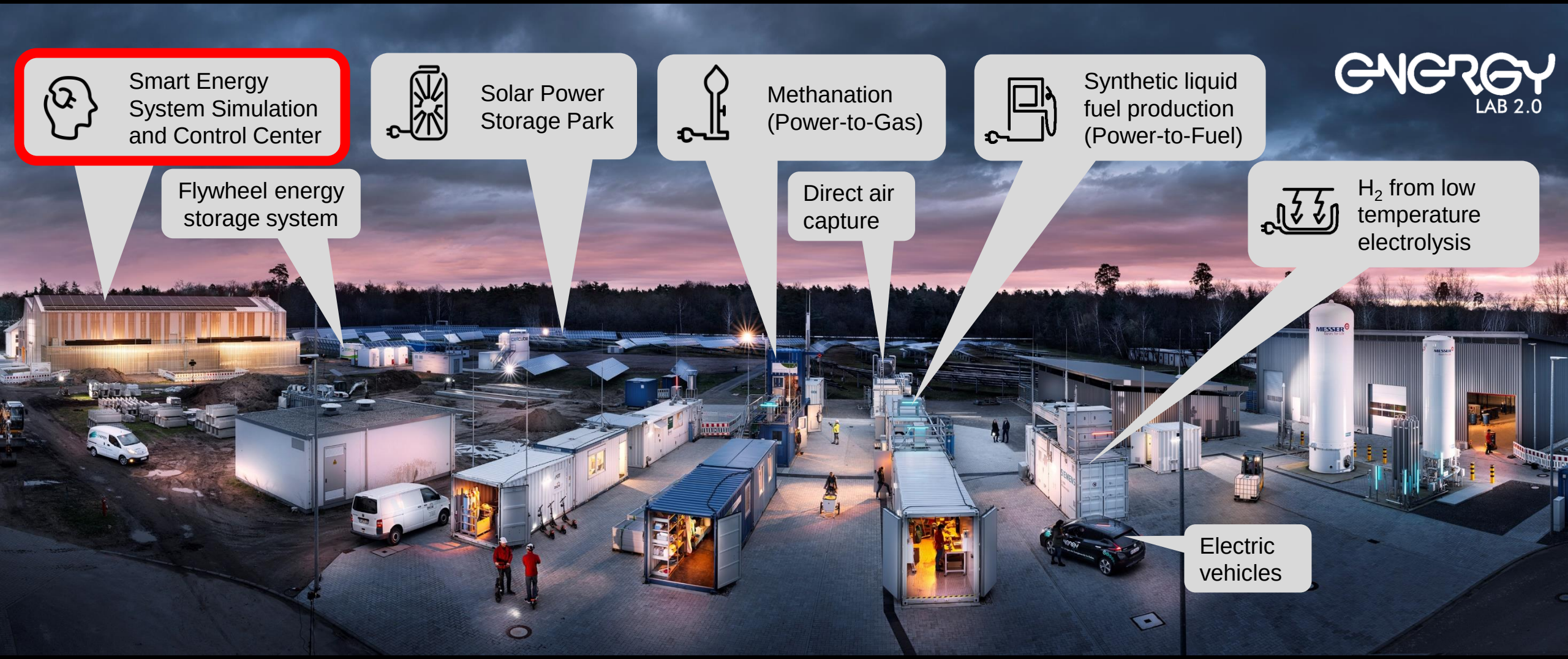
A joint venture between the accelerator **KARA** and the test-field **Energy Lab 2.0** to improve the energy use and power quality in large research infrastructures.

Accelerator Technology Platform

- 230 Researchers @ KIT
- R&D
- Consulting/QA
- Pilot projects
- Large test facilities
- Technology-transfer
- Bridge between

  R&D-Companies-Labs



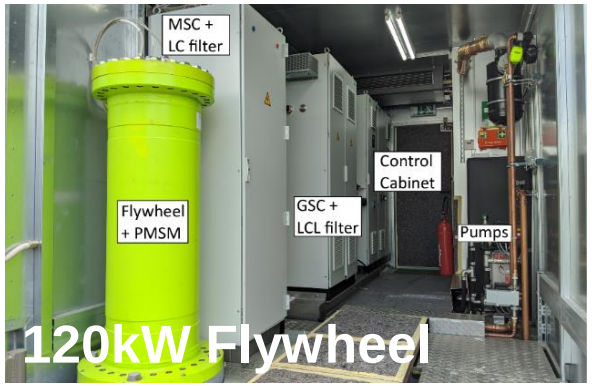

Smart Energy System Simulation and Control Center
Solar Power Storage Park
Methanation (Power-to-Gas)
Synthetic liquid fuel production (Power-to-Fuel)
ENERGY LAB 2.0
Flywheel energy storage system
Direct air capture
H_2 from low temperature electrolysis
Electric vehicles
Geothermal energy plant
Living Lab experimental buildings
HT thermal storage
Solid oxid fuel cell
Gas turbines

Power Hardware In the Loop lab – Energy Lab 2.0

- **Large testing facility:**
  - 1MVA PHIL Testing Hall
  - 45kW & 2x15kW PHIL Setup
- **Large set of energy resources**
  - 120kW high-speed flywheel
  - 500kW Supercaps system
  - 50kW Liquid Hydrogen energy plant

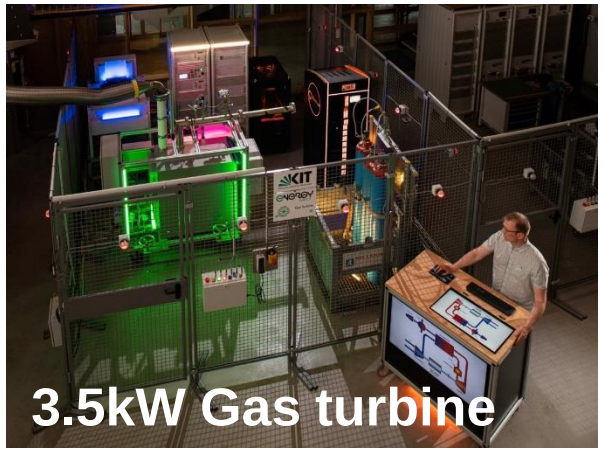
1 MVA PHIL Testing Hall

45kW PHIL Testing setup



120kW Flywheel

500kW Supercaps



3.5kW Gas turbine

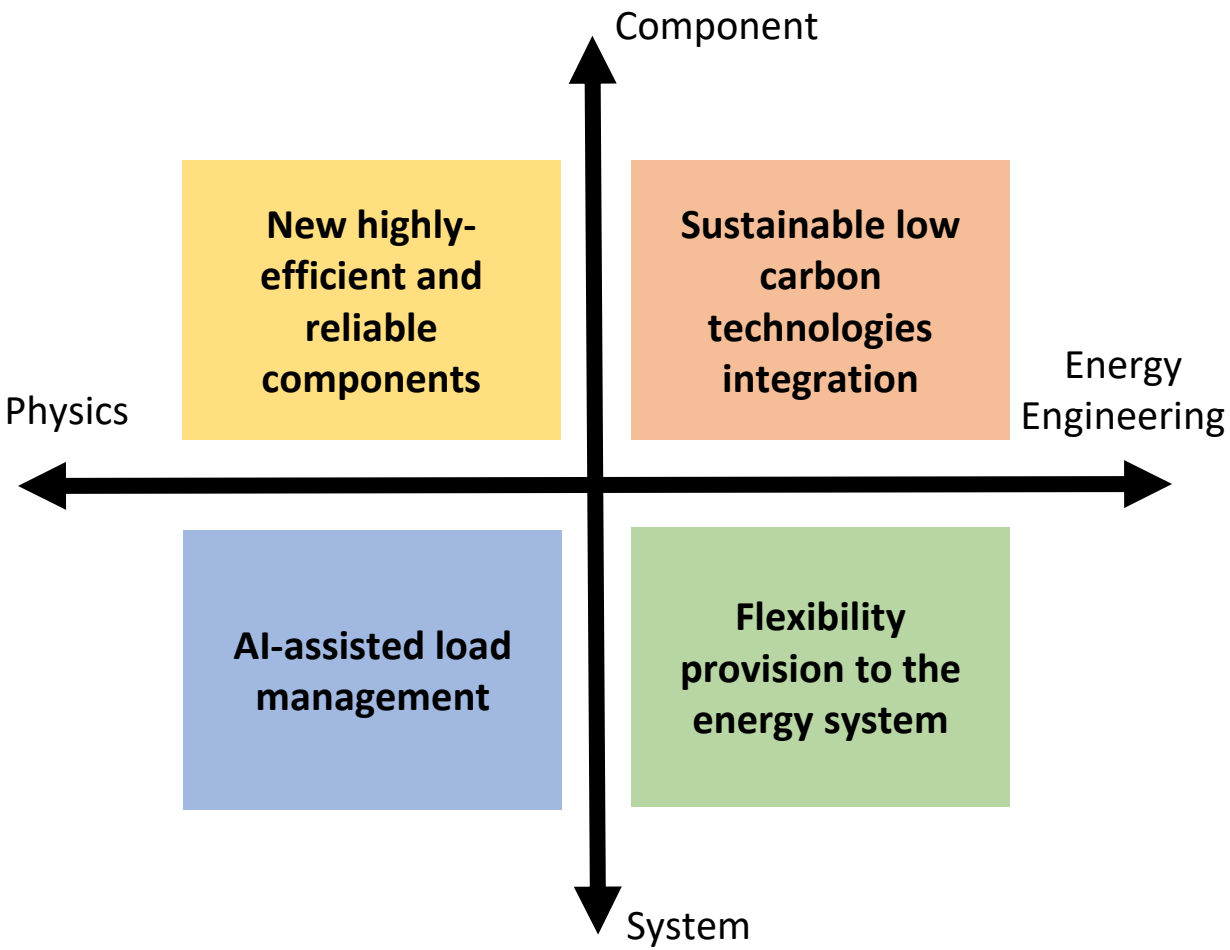

50kW LH2 Energy Plant

https://www.itep.kit.edu/rtset/english/index.php

The KITTEN Approach

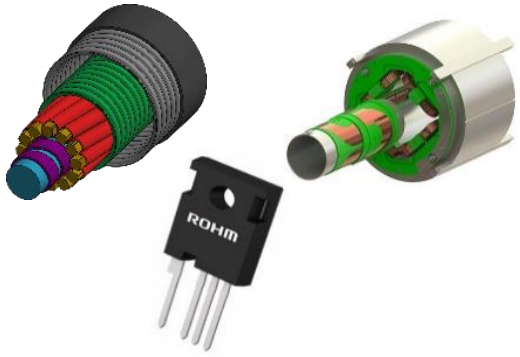
Need to work on 4 different levels

- **Physics / Component** level: new materials and components targeting an efficiency increase
- **Energy / Component** level: integration and optimal operations of sustainable low carbon technologies (e.g., energy storage, renewables)
- **Physics / System** level: improve the efficiency operations in large research facilities using AI
- **Energy / System** level: increase the sustainability of large research facilities in the electrical system



Potential improvements in the energy solutions*

New highly-efficient and reliable components



- HTS-Superconductors
- Variable permanent hybrid magnets
- New cooling concepts
- SiC / GaN-based power electronics

AI-assisted research infrastructure load management

- Real time digital twin of accelerators
- Optimized energy consumption by AI
- Adjustable power demand

Low carbon technologies integration

- Optimal integration of ESS with RES
- Sector-coupled Energy management
- Green high power computing
- Geothermal as cooling source

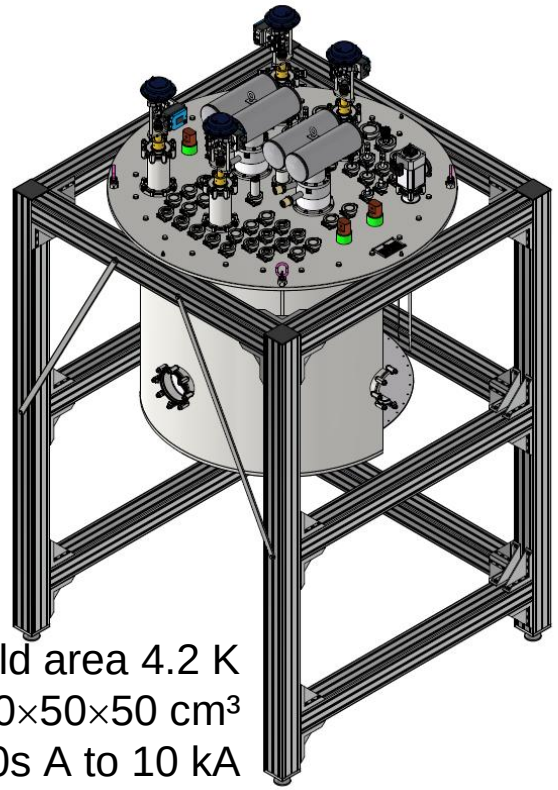
Flexibility provision to energy system

- 100% Renewable energy sources target
- Power demand flexibility
- New business models for flexibility provision

*Helmholtz Sustainability Challenge „Research Facility 2.0: towards a more energy-efficient and sustainable path”, KIT-DESY-HZB

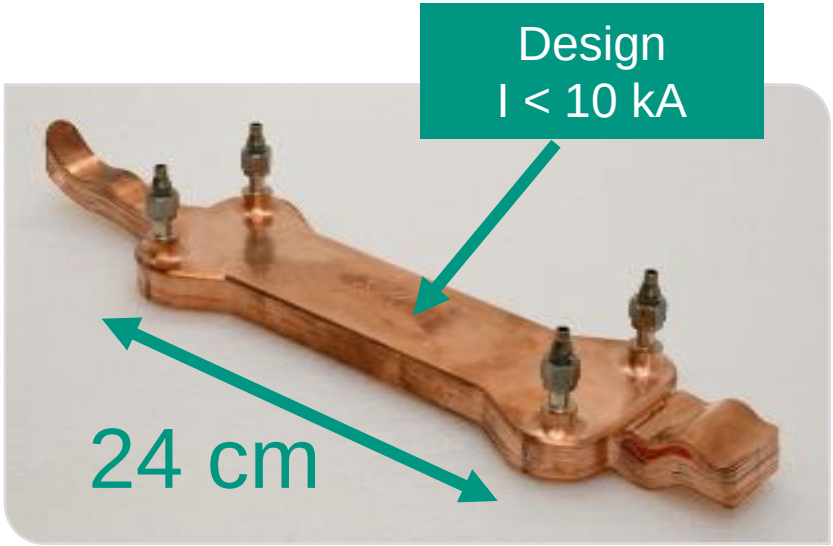
Ultra-efficient, ultra-compact, scalable components

Compact accelerator systems test stand (COMPASS)



Cold area 4.2 K
50×50×50 cm³
100s A to 10 kA

- Superconducting magnets and undulators
- Micro-structured mixed-refrigerant cooled current leads
- Superconducting cavities
- **Develop energy-efficient components**



Patented current leads
Power demand reduction by ⅔

InnovEEA
Innovation pool project for Energy Efficient Accelerators

J. Arnsberg, S. Grohmann, Innovationspool III. InnovEEA Meeting, Mar 2022 - https://indico.scc.kit.edu/event/2646/
E. Shabagin, Development of a CMRC cooled 10 kA current lead for HTS applications. PhD dissertation, KIT, Apr 2022 - https://doi.org/10.5445/IR/1000144514

KITTEN experimental setup

KITTEN
KIT Testfeld für Energieeffizienz und Netzstabilität in großen Forschungsinfrastrukturen

KIT
Karlsruhe Institute of Technology

Real Time Simulator

Energy Lab 2.0

1 – 1.5km

Communication Infrastructure

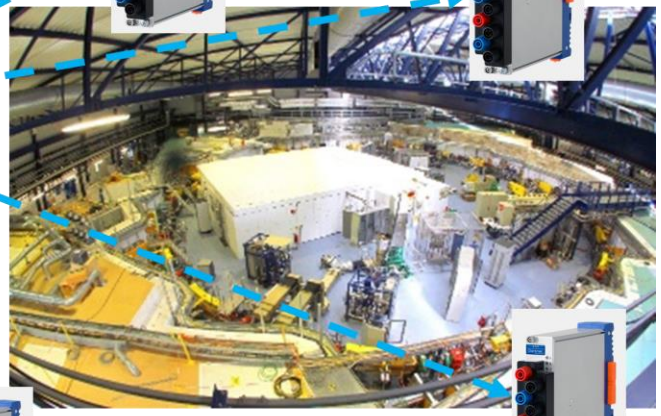
Master

5-10 m

Slave

Slave

KARA



Slave

PHIL Hall

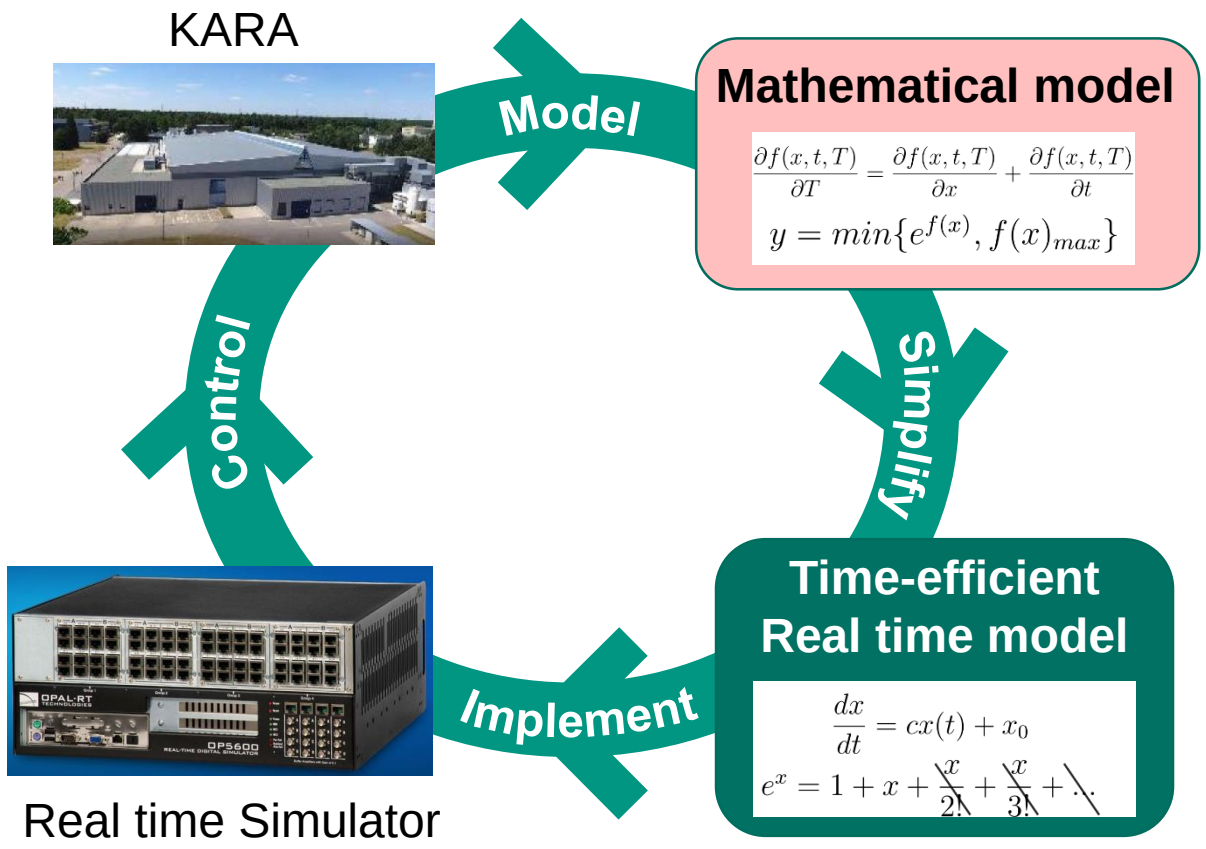
Flywheel

Solar PV Park 225kW

Groundwater Cooling System 1MW - Thermal

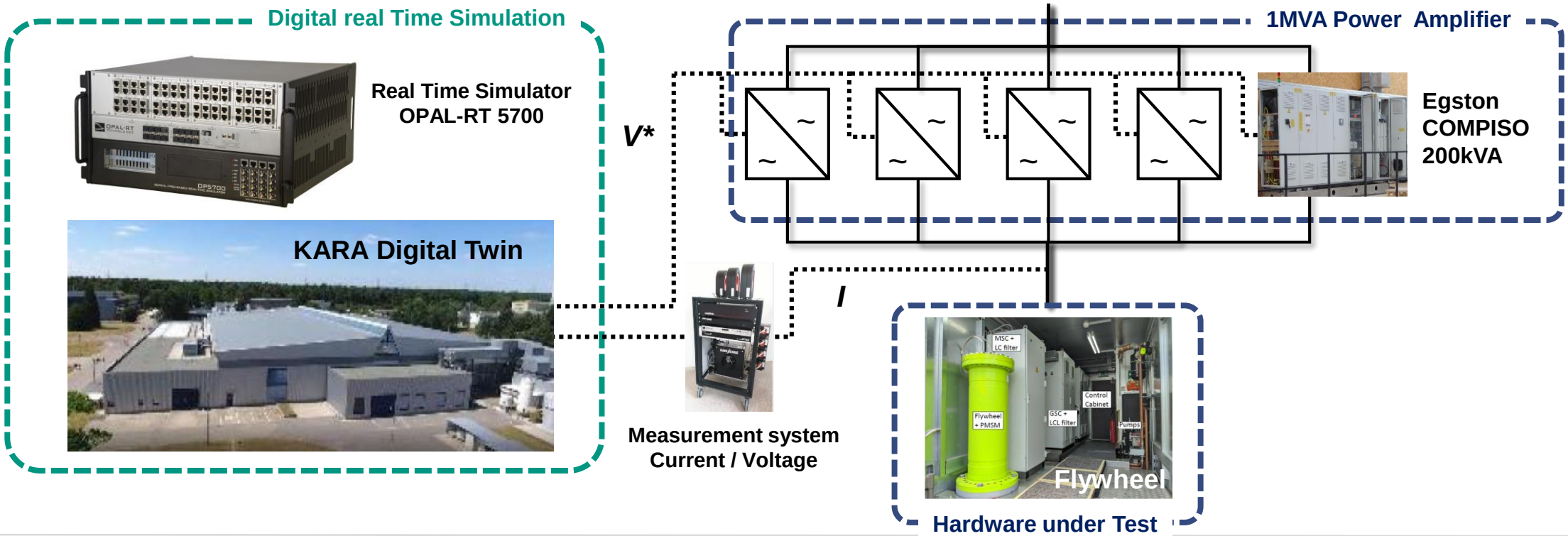
KITTEN next accelerators concept

- **Goal**
  - Develop solutions for stable, efficient and safe operations of accelerators (and not only!)
- **How to achieve it?**
  - KARA→ large field measurement availability
  - Data-drive models of KARA → IBPT experience is important!
  - Time-efficient real time modelling → EL2.0 experience is important!
  - Control feedback to KARA
- **Expected outcome**
  - Digital Twin of KARA to be employed for analyzing, developing and testing future energy solutions for accelerators



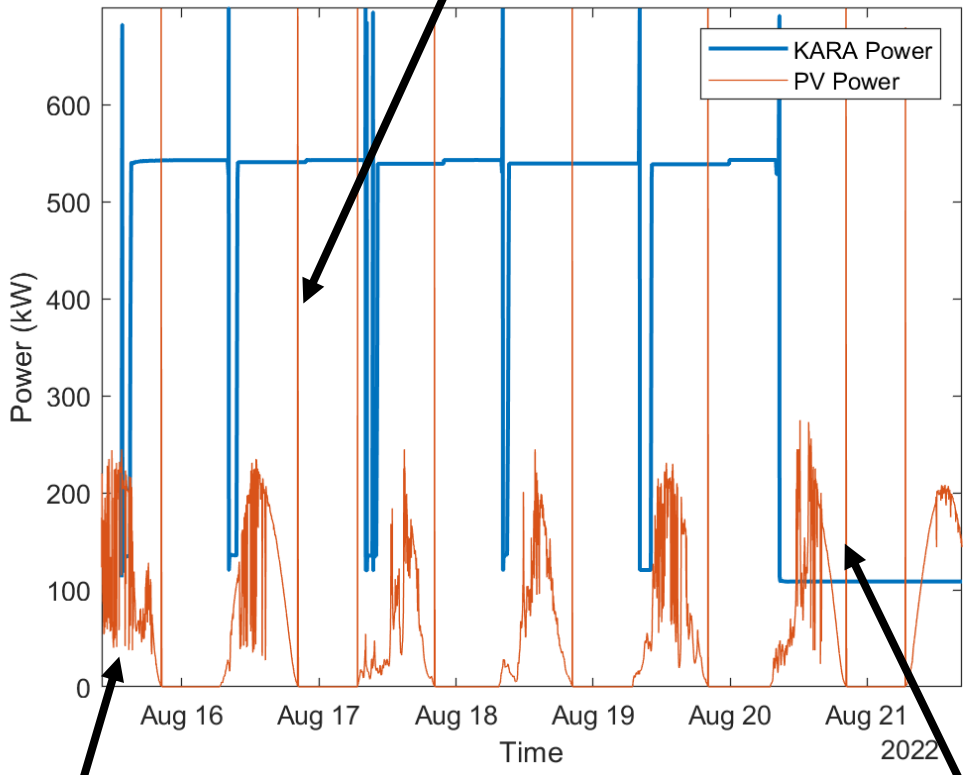
Unique selling point: Validation by means of Power Hardware In the Loop

- **Digital real time simulator**: simulate the KARA electrical grid
- **Power amplifier**: reproduce a point of the simulated grid in lab (e.g., measured voltage)
- **Hardware under Test**: this is the technology, which performances we want to test



First power analysis for KARA – Solutions and challenges

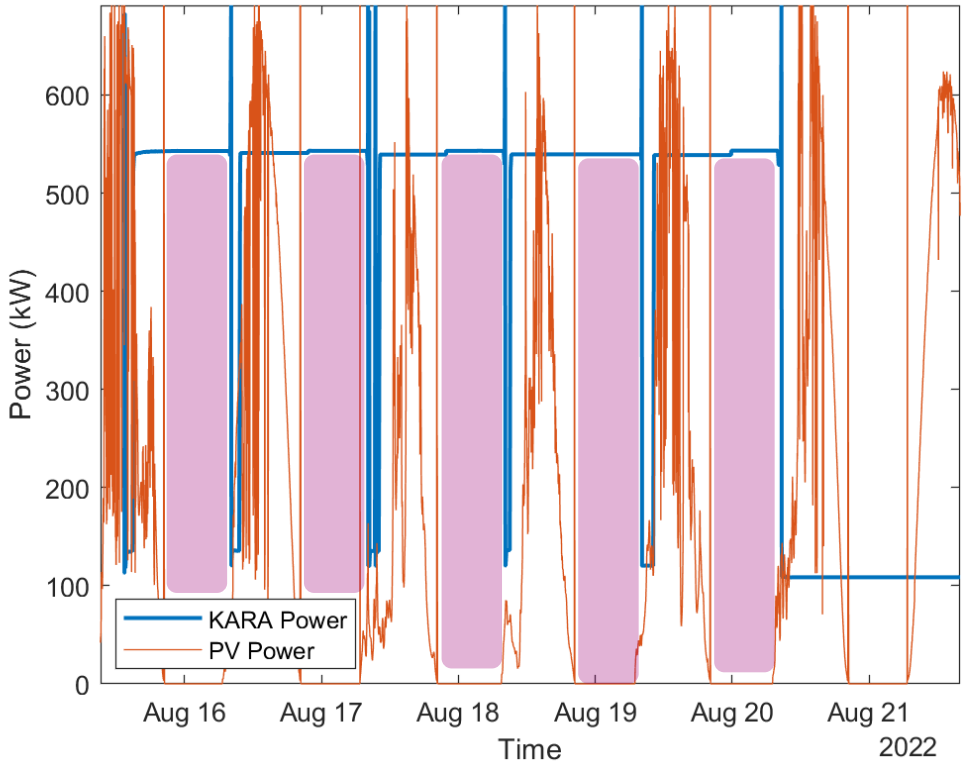
Not sufficient power



Not synchronized PV production and consumption

PV power exceeding the consumption during weekend

PV Plant 3 times bigger



Missing everyday 550kW for ca. 10 hours = 5550kWh

First power analysis for KARA – Solutions and challenges

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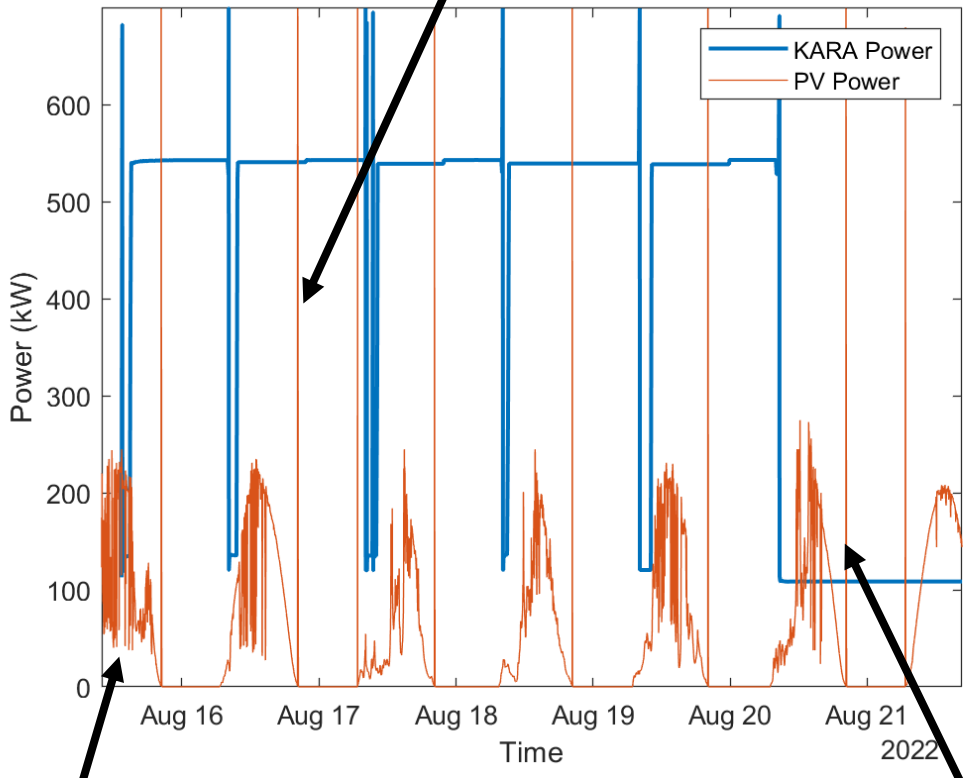

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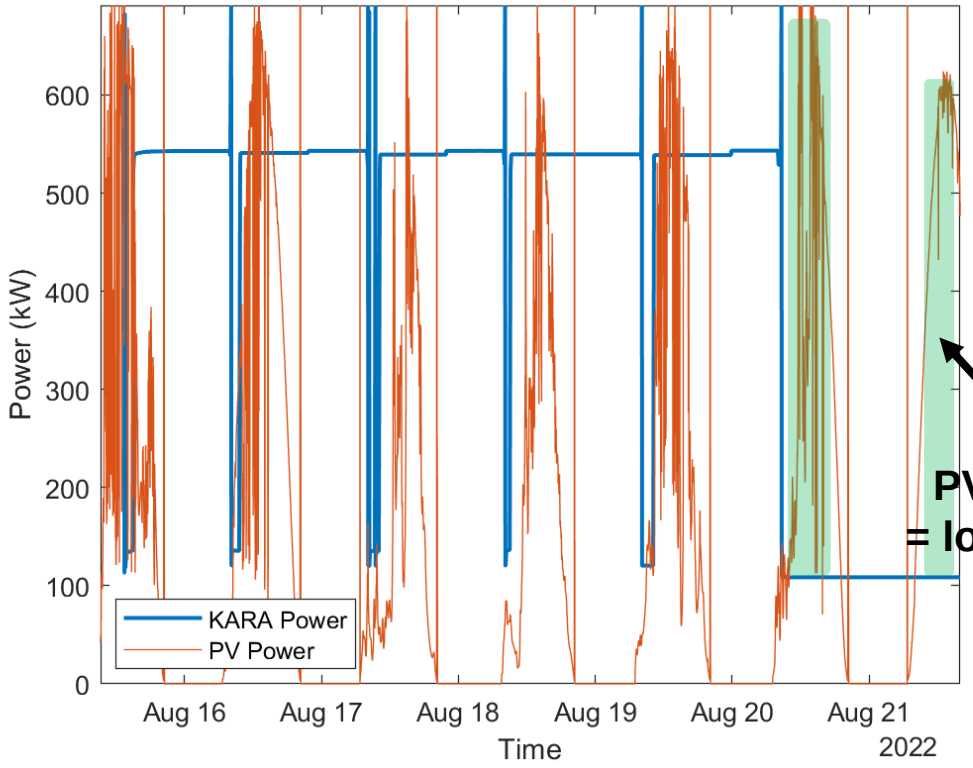

PV capping = lost revenue

450kW for ca. 16 hours missed revenue

Energy storage solutions for accelerators

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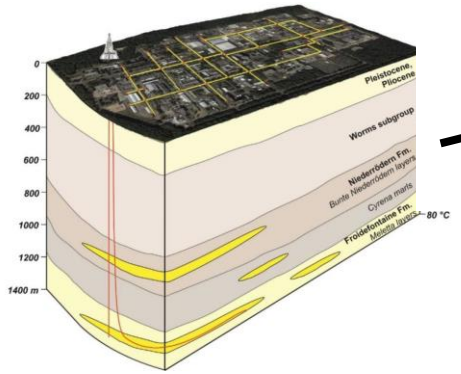
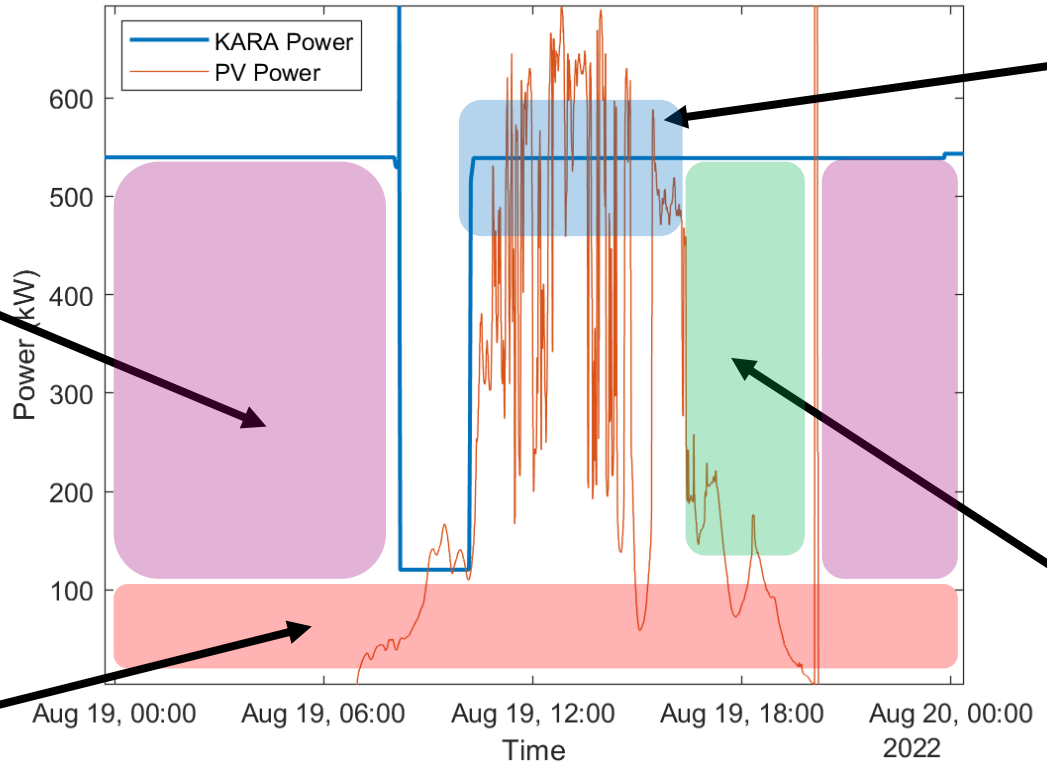
Long-term (>12 hours) storage solutions

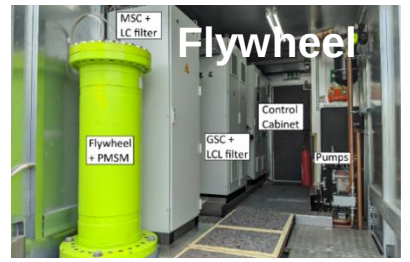
Seasonal energy storage solutions

Geothermal





Fast dynamics solutions



Medium-term solutions

Next steps

- Implement the full electrical model of the KARA accelerator in the digital real time simulator
- Real time transfer of the electrical variables measurement in the simulated model: real time digital twin
- Power Hardware In the Loop testing of new hardware and control energy solutions for accelerators
- Real time monitoring of KARA anad provision of corrective feedback to improve on-line the energy usage

HIRING!!!
Looking for talented
PhDs and Post-docs
to work on the topic!

THANK YOU
Questions?

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