Karlsruhe Institute of Technology

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

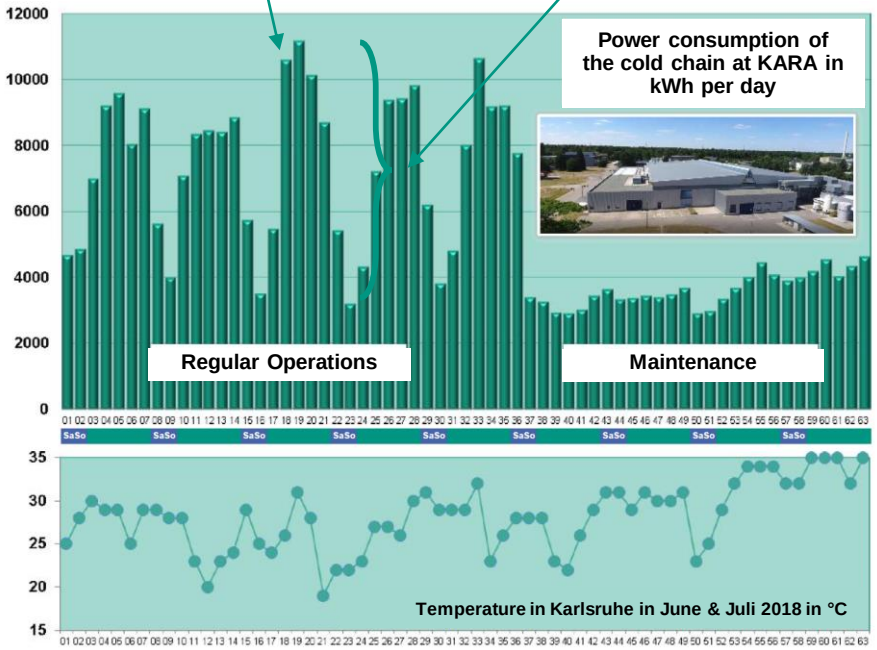
Dr.-Ing. Giovanni De Carne, Prof. Dr. Anke-Susanne Müller, Dr. Erik Bründermann

Karlsruhe Institute for Technology - 26/09/2022

The Challenge

11GWh ≈ 10.000 citizens city

Variable consumption ≈ 8 MWh



X High power demand

X High carbon footprint

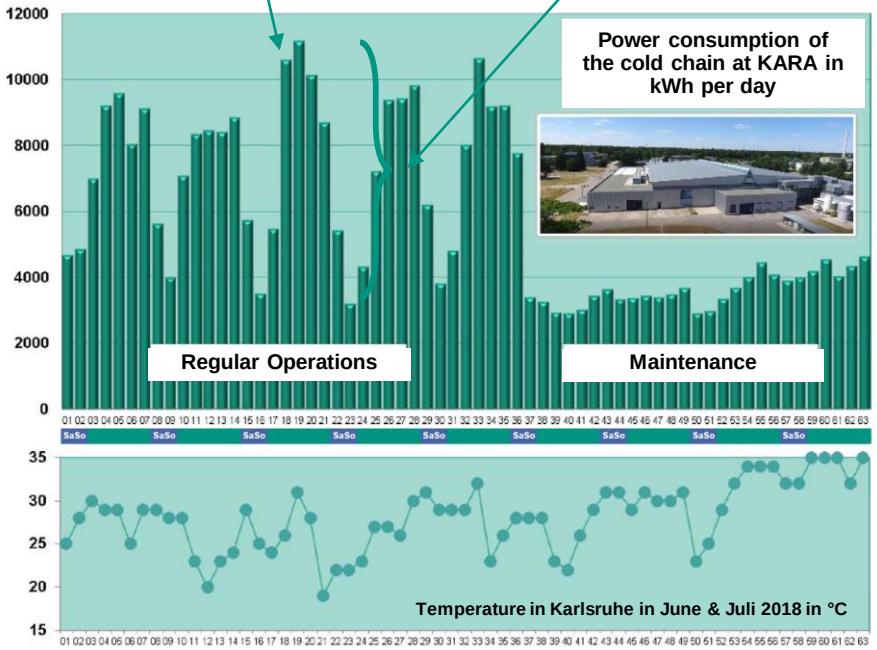
X Need for a stable grid

X High energy costs

The Challenge

11GWh ≈ 10.000 citizens city

Variable consumption ≈ 8 MWh



✓ Highly efficient

✓ Flexible, offer services to the grid

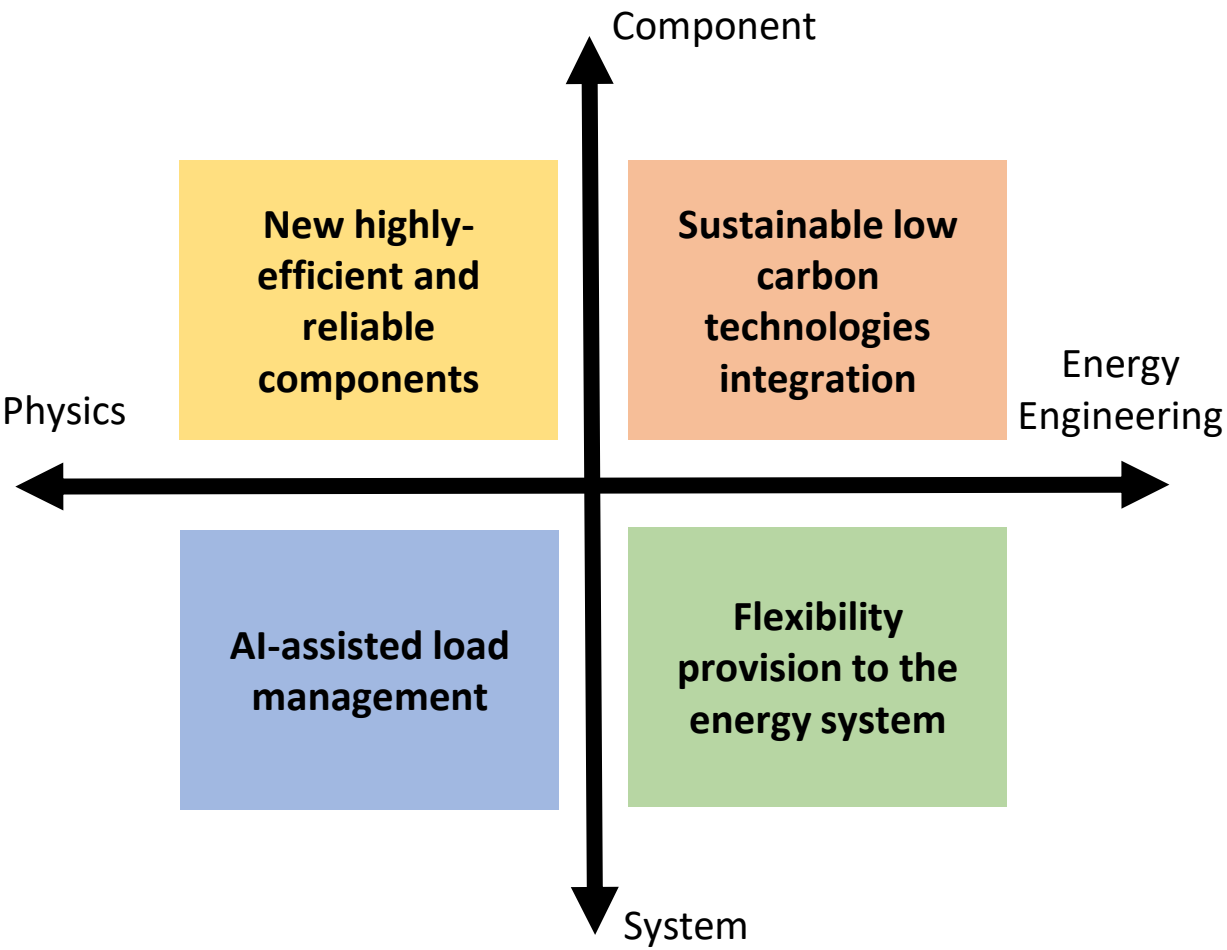
✓ Rely on green energy

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

The Challenge

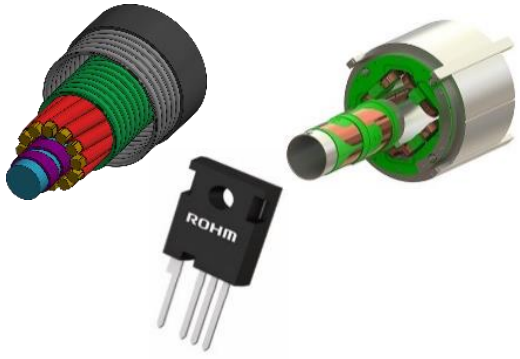
Need to work on 4 different levels

- **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

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.

KITTEN experimental setup

Real Time Simulator

Energy Lab 2.0

1 – 1.5km

Communication Infrastructure

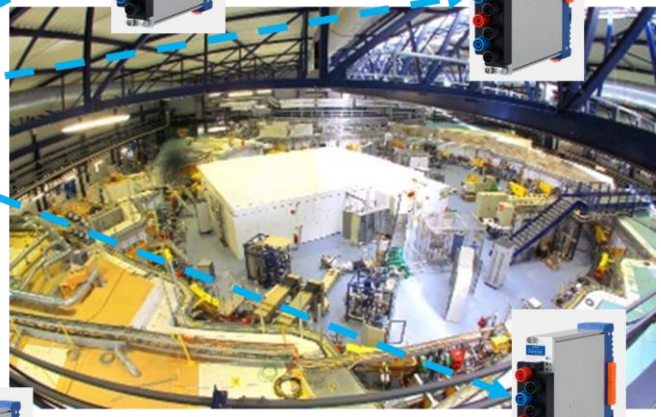
Master

5-10 m

Slave

Slave

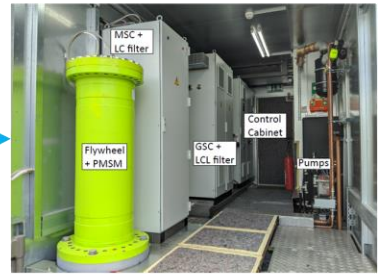
KARA



Slave

PHIL Hall

Flywheel

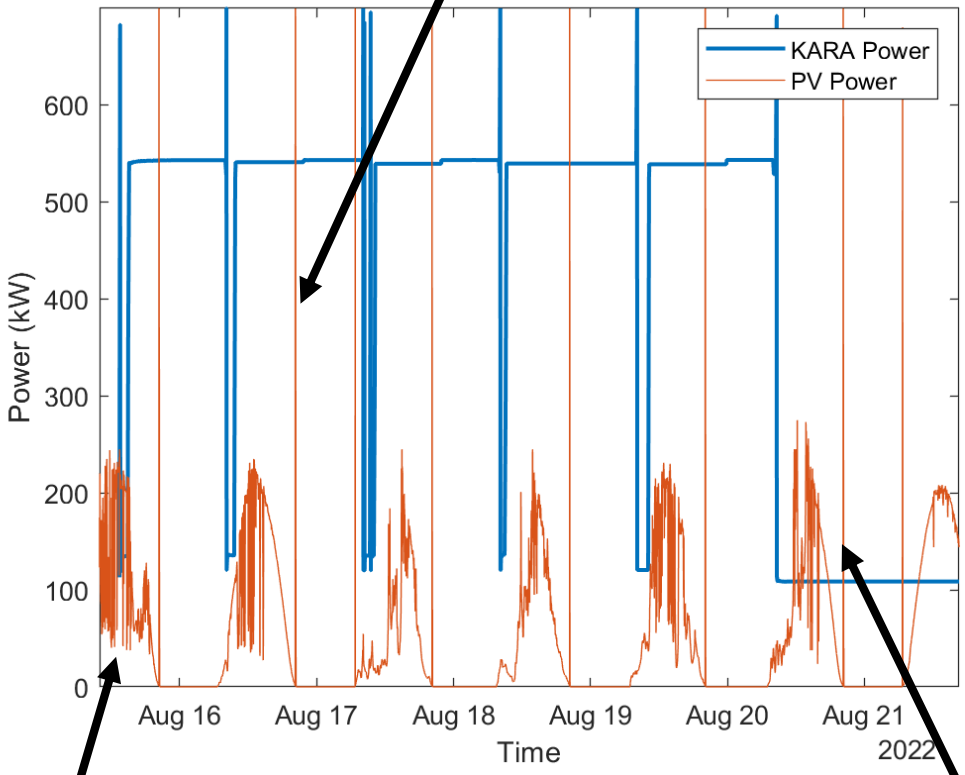


Solar PV Park 225kW

Groundwater Cooling System 1MW - Thermal

First power analysis for KARA – Solutions and challenges

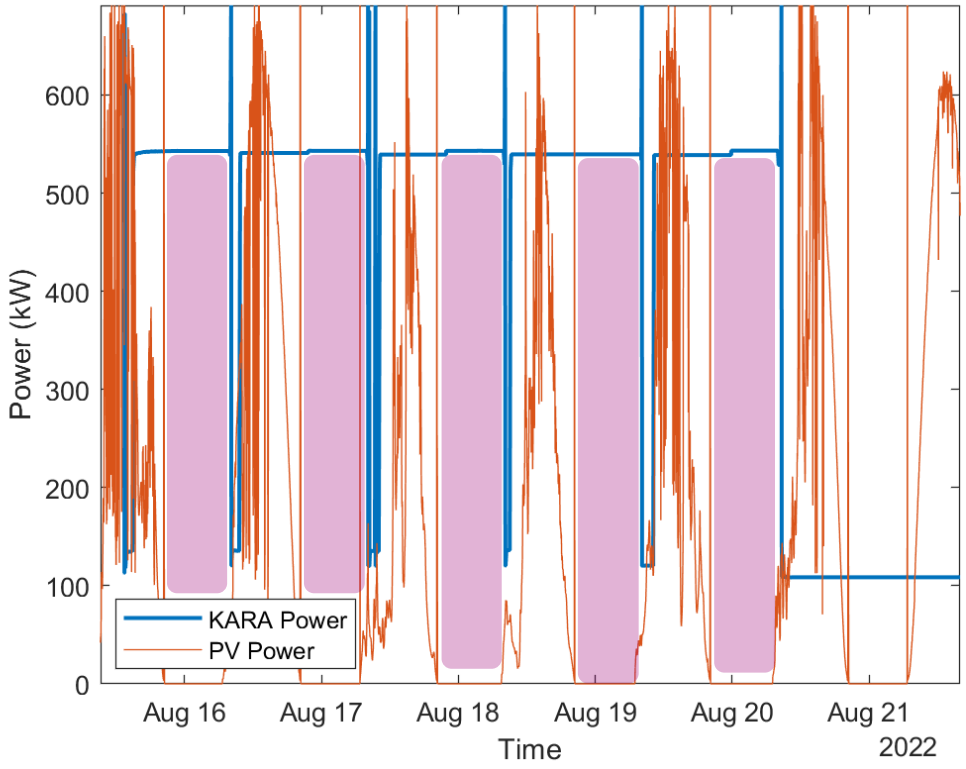
Not sufficient power



Not synchronized PV production and consumption

PV power exceeding the consumption during weekend

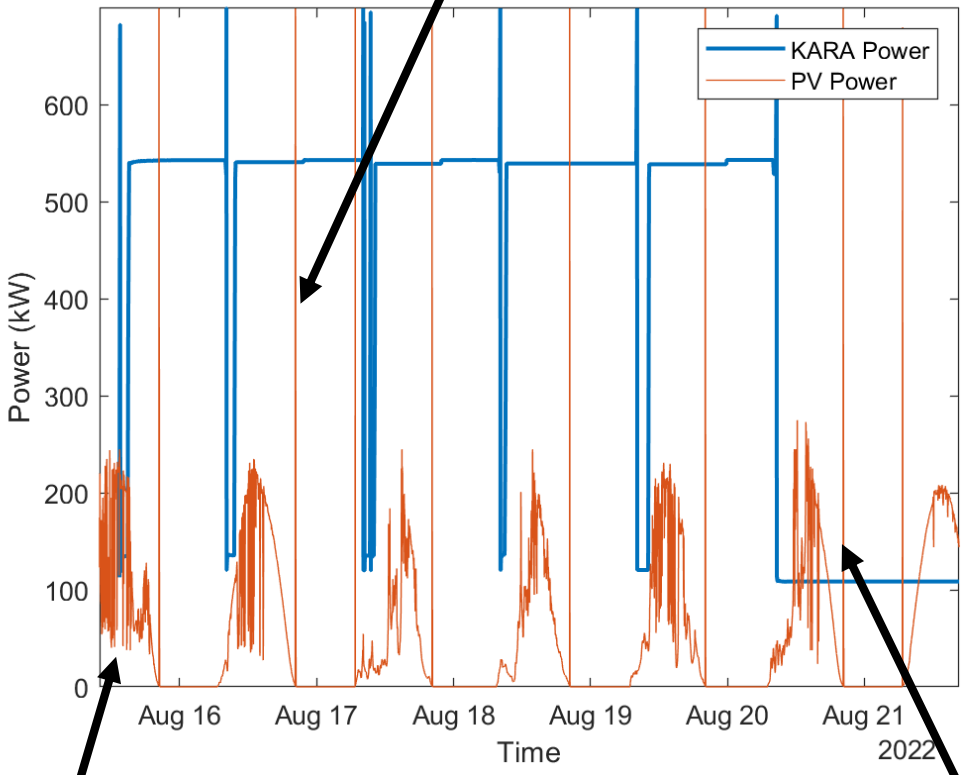
PV Plant 3 times bigger



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

First power analysis for KARA – Solutions and challenges

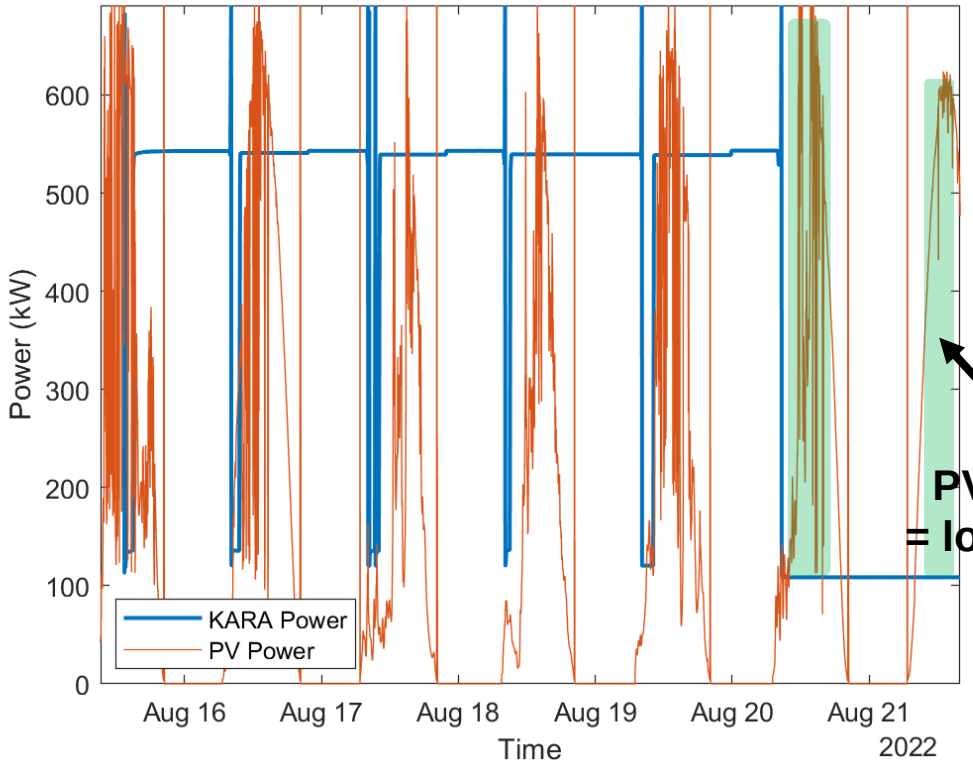
Not sufficient power



Not synchronized PV production and consumption

PV power exceeding the consumption during weekend

PV Plant 3 times bigger



PV capping = lost revenue

450kW for ca. 16 hours missed revenue

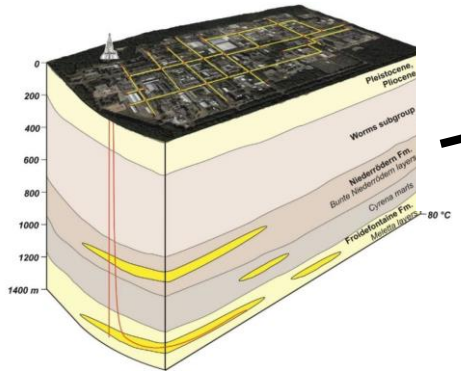
Energy storage solutions for accelerators

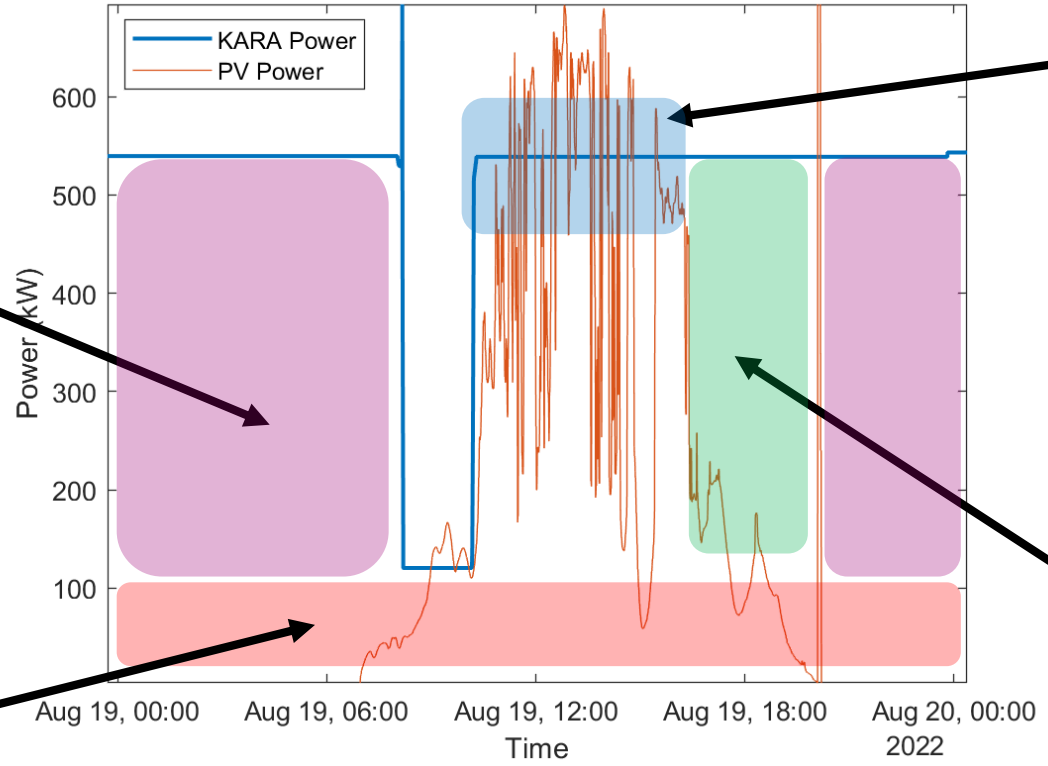
Karlsruhe Institute of Technology

Long-term (>12 hours) storage solutions

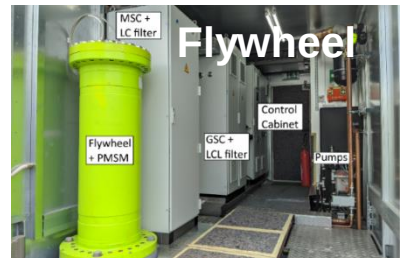
Seasonal energy storage solutions

Geothermal





Fast dynamics solutions

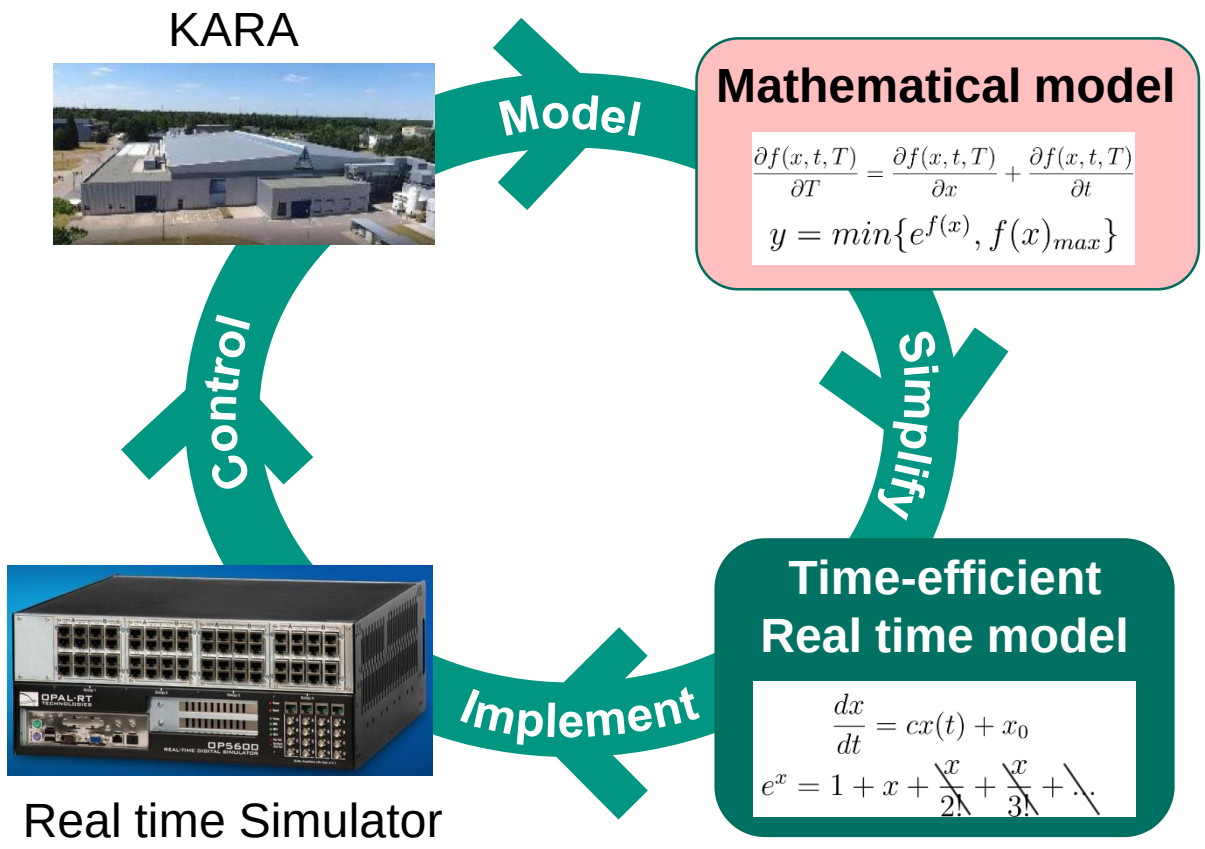


Medium-term solutions

How to choose and size properly energy solutions for accelerators?

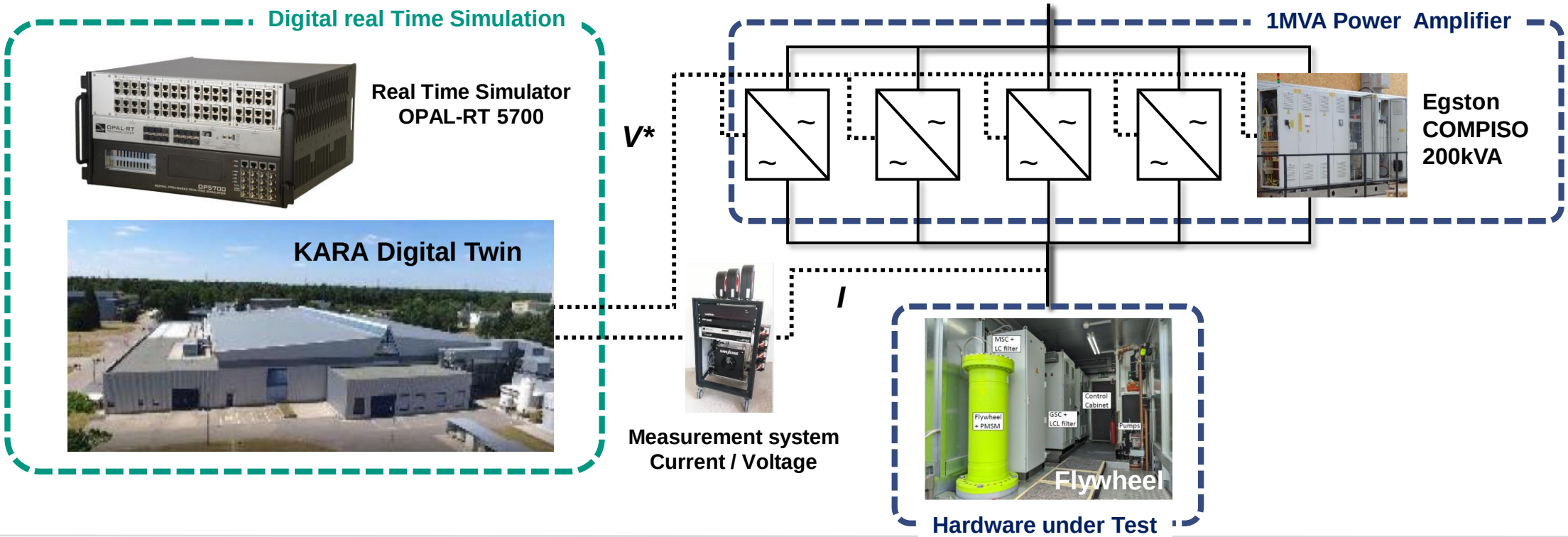
KITTEN next accelerators concept

- **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



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

THANK YOU
Questions?

Dr.-Ing. Giovanni De Carne
Head of „Real Time System Integration“ group
Helmholtz young investigator group leader

Karlsruhe Institute of Technology
Institute for Technical Physics (ITEP)

Phone: +49 721 608-25924
Email: giovanni.carne@kit.edu

www.itep.kit.edu