A HIERARCHICAL CONTROL ALGORITHM FOR FLEXIBLE MULTI-ENERGY-STORAGE SYSTEMS

"16th OERC Symposium 2022 – An Equitable and Low-Cost Energy Transition, 28–29 November, Room 1.17, Otago Business School, University of Otago, Dunedin"

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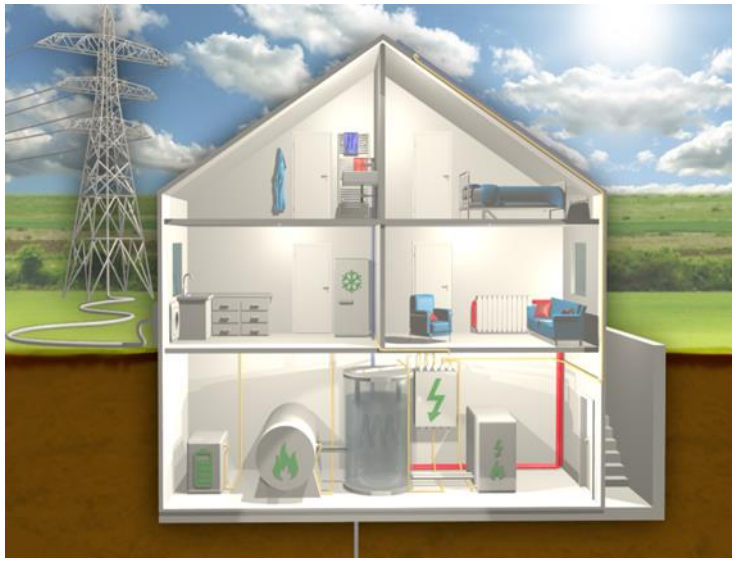
MOTIVATION: BETTER ENERGY MANAGEMENT SYSTEMS IN RESIDENTIAL BUILDINGS

- **Reliable energy supply (electricity and heat)**
- **Higher efficiency** → less losses due to better storage usage, self-consumption
- **Lower operational costs** (energy costs) → forecast and optimization of electrical & thermal demand
- **Transparency** for inhabitants, owners, energy suppliers and grid operators (digitization)
- **Flexibility** → Optimizing the control for minimal costs OR CO2 emission and at the same time adding incentives or requirements by a third partie (grid operators, energy market, energy suppliers) → adapt easily to new components e.g. wallbox



OPTIMIZED PROSUMER *)

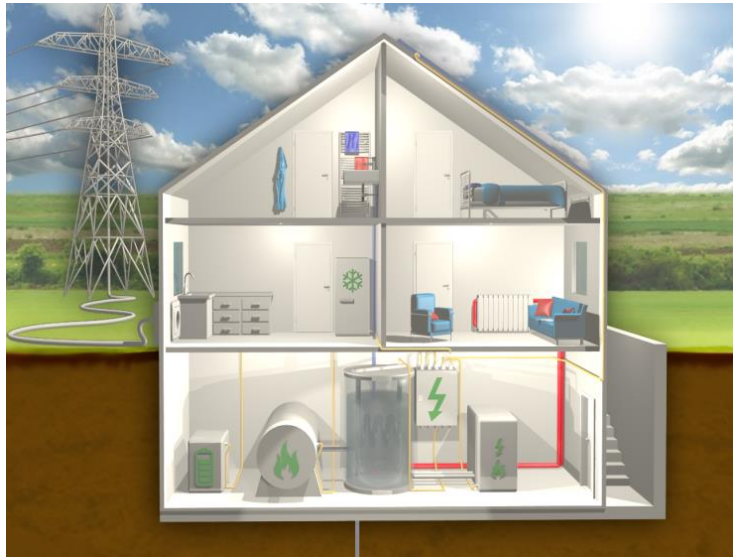
- **Prosumer** – producer + consumer (e.g. of electricity)

- **Optimized** – Using a mathematical optimization like a MILP within a model predictive control approach (MPC)

- **Optimized Prosumer**– *Group of energy components* (loads, production unit, storage systems) which are *controlled together* as one system by an MPC

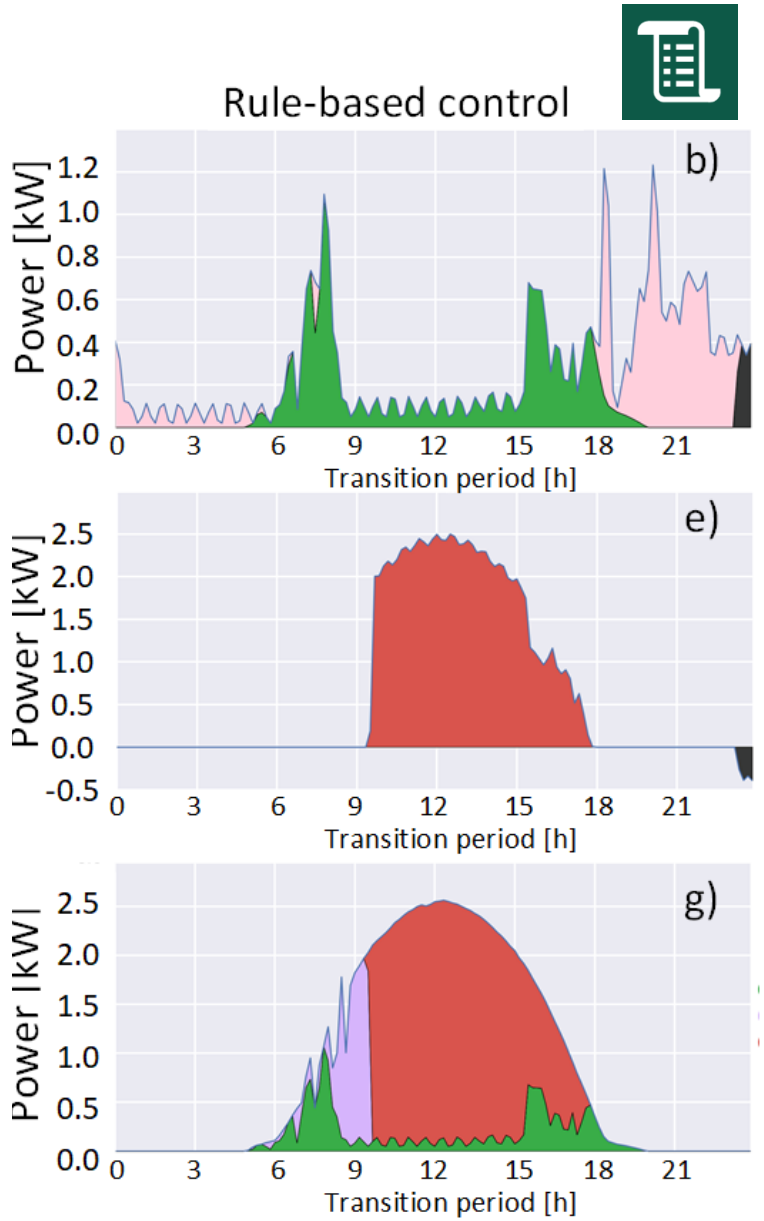
*) aka Multi energy system

Rule-based control



Based on rules

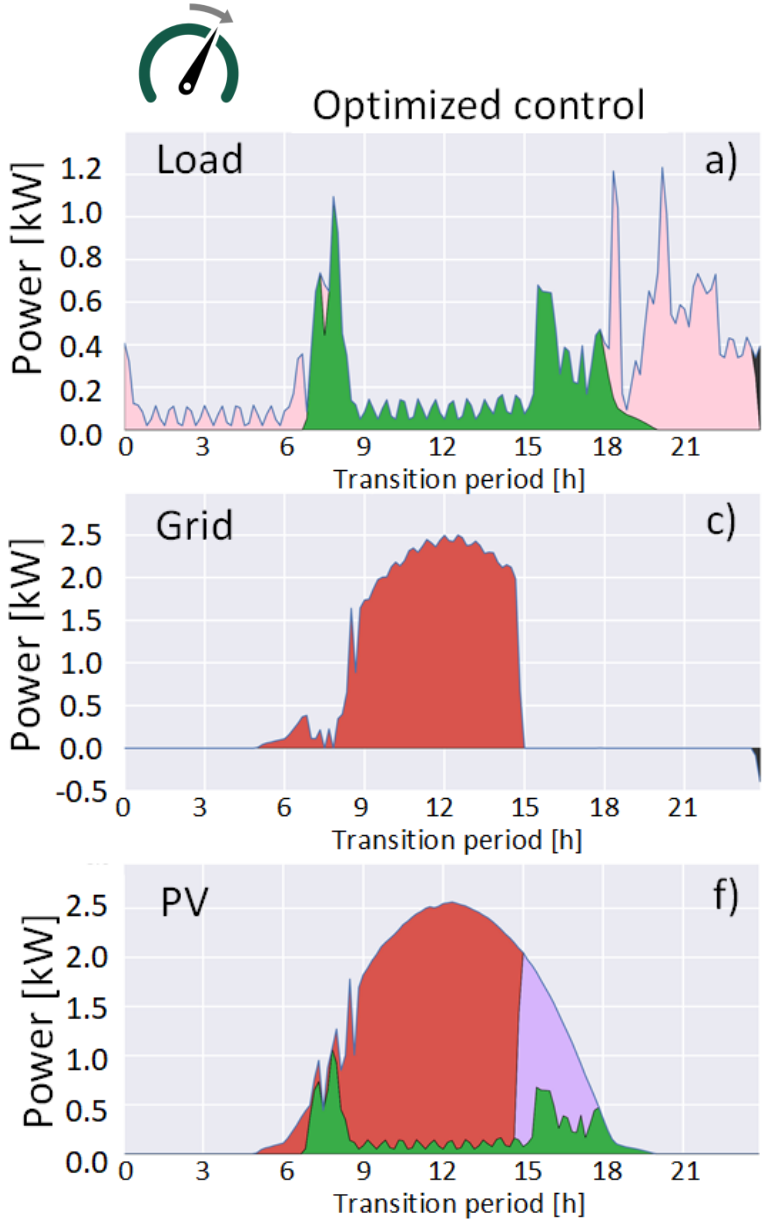
- If there is PV-energy available use it for the household applicances! → GREEN
- If there is still PV-energy available use it to charge the battery! → VIOLET / PINK
- If there is still PV-energy feed it into the power grid! --> RED



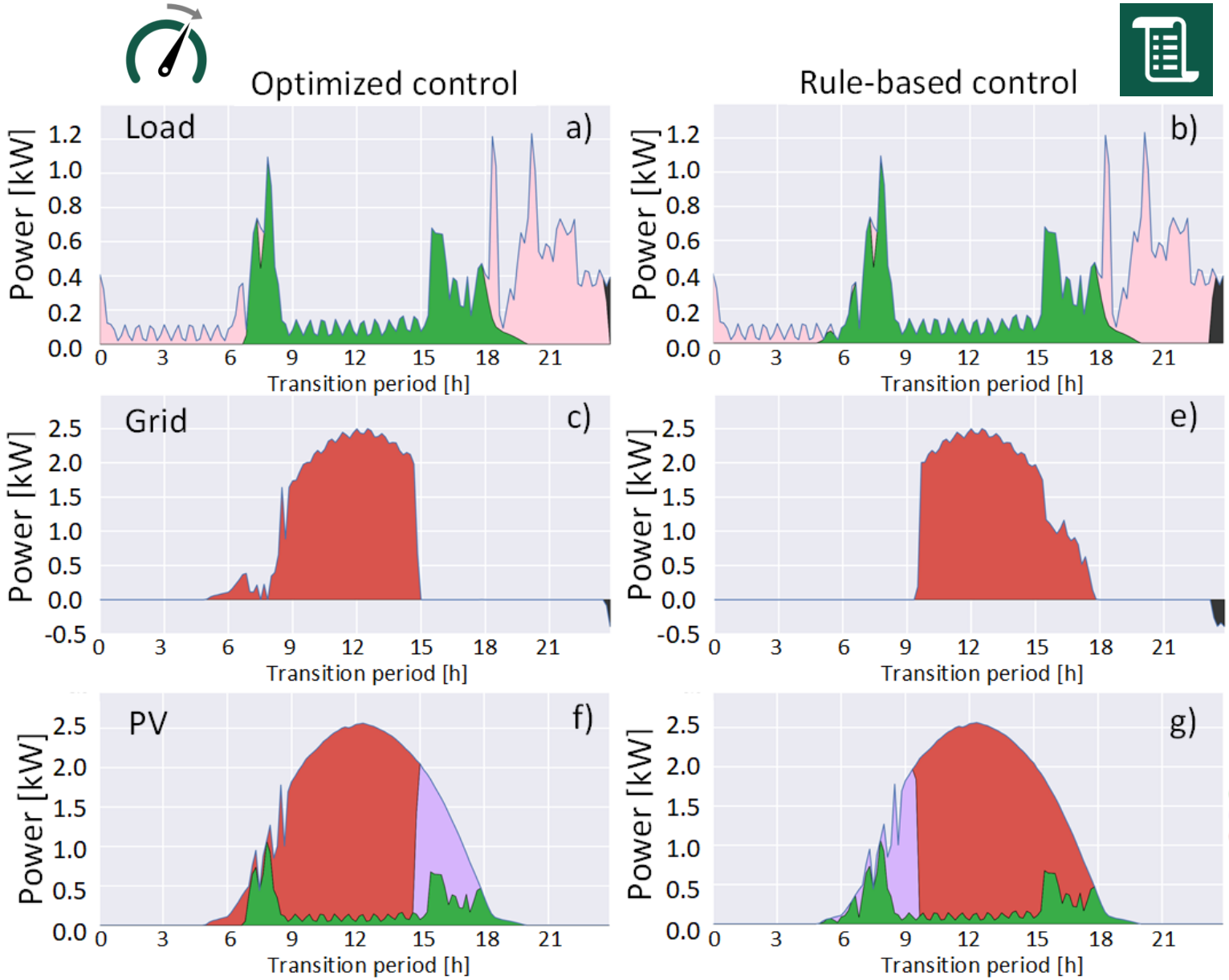
Otimized control

Based on forecasting the future:

- Forecast the PV-emission for the next 12 hours
- Forecast the needed electrical energy
- Use a model for the PV-battery system to calculate lowest energ costs
- Send set points for the next 10 min to the battery system



Rule-based vs Otimized control



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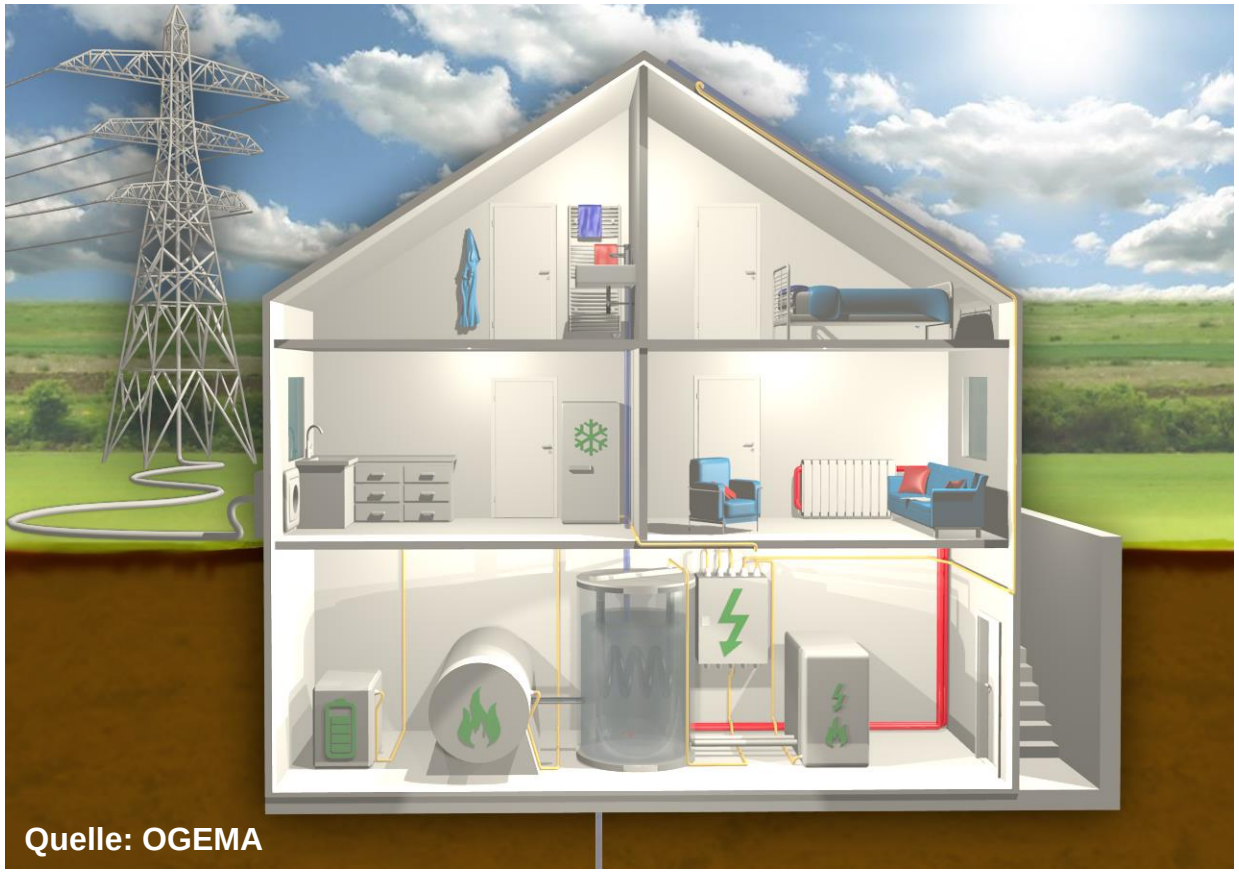
Project „Ine-Ves“

- **Energy components for a single and multi-family home**

Power grid

PV

(5 kW, 12 kW)



Combined heat and powert **(1 kWel, 4,7 kWel)**

Thermal storage
(300l, 500l)

Battery **(4kWh, 12 kWh)**

Gas boiler **(12 kW, 20 kW)**

Gas network

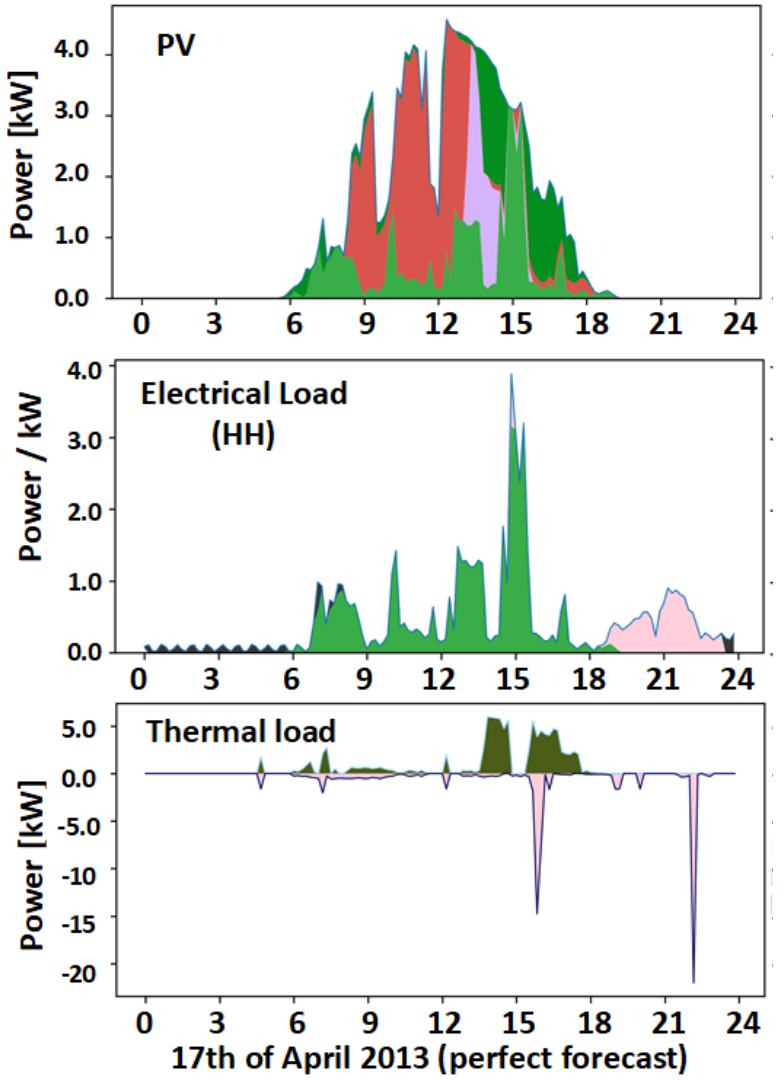
Gefördert durch:

Bundesministerium für Wirtschaft und Energie

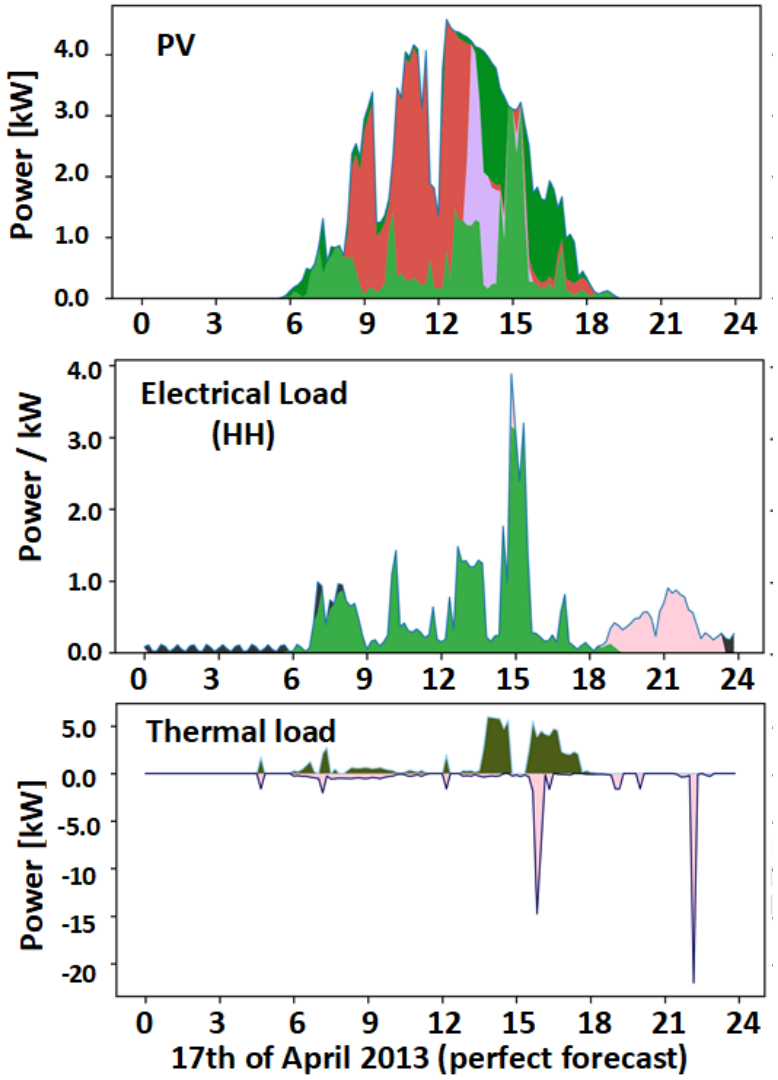
aufgrund eines Beschlusses des Deutschen Bundestages

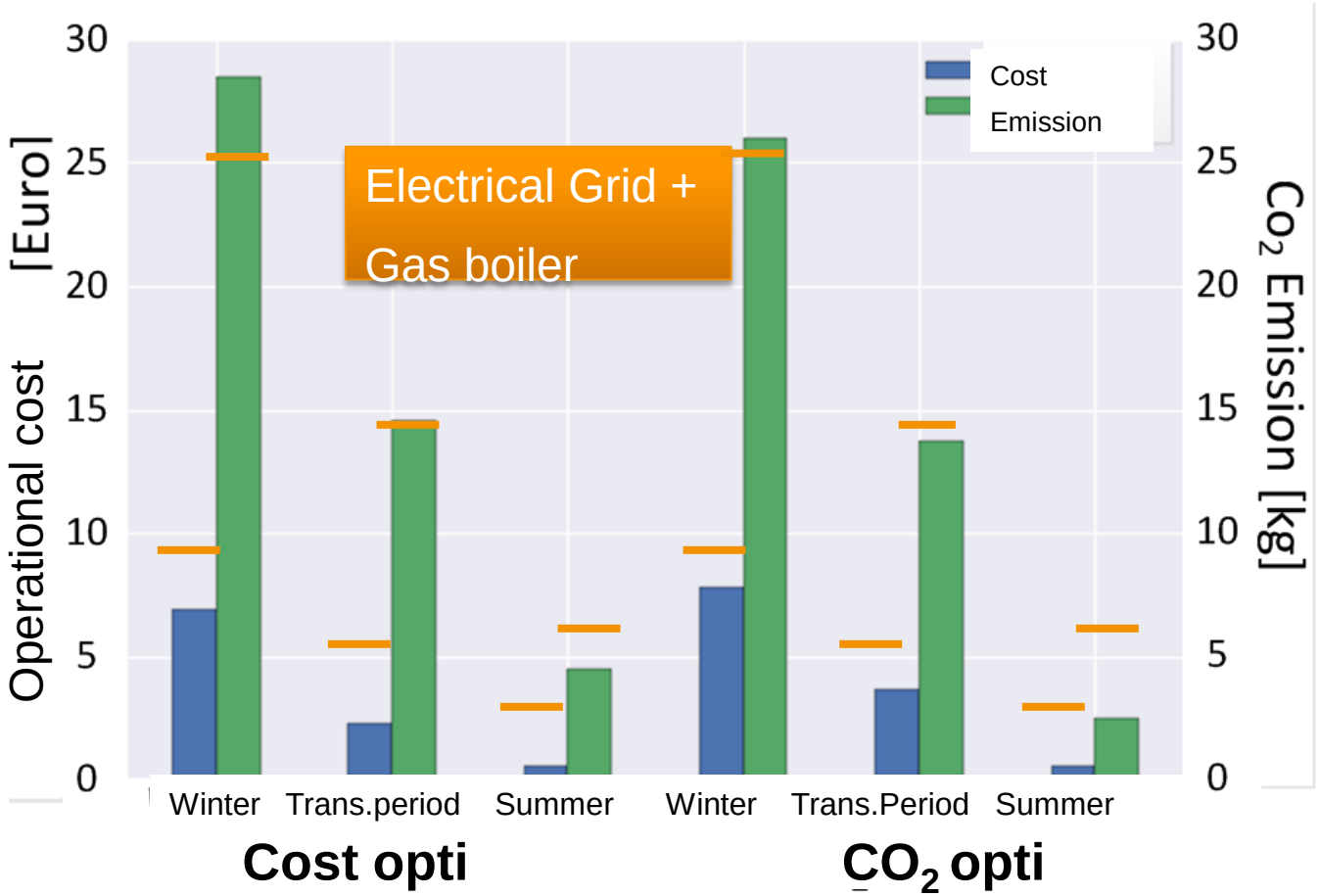
ENERGIESPEICHER
Forschungsinitiative der Bundesregierung

MPC Simulation for a Multi-energy-system - Results for 1 day



MPC Simulation - Results for 1 day – two optimization objectives (cost, CO2)





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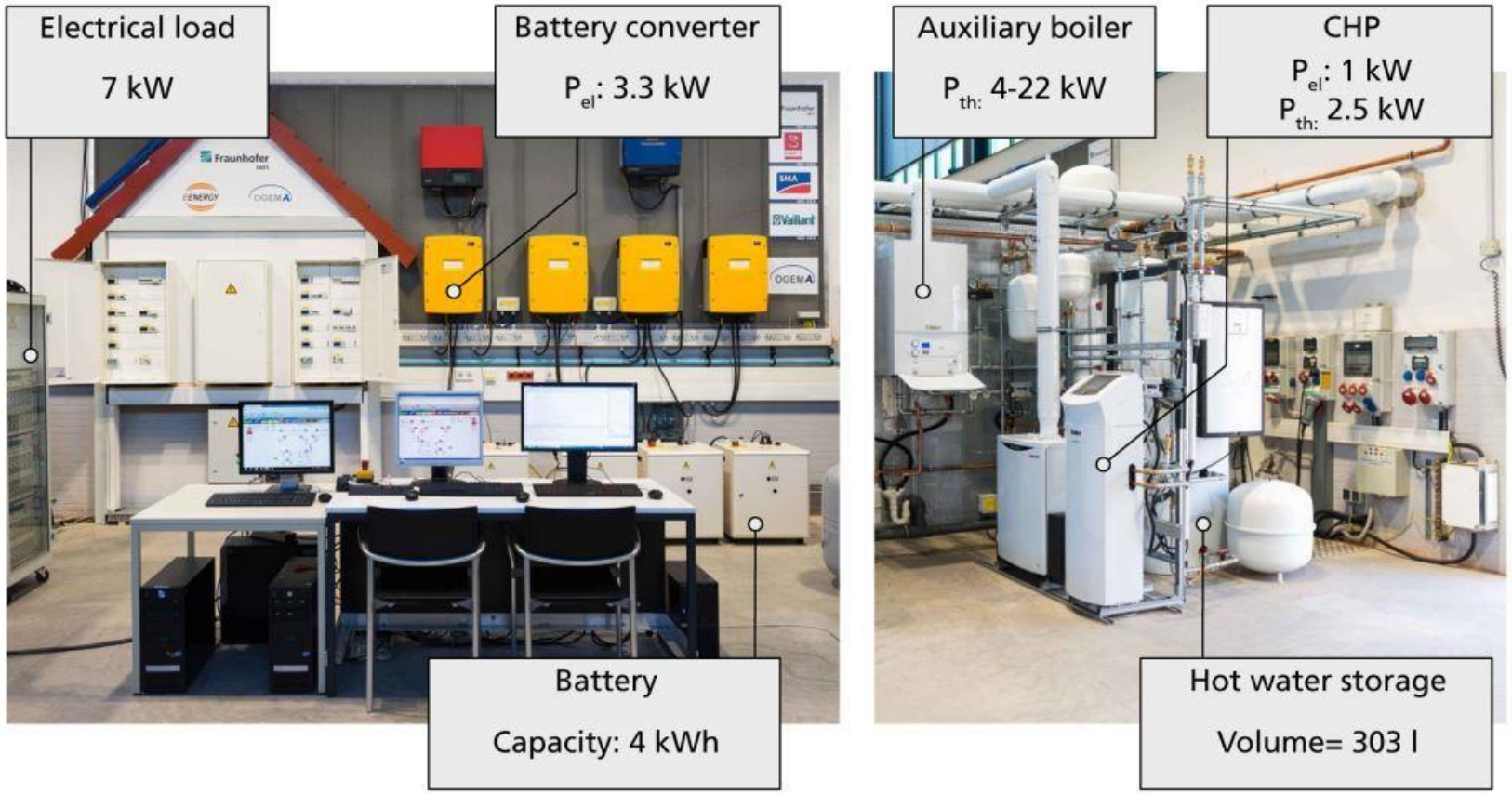
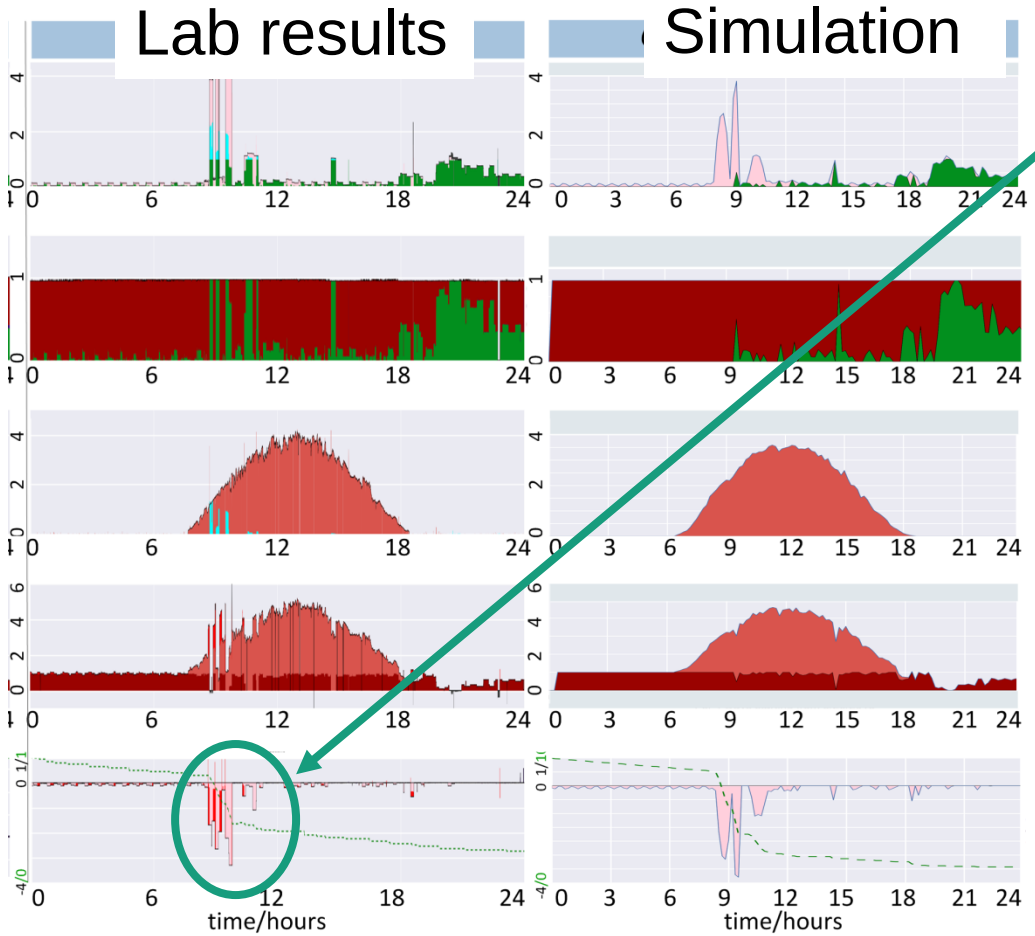
TEST IT IN THE LAB !

- Laboratory test bench for PV-CHP system (compare one day real operation with simulation results)



IT IS POSSIBLE TO USE AN OPTIMAL CONTROL ON REAL COMPONENTS, BUT…



…the battery was charging energy from the grid

…and was injecting energy into the grid.

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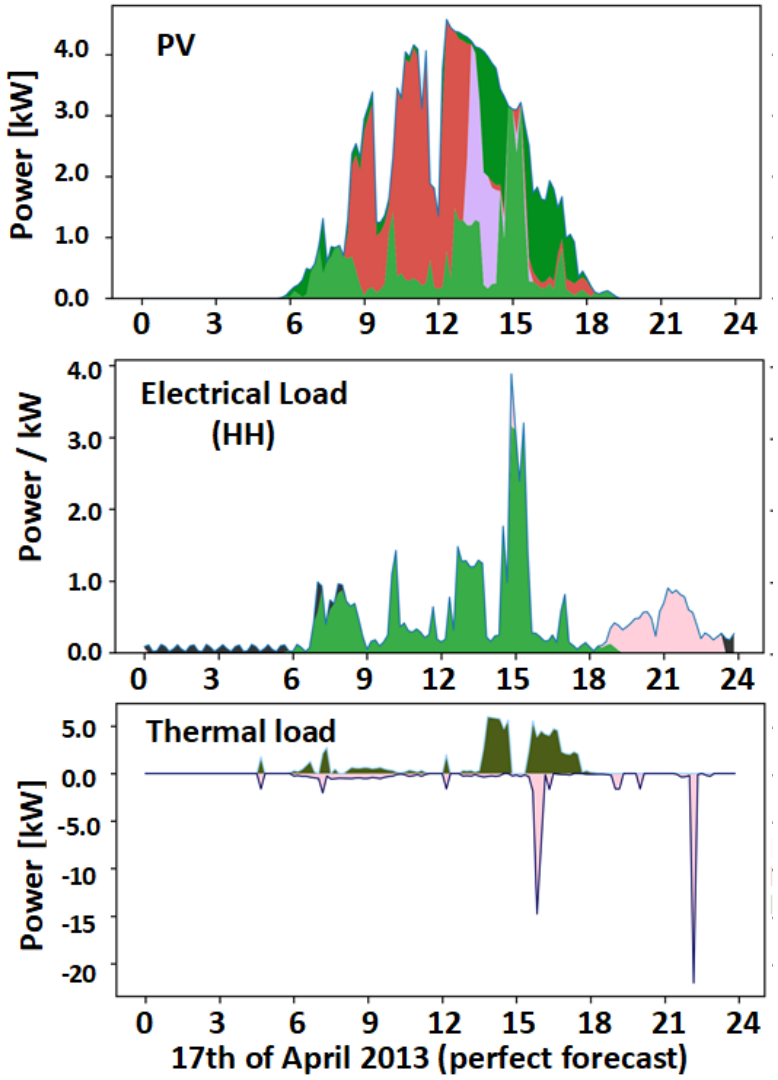
MPC - Forecast Methods



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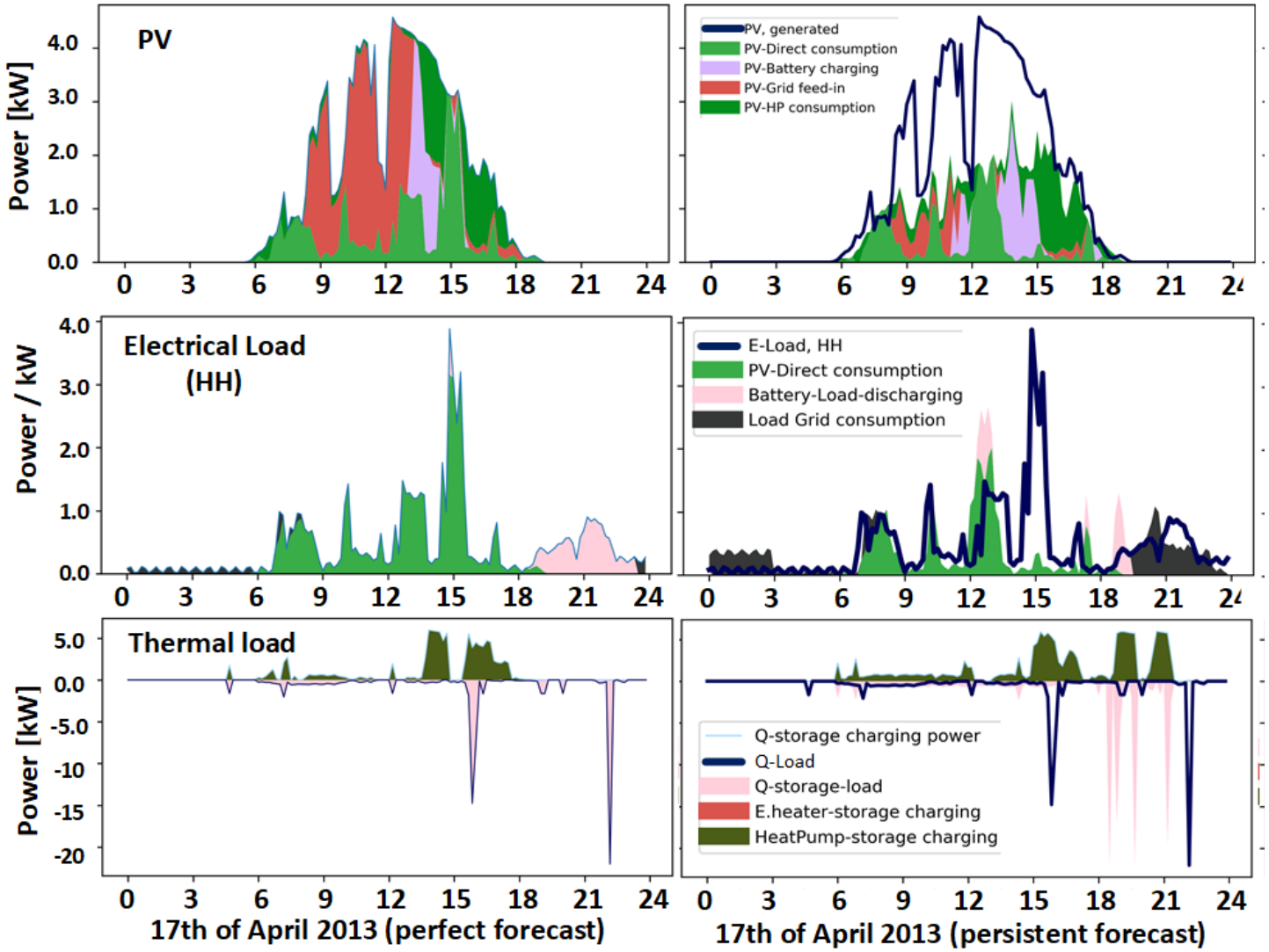

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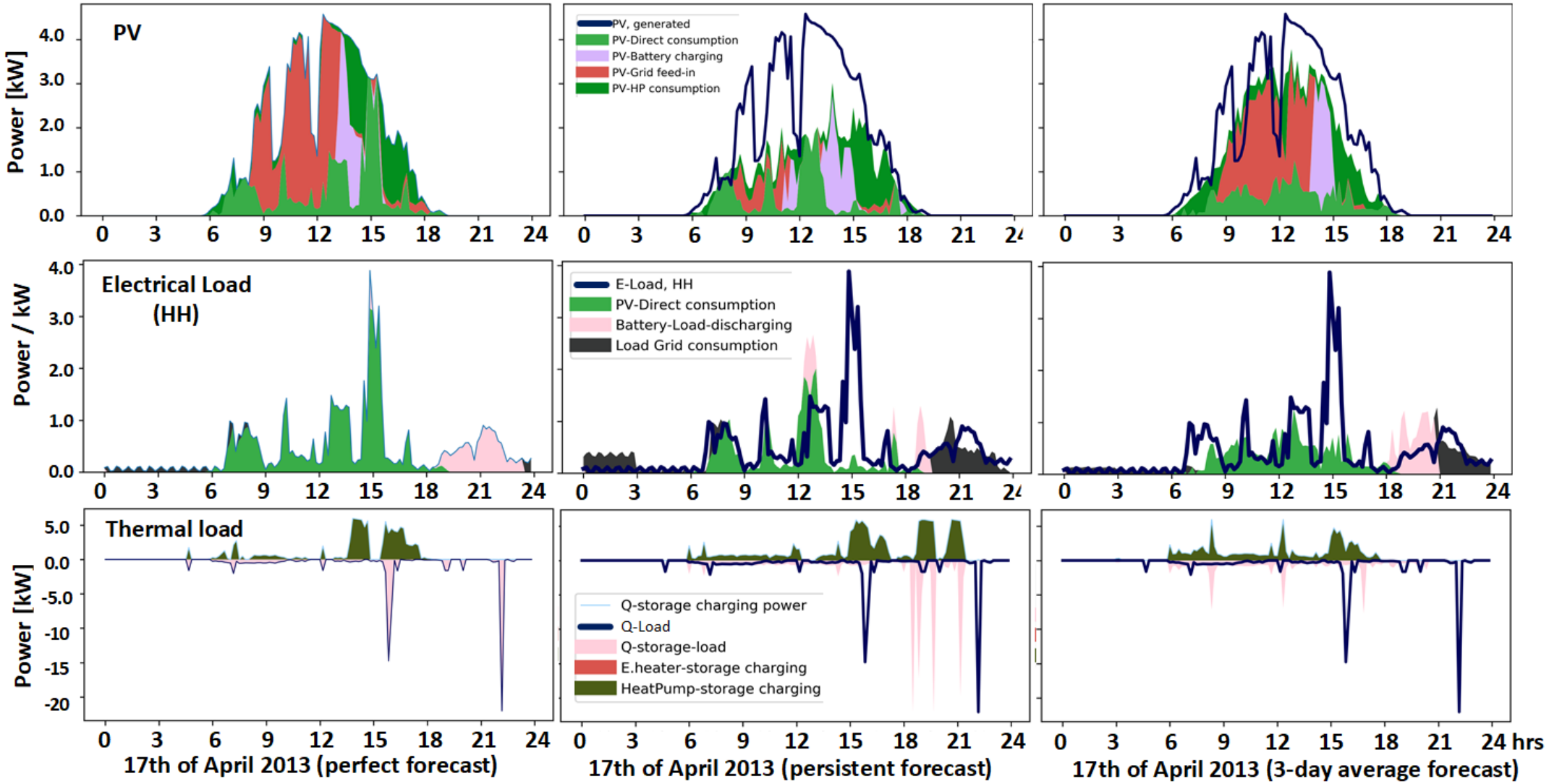
MPC - Forecast Methods



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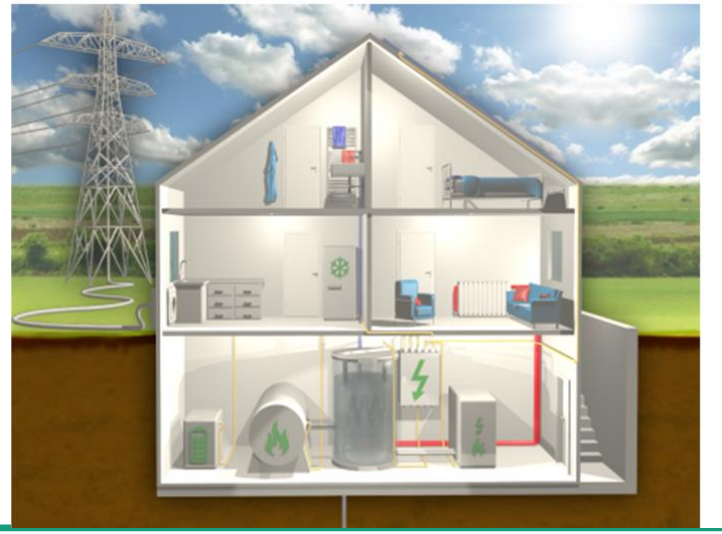
Hierarchical control algorithm

High level control

low level control

forecast

Optimizer



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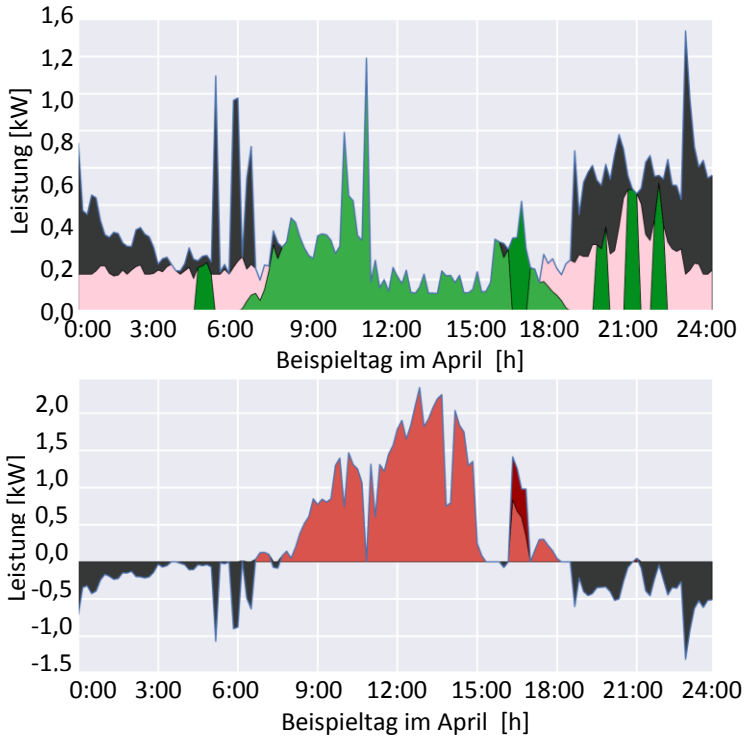
RESULTS OF THE HIERARCHICAL CONTROL ALGORITHM

ALL CONDITIONS ARE MET!

Hierarchical control algorithm



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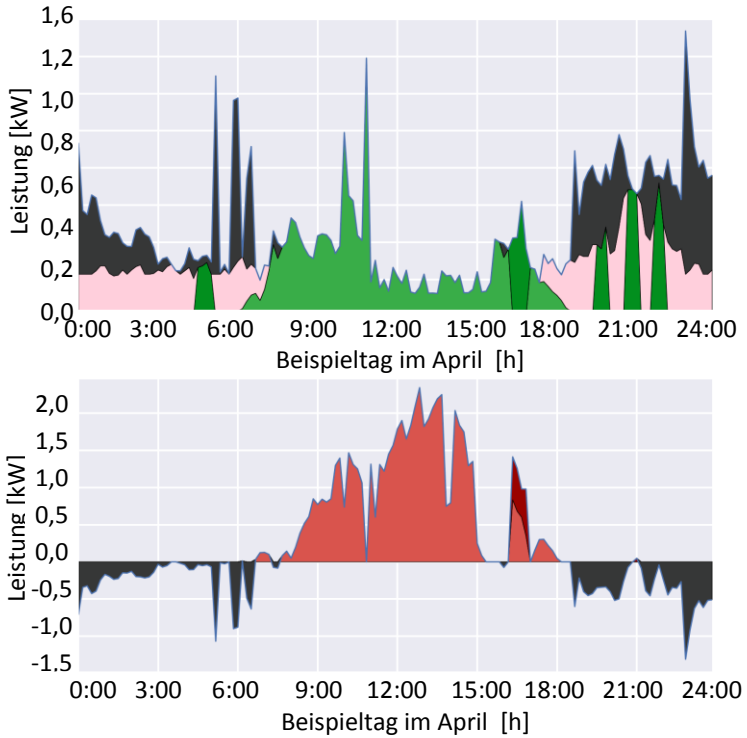
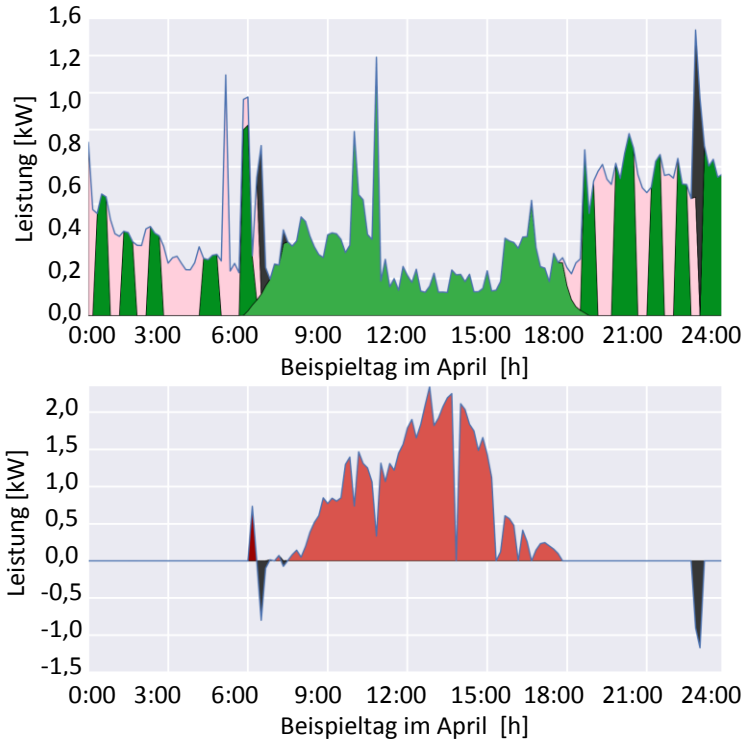
RESULTS OF THE HIERARCHICAL CONTROL ALGORITHM

BATTERY & CHP ARE ADAPTED TO REAL VALUES !

Hierarchical control algorithm



MPC – Perfect forecast



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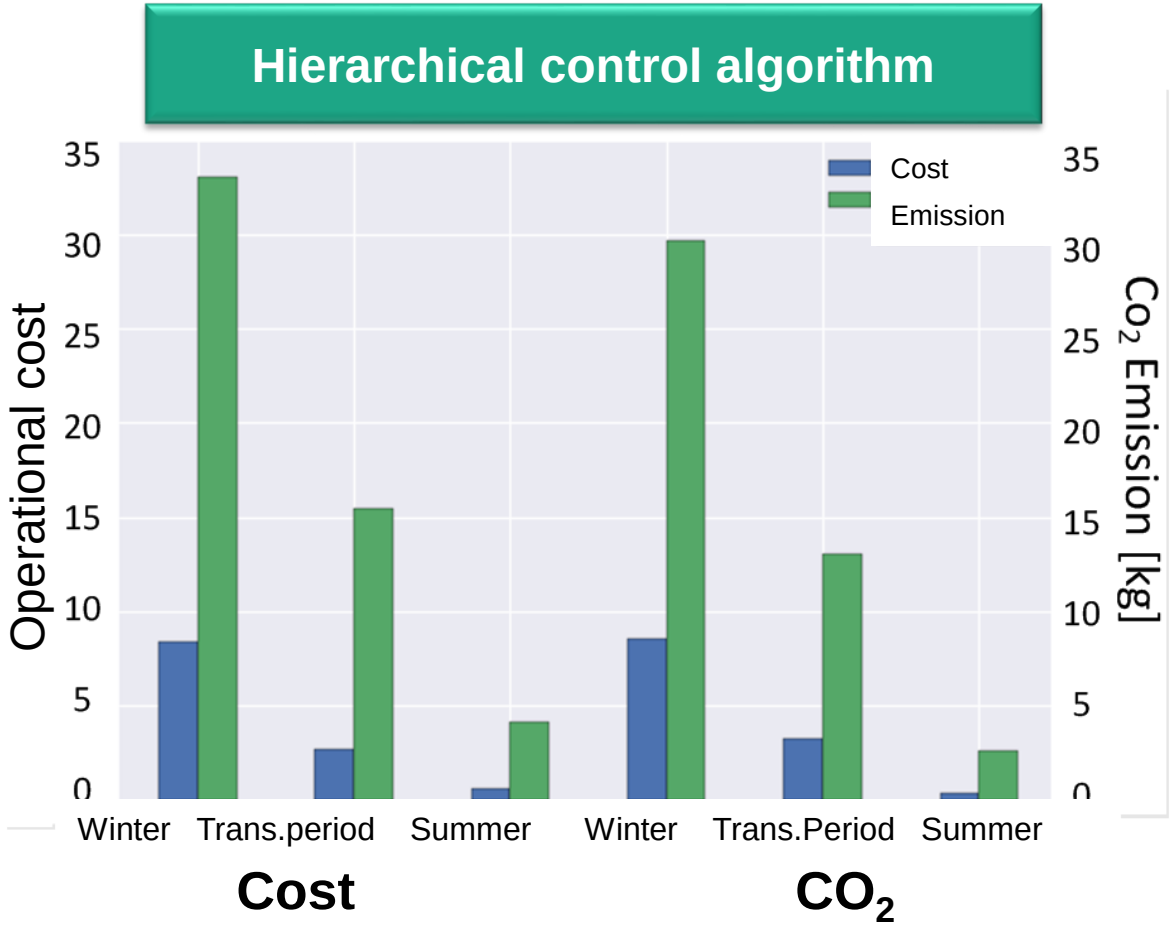
RESULTS OF THE HIERARCHICAL CONTROL ALGORITHM



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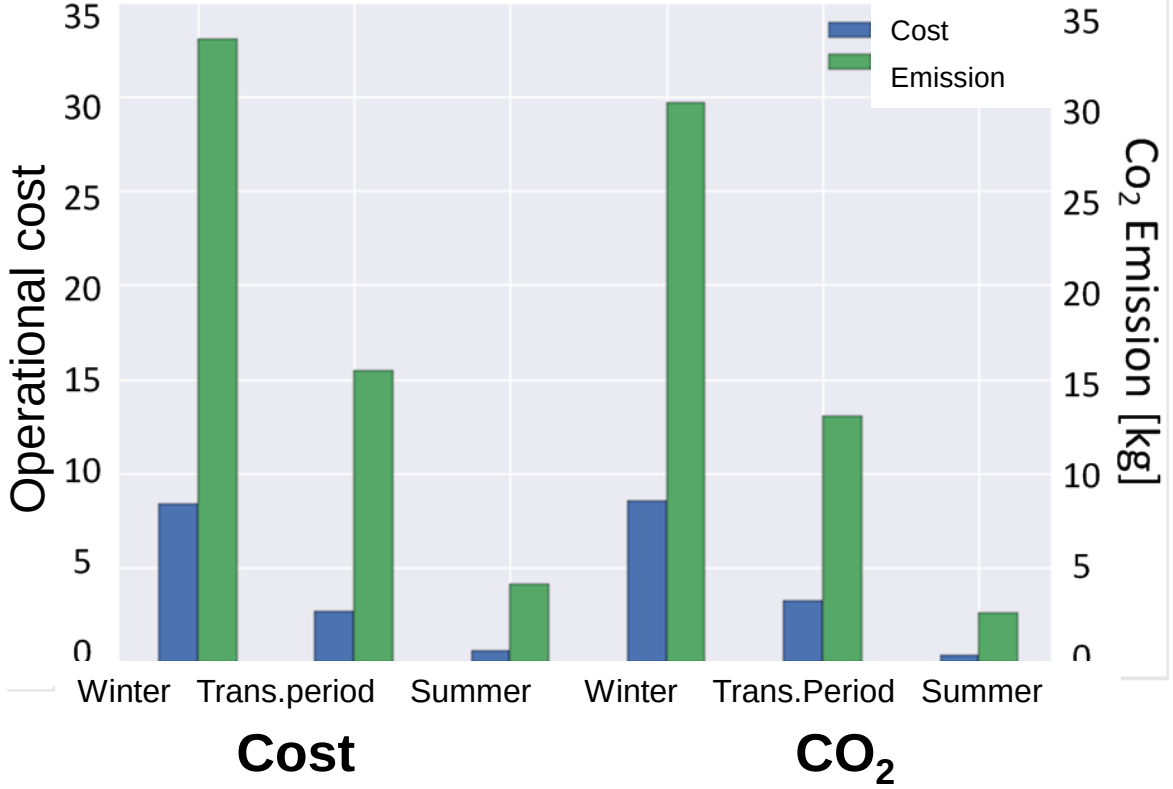
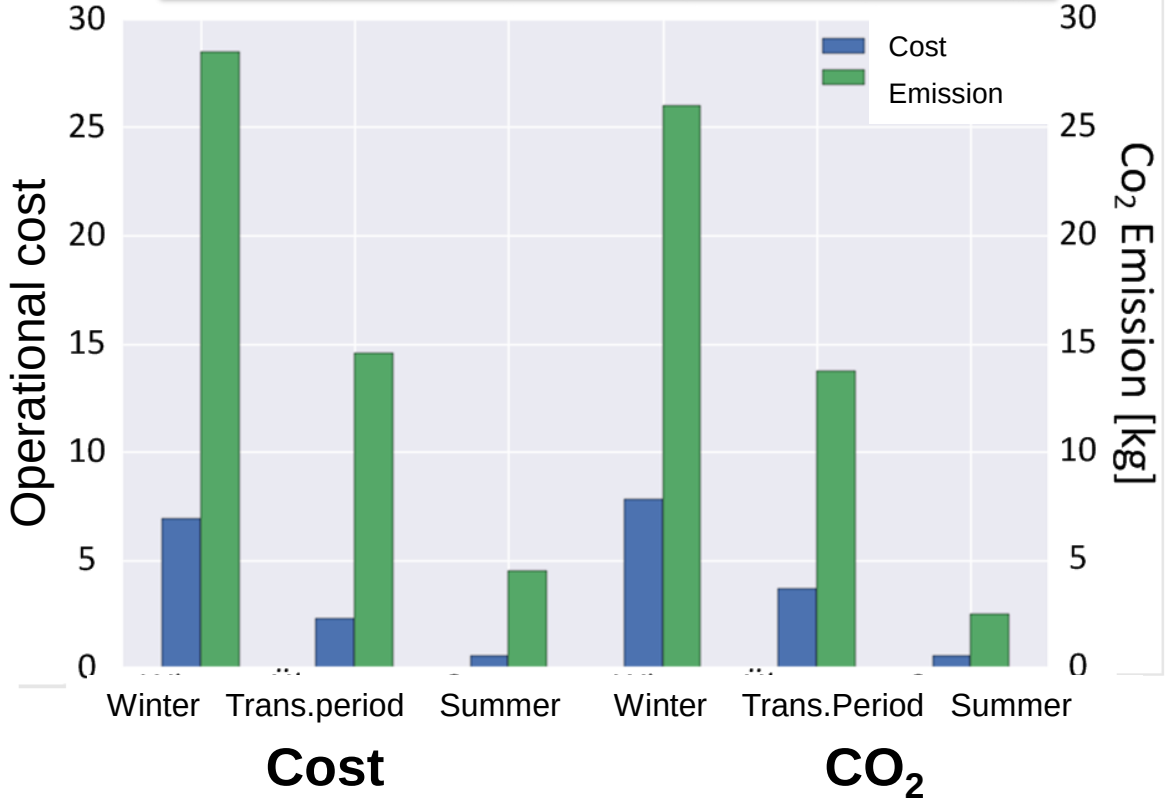
RESULTS OF THE HIERARCHICAL CONTROL ALGORITHM

Hierarchical control algorithm



MPC – Perfect forecast



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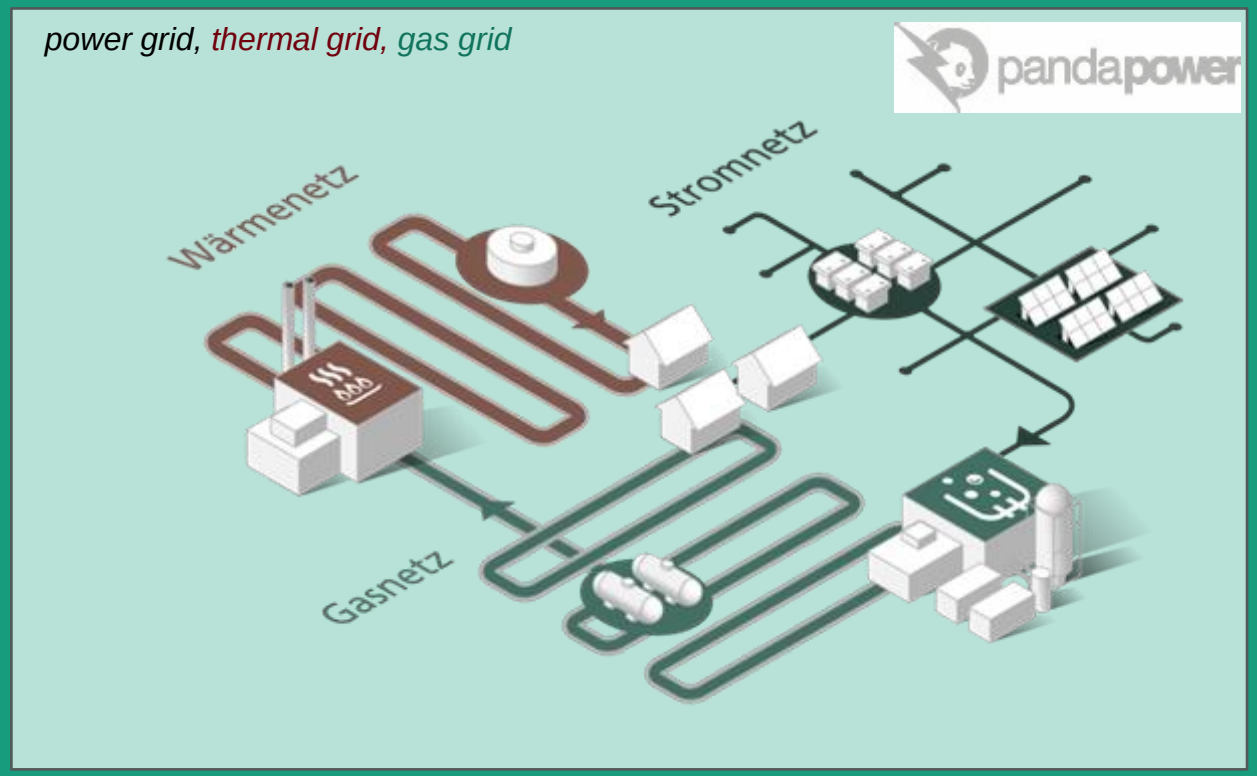
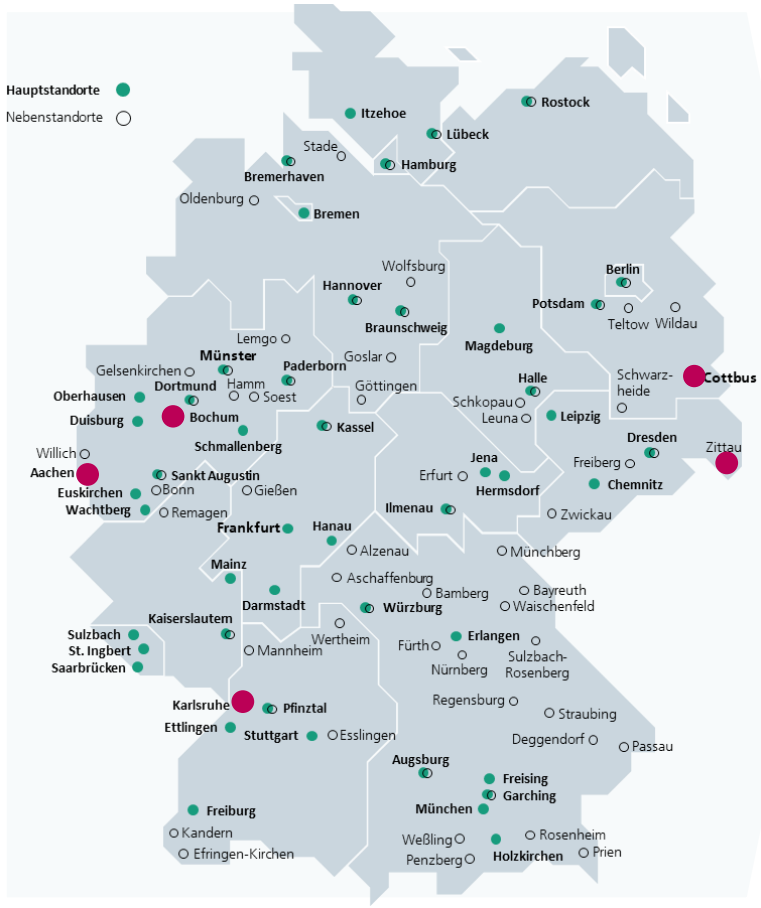


Die Fraunhofer-Gesellschaft auf einen Blick

Anwendungsorientierte Forschung zum unmittelbaren Nutzen für Wirtschaft und Gesellschaft



Ziele

- Bezahlbare Gesundheit
- Digitalisierte Wertschöpfung
- Sicherheit und resiliente Gesellschaft
- Vollendete Energiewende
- Ganzheitliche Kreislaufwirtschaft

Strategische Forschungsfelder

- Bioökonomie
- Next Generation Computing
- Intelligente Medizin
- Künstliche Intelligenz
- Quantentechnologien
- Ressourceneffizienz und Klimatechnologien
- Wasserstofftechnologien

Leitmärkte

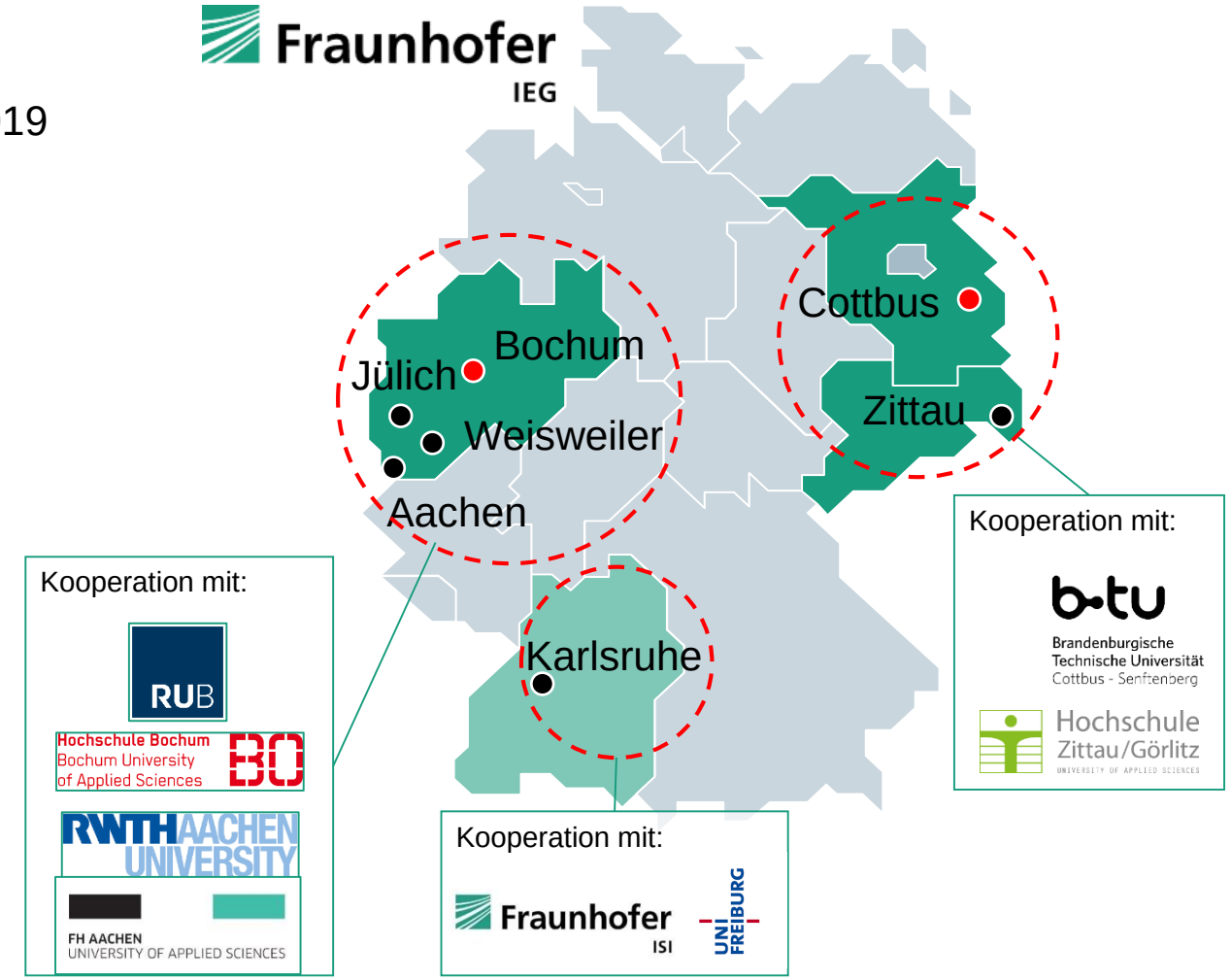
- Digitalwirtschaft
- Mobilitätswirtschaft
- Anlagen- und Maschinenbau
- Gesundheitswirtschaft
- Chemische Industrie
- Ernährungswirtschaft
- Energiewirtschaft
- Bauwirtschaft
- Luft- und Raumfahrtwirtschaft

30.000 Mitarbeitende in 76 Fraunhofer Instituten

Fraunhofer-Einrichtung für Energieinfrastrukturen und Geothermie IEG

Kurzvorstellung und Kennzahlen

- Gründung als selbstständige Einrichtung zum 01.12.2019
- Standorte in den deutschen Kohleregionen
- Mitarbeitende: ~200
- 6 Geschäftsbereiche mit 24 Competence Centers
- Koordination des Fraunhofer Wasserstoff Netzwerks (32 Institute)
- Institutsleitung: Prof. Dr. Rolf Bracke & Prof. Dr. Mario Ragwitz



Fraunhofer IEG – Forschungsfelder im Überblick

»Wir gestalten die klimaneutralen Energiesysteme der Zukunft«

- Integrierte **Energieinfrastrukturen**
- Transport-/Übertragungs- und **Verteilnetze**
- Integrierte **Quartiersversorgung** (Open District Hub)
- **Wasserstoff**infrastrukturen (Netze und Speicher)
- Systemtransformation und Technologietransfer

- Exploration und Reservoirsimulation von Georessourcen
- **Geothermale Energie** und Systeme, Tiefengeothermie
- **Geotechnologien**, Bohrtechniken und -verfahren
- **Speicher** für Stoffe und Wärme, Bergbaufolgenutzung
- Carbon Capture & Storage/Utilization (CCS/CCU)

- Thermodynamische Wandler
- Hochtemperatur-**Wärmepumpen**
- **Wärme-/Kälte**netze und Wärmeversorgungssysteme
- Wärme-/Kältequellen und -speicher

- **Steuerung, Regelung, Automatisierung** & Betriebsführung von Energiesystemen
- Dezentrale, intelligente und digitale Netze und Systeme
- **Großdemonstratoren / Reallabore**

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