ETH zürich

Energy Science Center

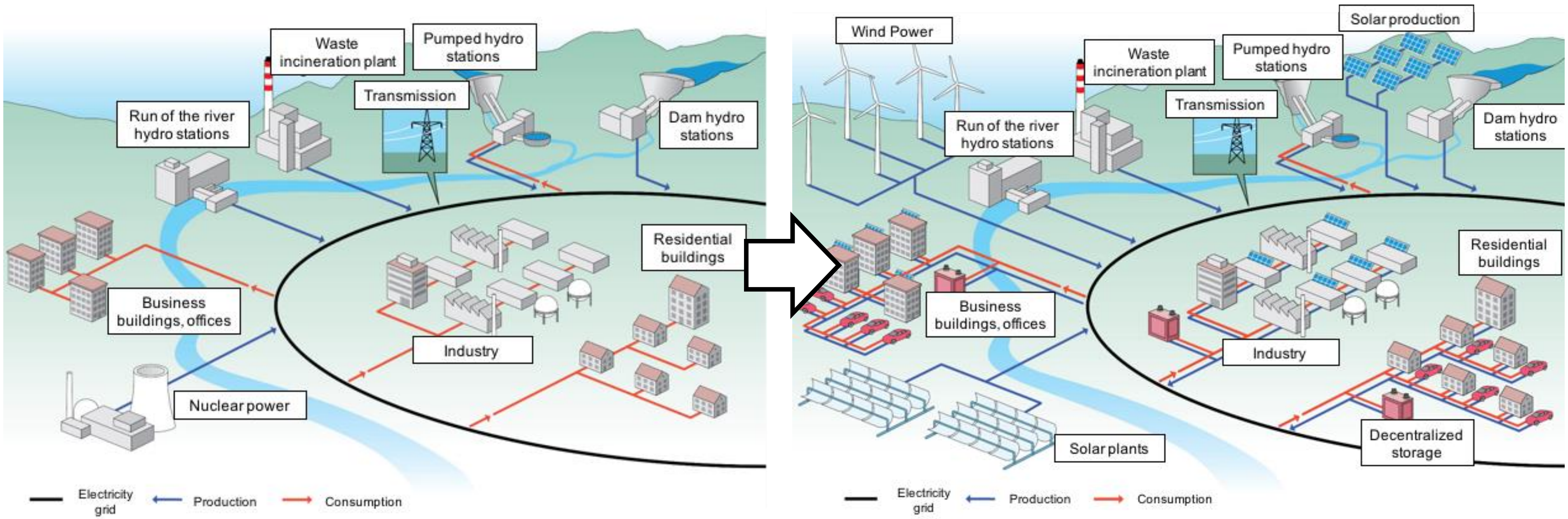
FNSNF SWISS NATIONAL SCIENCE FOUNDATION

Energy Turnaround National Research Programme NRP 70

IMES - Integration of sustainable multi-energy-hub systems at neighbourhood scale

Portia Murray

IMES: From centralized to decentralized energy production



- Nuclear resources (~35% currently) phased out between 2020-2035
- To be replaced with renewable power generation according to the Swiss Energy Strategy 2050

IMES project goals

- To identify the **critical technical issues** in a decentralized system with integration of renewables, natural gas micro-cogeneration and storage (power-to-gas and batteries)
- To develop **robust techniques for design and control** of multi-energy systems (e.g. including long-term storage) to minimize costs and CO_2 emissions
- To identify **the best technology portfolios** for the multi-energy hub
- To assess the **techno-economic implications** of the energy hub
- To assess the **social feasibility** of decentralized systems

- To translate the analysis into practice by selecting **Swiss-based test cases** for the evaluation of decentralized energy systems in different realistic conditions: Zurich Altstetten; Zernez, Graubünden.

IMES: system investigated in the joint project

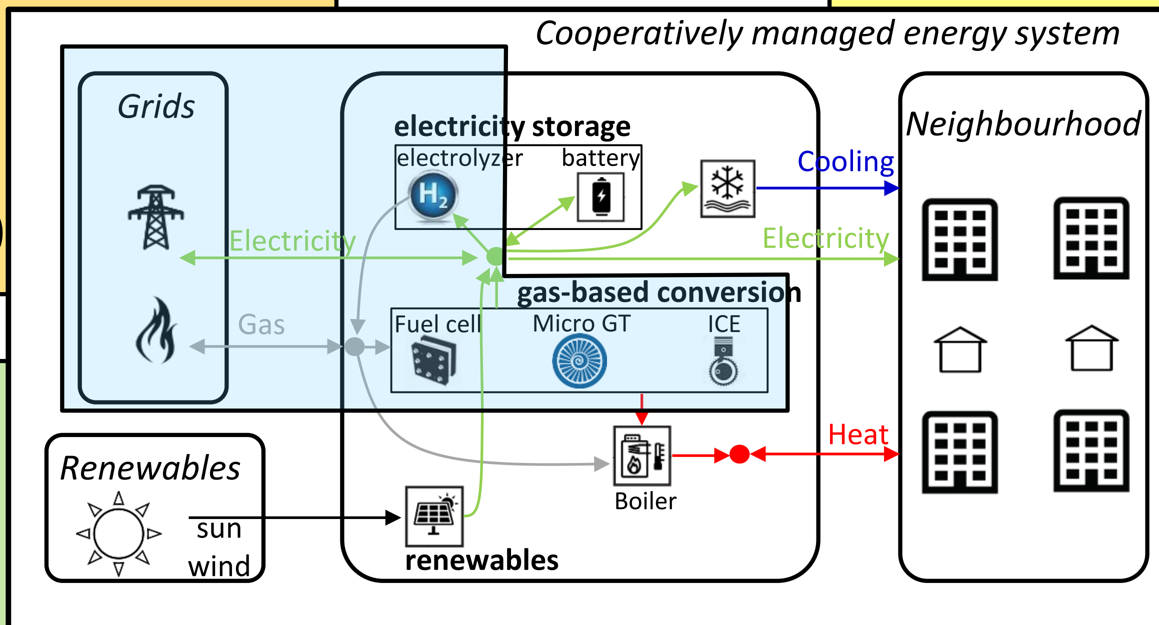
- Energy demand and potential
- Optimal energy HUB design: size and technology selection

IMES-BP (Building Performance)

IMES- TEC (Technology Performance)

- Optimal control
- Dynamic analysis
- Stochastic optimization

IMES-SC (System control)



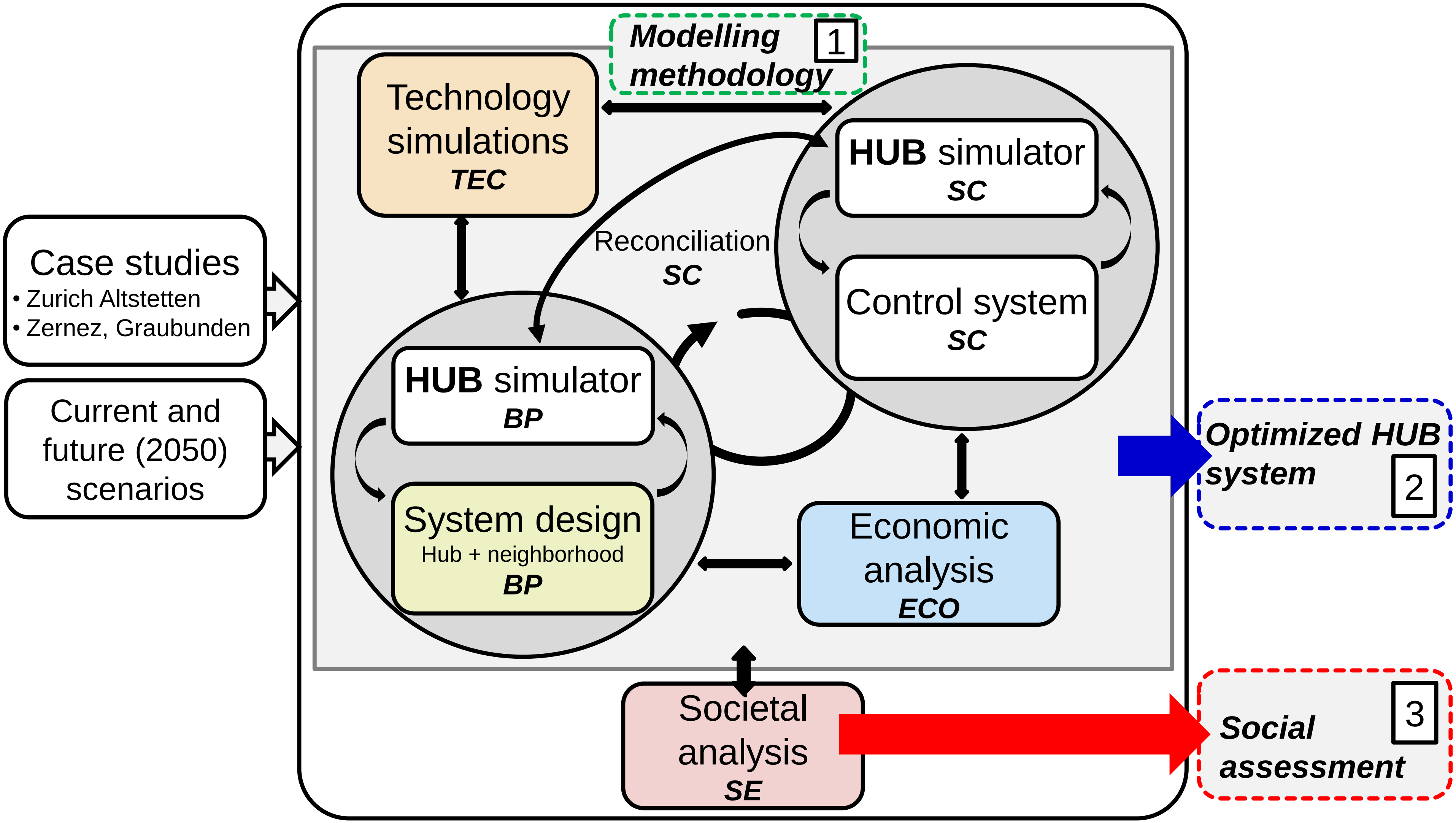
IMES-ECO (Economics and Market Evaluation)

- Techno-economic assessment
- Market analysis

IMES-SE (Social acceptability)

- Societal perspectives: challenges/opportunities

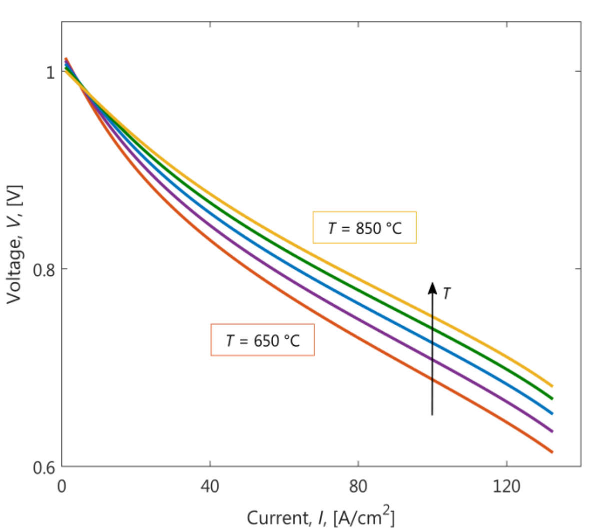
IMES Structure and Interactions



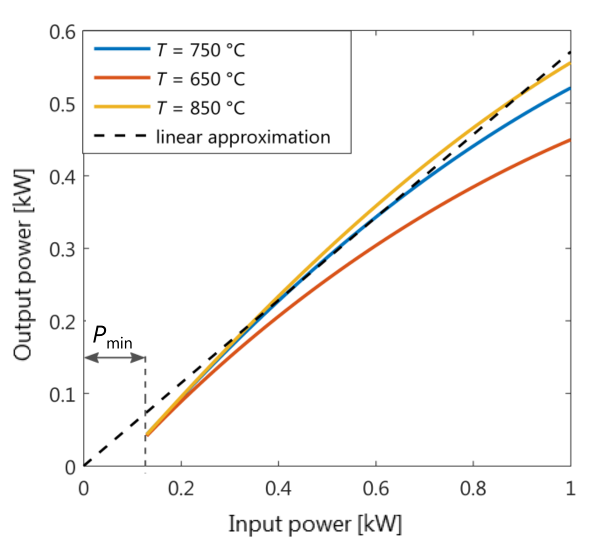
IMES-Tech: Technology modelling

- Thermodynamic models describing partial-load and dynamic performance of the technologies
- Identification of most suitable level of details to model conversion technologies within integrated MES.

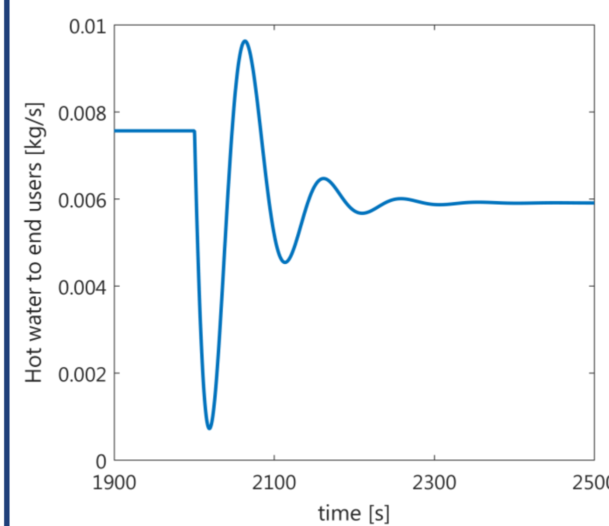
From single component



to commercial product: partial load



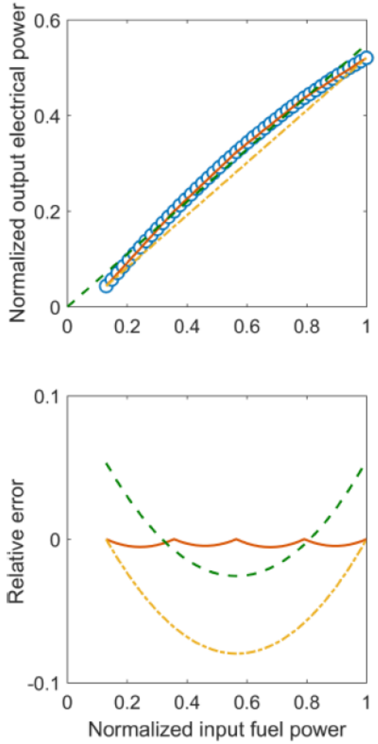
to commercial product: dynamics



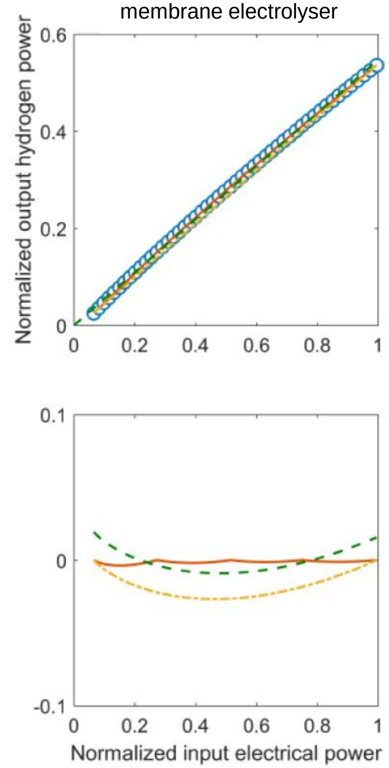
IMES-TEC: Development of Reduced-Order Models

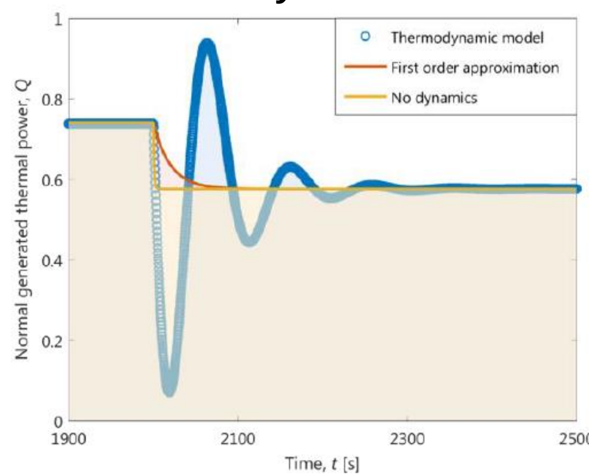
- Definition of different reduced order models with different complexity and level of details.
- Evaluation of the impact of performance linearization, dynamic behavior, and minimum power requirements

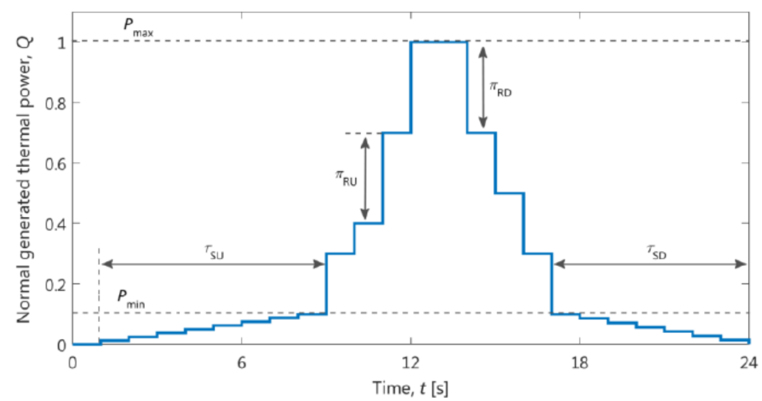
Solid oxide fuel cell



Polymer electrolyte membrane electrolyser

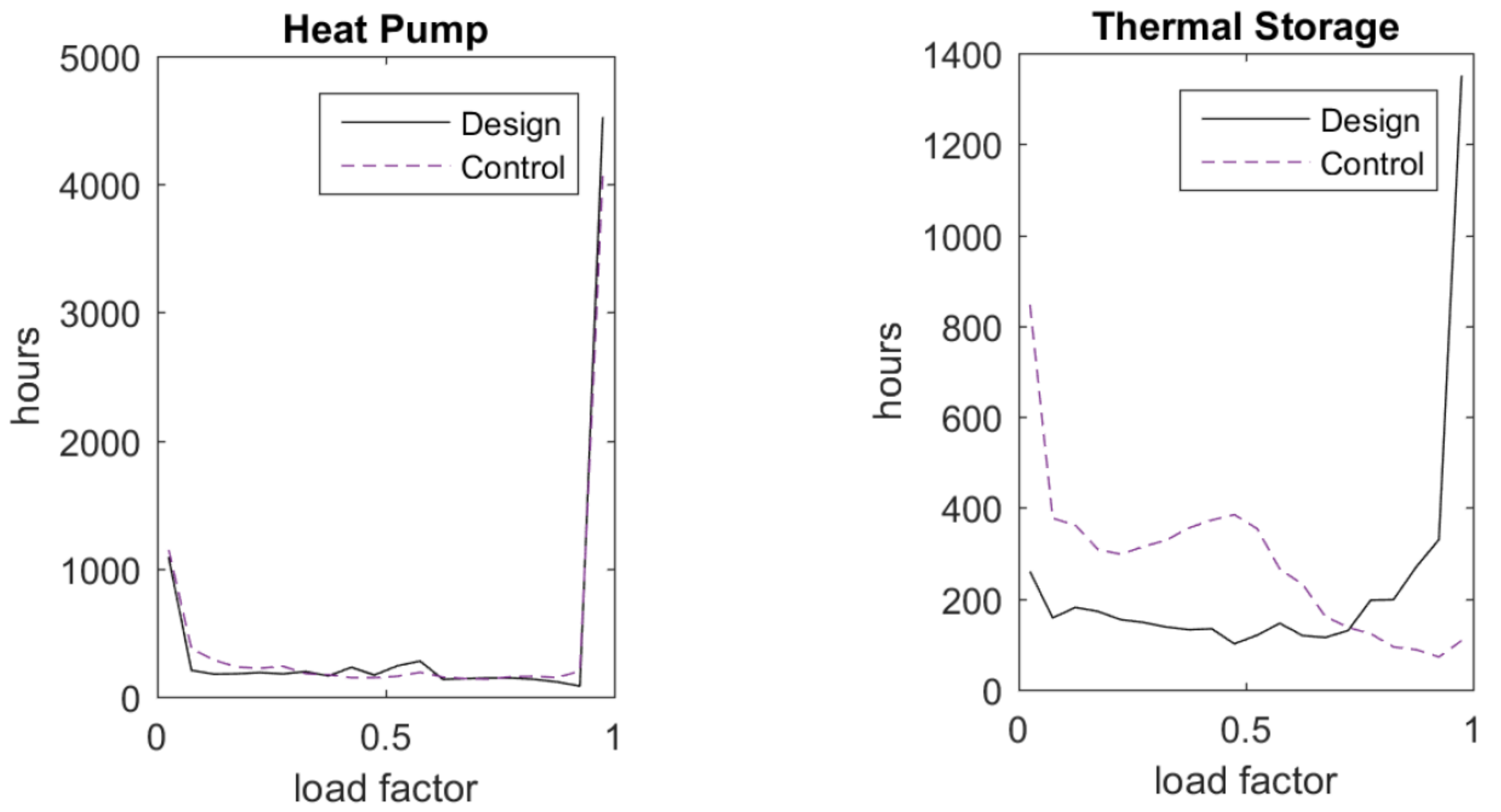






IMES-SC: Control feedback

Hub control: real time control with data uncertainty and customer privacy

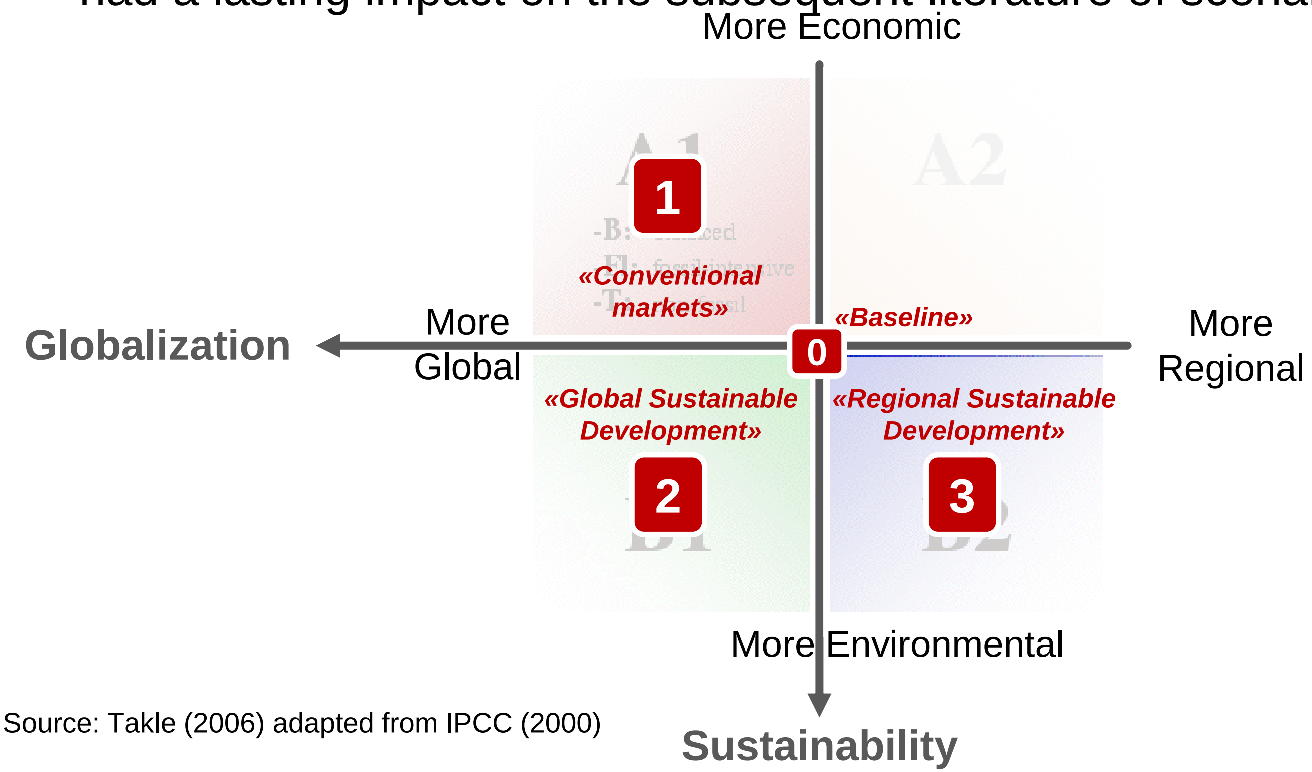


Challenges and Opportunities

- **Future scenarios**: evaluating the system with different input data and assumptions to reflect future trends and provide general design guidelines (IPCC scenario matrix).

IMES scenario development is based on the two axes of the well-established IPCC SRES scenarios

- Intergovernmental Panel on Climate Change's (IPCC) *Special Report on Emissions Scenarios (SRES)* from 2000 is the key reference in scenario development/analysis with more than 5000 citations
- The scenarios are based on four narrative storylines (A1, A2, B1, B2) that had a lasting impact on the subsequent literature of scenario analysis



Source: Takle (2006) adapted from IPCC (2000)

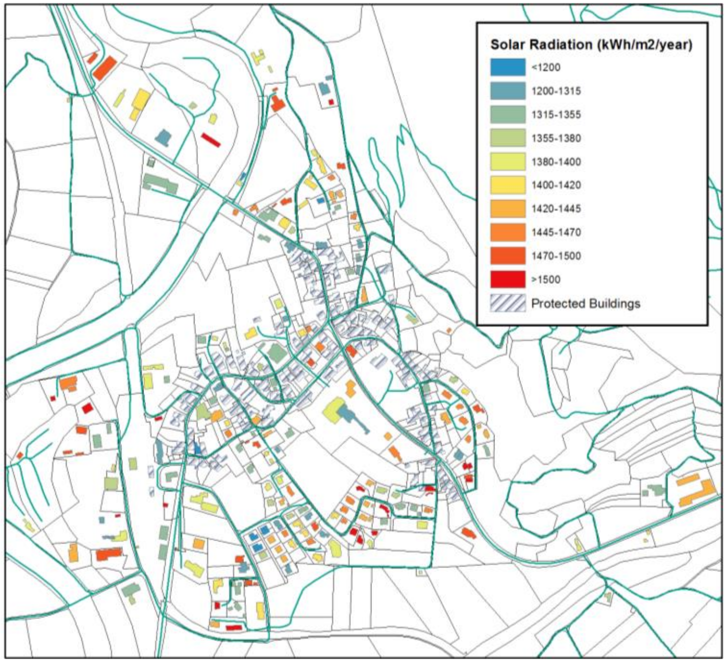
Three scenario profiles were defined to describe the potential developments to 2020, 2035 and 2050

	0	1	2	3
	2015	*2020 – 2035 – 2050*	*2020 – 2035 – 2050*	*2020 – 2035 – 2050*
Name	*«Baseline»*	*«Conventional markets»*	*«Global Sustainable Development»*	*«Regional Sustainable Development»*
Logic	2015 levels (as-is)	Global markets that are well connected, RES deployment remains on a low-level. (cf. «business as usual»)	Global markets that are well connected, fossil phase-out, high RES deployment in centralized settings	Local/decentralized systems with high RES share, fossil phase-out
Variables - excerpt -				
Energy prices (e.g. electricity, gas, oil)	as-is	low	medium	high
Feed-in tariff	as-is	low (fast phase-out)	high	medium (slow phase-out)
CO2 tax	as-is	low (as-is)	high	high
Demand reduction	none	low/none (as-is)	medium-high (efficiency)	medium-high (efficiency)
Technology cost	as-is, medium	RES high, fossil-fueled low, others medium	RES low, fossil-fueled medium (as-is), others medium	RES low, fossil-fueled medium (as-is), others medium
Tech. performance	as-is, medium	RES as-is, fossil-fueled high, others medium	RES high, fossil-fueled as-is, others medium	RES high, fossil-fueled as-is, others medium

Case Studies

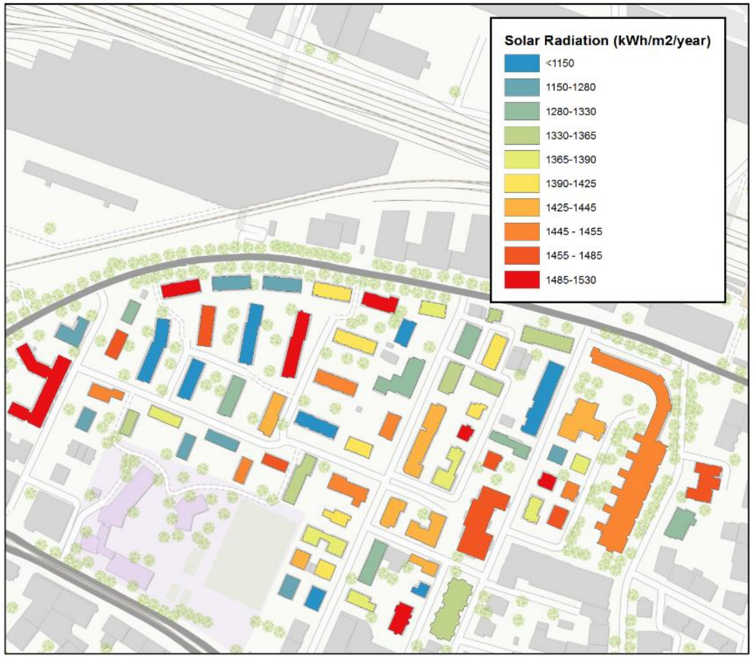
Zernez: 305 buildings, 1150 inhabitants

- Mix of single and multi family homes
- Other buildings include primarily shops, hotels, and agricultural buildings
- Small-hydro, solar, and some wind available
- 25200 m2 of rooftop area available



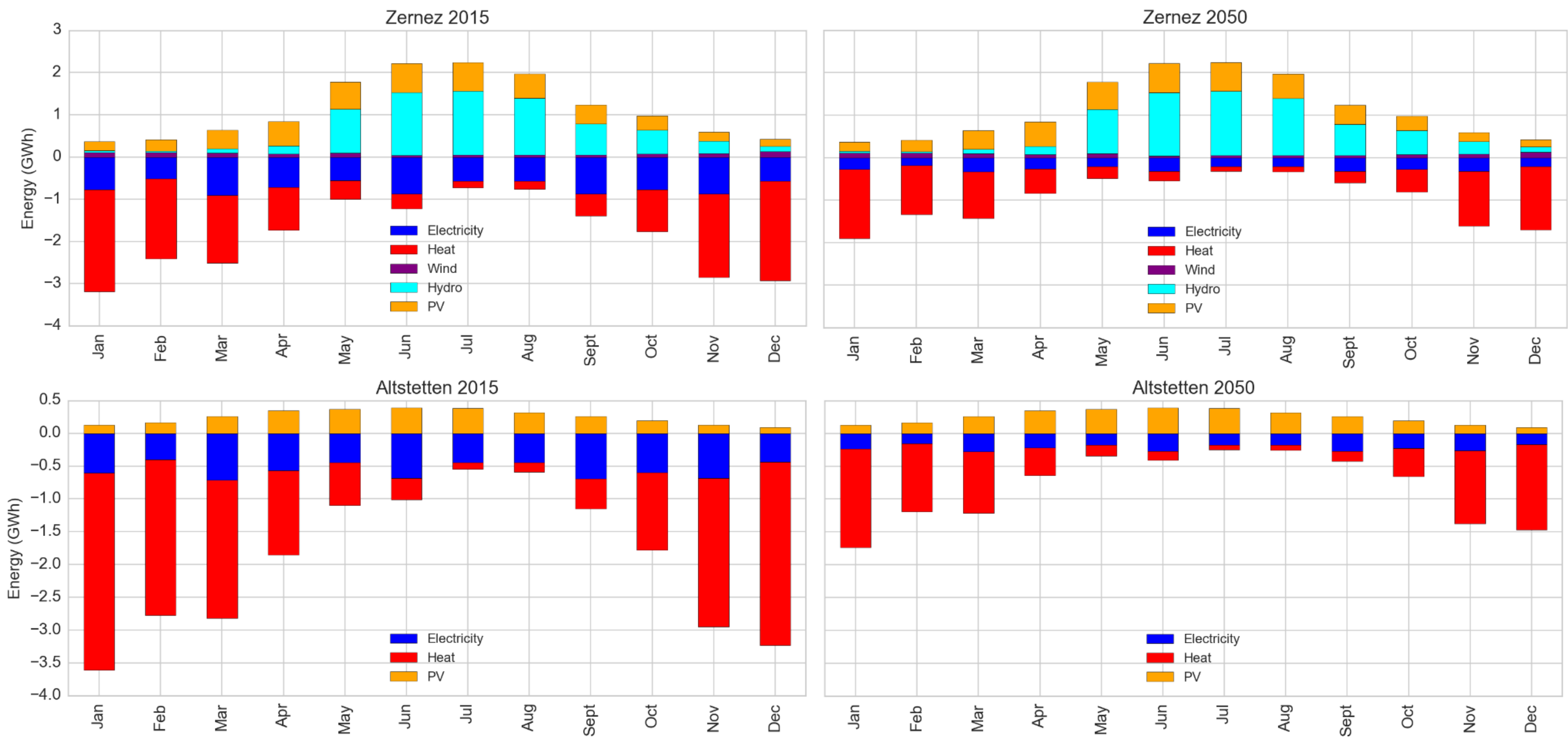
Altstetten: 77 buildings approximately 1784 inhabitants in residences

- Almost all residences multi-family homes
- Only solar PV available as renewable resource
- 12080 m2 of rooftop area available

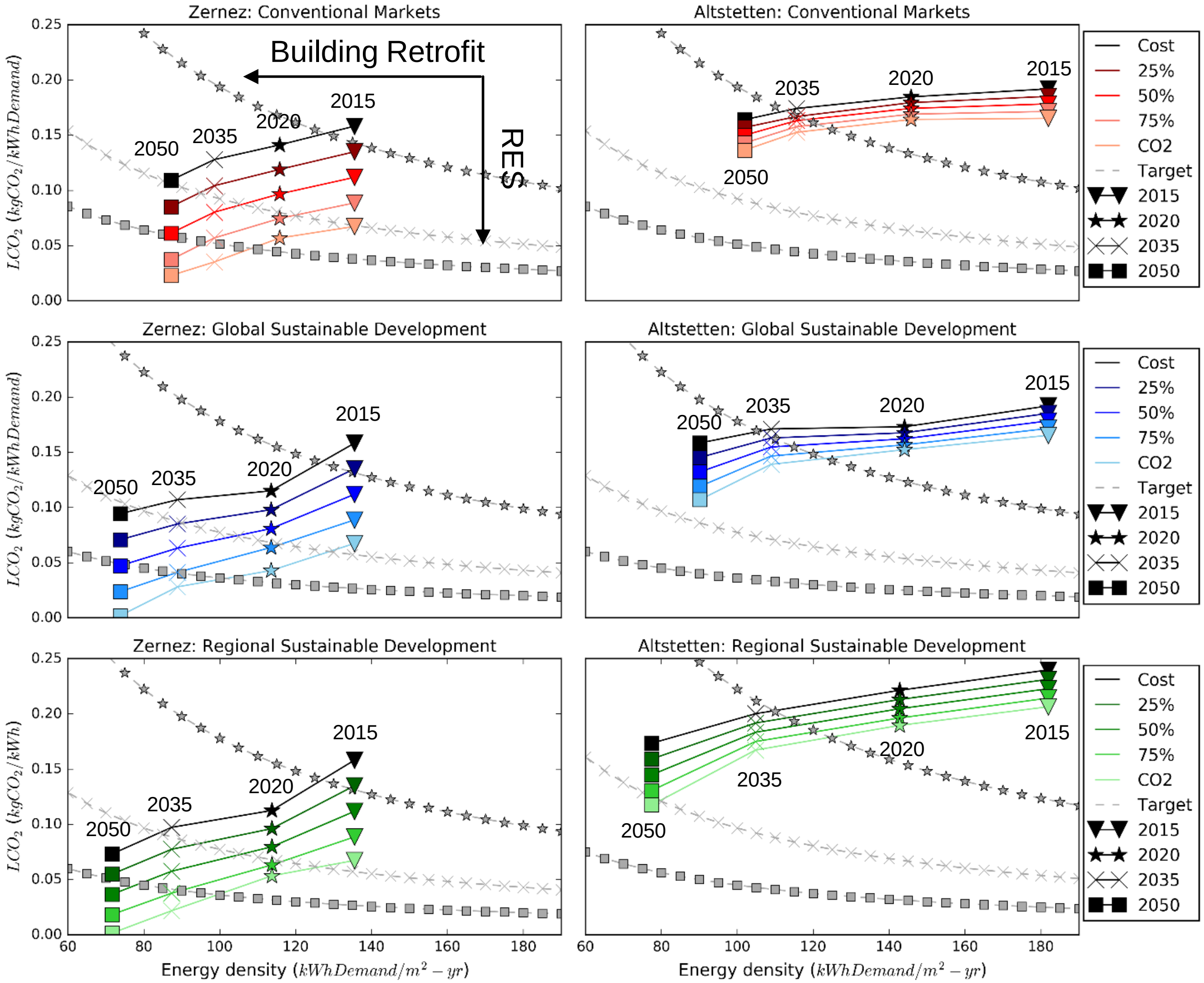


Optimization Model Input Data

- Energy demand predicted to decrease over time, but renewable potential will remain approximately the same
- Renewable surpluses will increase over time



Comparison with 2050 Emissions Targets



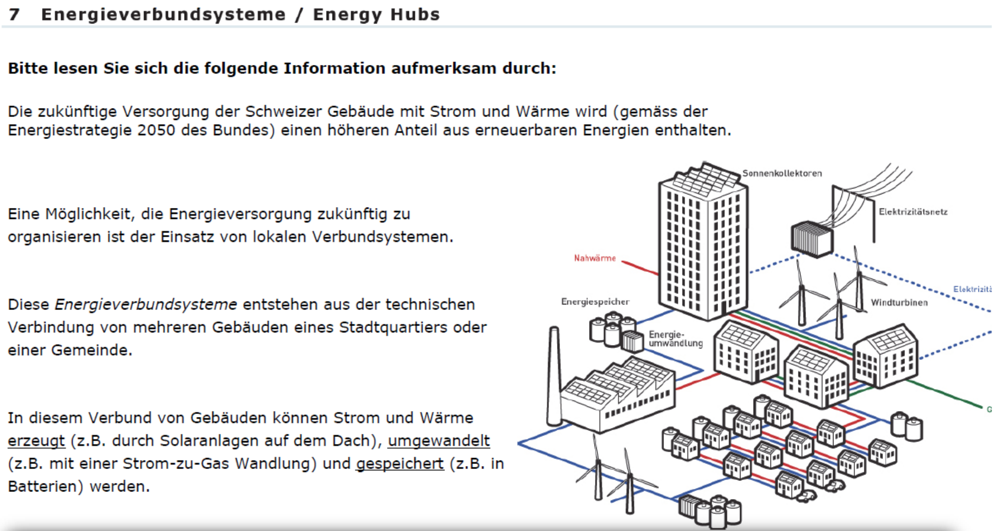
- Multi-objective optimization reducing emissions and cost
- Solutions benchmarked against CO_2 targets in kg/m2
- Both building retrofit and RES important to meet targets

IMES-SE: Challenges and Opportunities

- **Future scenarios**: evaluating the system with different input data and assumptions to reflect future trends and provide general design guidelines (IPCC scenario matrix).
- **Social acceptance** of multi-energy hub systems in Switzerland (N=1088) and Europe (Germany, 536; Austria, 530) to provide guidelines to improve their deployment.

From theory to practice: social acceptance

- Survey completed in
  - Switzerland (*N* = 1088)
  - Germany (*N* = 536)
  - Austria (*N* = 530)


7 **Energieverbundsysteme / Energy Hubs**

Bitte lesen Sie sich die folgende Information aufmerksam durch:

Die zukünftige Versorgung der Schweizer Gebäude mit Strom und Wärme wird (gemäss der Energiestrategie 2050 des Bundes) einen höheren Anteil aus erneuerbaren Energien enthalten.

Eine Möglichkeit, die Energieversorgung zukünftig zu organisieren ist der Einsatz von lokalen Verbundsystemen.

Diese *Energieverbundsysteme* entstehen aus der technischen Verbindung von mehreren Gebäuden eines Stadtquartiers oder einer Gemeinde.

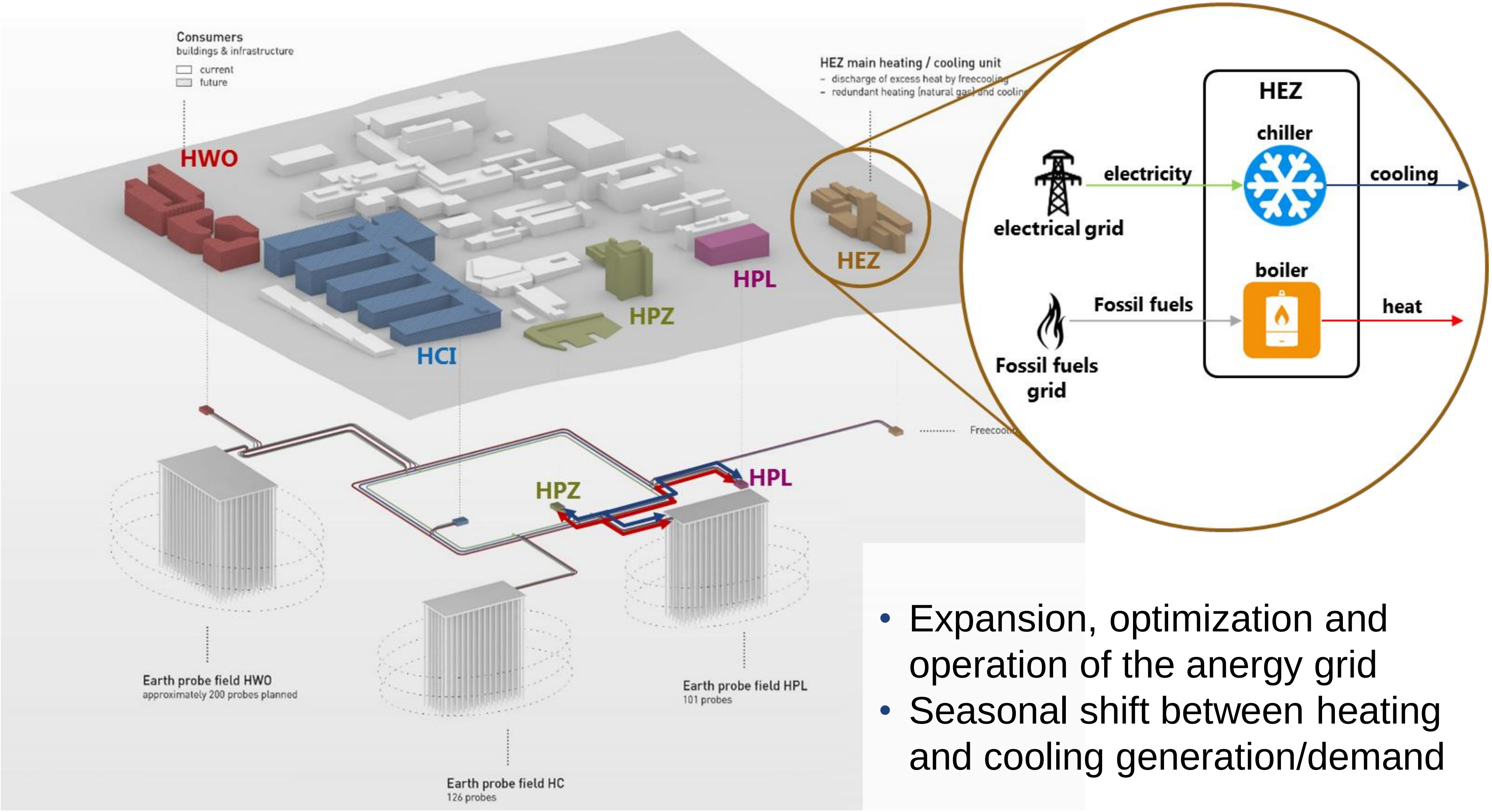
In diesem Verbund von Gebäuden können Strom und Wärme erzeugt (z.B. durch Solaranlagen auf dem Dach), umgewandelt (z.B. mit einer Strom-zu-Gas Wandlung) und gespeichert (z.B. in Batterien) werden.

Swiss people are generally positive towards multi-energy-hub systems and perceive the Swiss Federal office of Energy (SFOE) as the main responsible for the energy transition

Challenges and Opportunities

- **Future scenarios**: evaluating the system with different input data and assumptions to reflect future trends and provide general design guidelines (IPCC scenario matrix).
- **Social acceptance** of multi-energy hub systems in Switzerland (N=1088) and Europe (Germany, 536; Austria, 530) to provide guidelines to improve their deployment.
- **Portability**: in principle the developed methodology can be applied to any case-study, provided the required input data are available. Possible application to the anergy grid installed at ETH Hönggerberg.

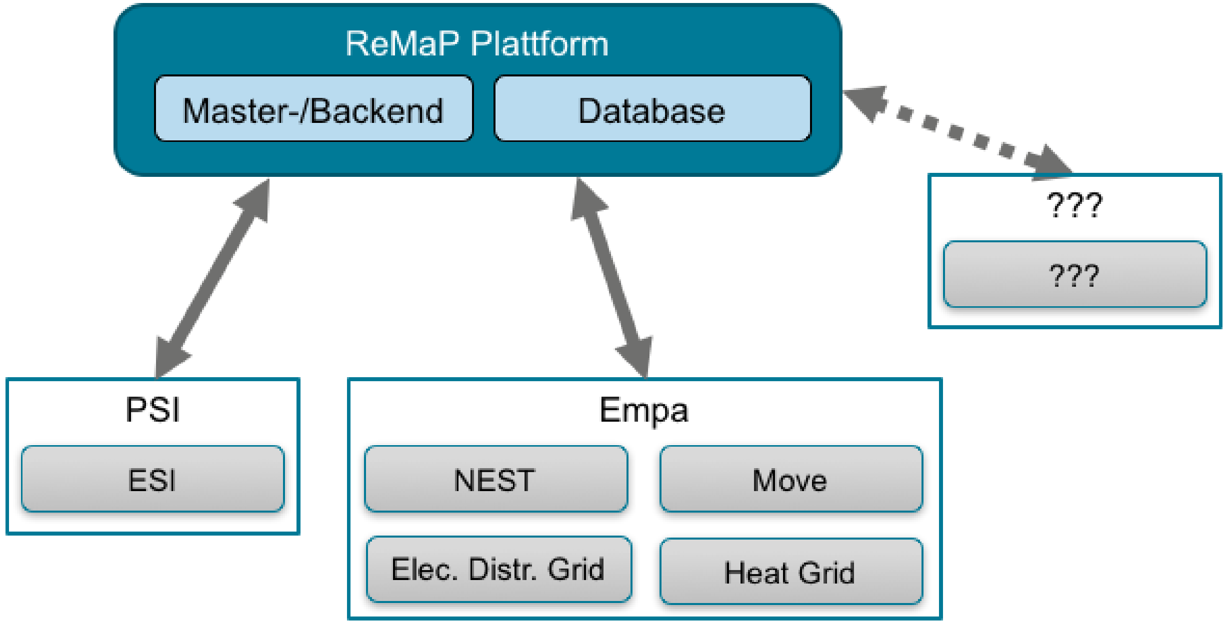
Portability: Anergy Grid of ETH Hönggerberg



- Expansion, optimization and operation of the anergy grid
- Seasonal shift between heating and cooling generation/demand

ReMaP Project

- ReMaP will enable the testing, analysis and optimization of multi-component, multi-energy carrier systems on the distribution level
- Collaboration of multi-disciplinary research teams from both academia and industry
- Provide control and communication infrastructure for the joint operation of existing platforms and demonstrator sites.



ReMaP Phase 1 Experiments:

- Distributed / Dynamic State Estimation of distribution grids
- Power System / Load modelling
- Reliability Assessments
- Dynamic Housing Stock Model
- Evaluation of CHP swarms
- Battery Storage
- Power Electronic Test Bench

Key Messages

- Multi-energy-hub systems (MES) for residential neighborhoods **can be economically and environmentally competitive** with conventional solutions, when designed, optimized, operated and controlled **using the integrated methodology developed**, tested and implemented within the IMES project.
- **The developed methodology delivers different multi-energy-hub systems-based** solutions, tailor-made to meet the goals of the Swiss Energy Strategy 2050, for the resources, demands and constraints of different types of neighborhoods.
- Integrated MES lead to **increased efficiency, complexity and inter-dependence**, that have to be addressed through multi-stakeholder processes.

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