Cellular Energy Systems – An Approach to Planning and Operating Future's Hybrid Energy Systems

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Introduction

- **Hybrid energy system will be the future**
  - RES generation
  - Thermal backup generation
  - Storages
  - Sector coupling (including storages, thermal, gas, ….)
- **New demands**
  - Electric mobility
  - Heat pumps
  - Synthetic energy carriers

Motivation

- Dispersion & number of active system participants @ low system levels
- Degrees of freedom
- Spatiotemporal divergence between generation and load
- Limited grid capabilities
- Expensive storages
- Slow grid extension
- Market integration of new technologies
- Utilization of flexibilities on all system levels

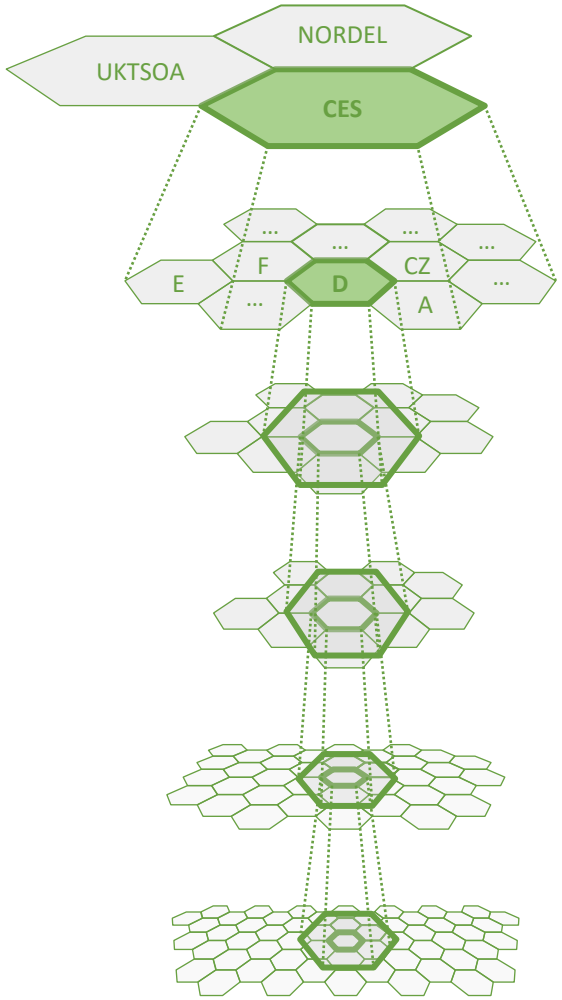
⇒ Optimization problem is not solvable

Idea

- **Reduction of system complexity**
  - Partitioning into subsidiary units
- **Efficient utilization of flexibilities & sector coupling**
  - Technologically
  - Economically
  - Organizationally
- **Trade-Off between flexibility provision and transmission**
  - Economic evaluation
- **Holistic market concept**
  - Economic incentives for efficient operation

Energy Cells

- **Spatially delimited**
  - Electrical grids
  - Ownership
- **Control entity**
- **No implication of autonomy**
  - Im- and export as economically reasonable
  - But technically restricted
- **Hierarchically ordered**



Working Principle

System Level

Based on local optimization results of cells
Transmission across cells
System responsibility
Ancillary services
Result: best possible optimization result

CLOSED, CENTRAL OPTIMIZATION IMPOSSIBLE

SYSTEM-WIDE UNIT COMMITMENT

Cell Level

Load and generation forecasts
Utilization of flexibilities
Interactions with superior/inferior cells
Result: single power-cost function

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Markets

- **Hypothesis: Using economic measures to impact actors' behaviours lowers overall system cost**
- **Market structure following cellular design**
  - Limitation of communication partners of each cell
- **Economic incentives**
  - Grid congestions
  - Flexibility utilization
  - Energy transmission

The Cellular Approach and Today's Hybrid Energy Systems

- **Islands or remote areas**
  - Renewable generation
  - Conventional backup
  - Storages
  - Connections to other systems

⇒ **Prime field of application**

- **Cellular approach: One option to determine the optimal utilization of local portfolio**
- **Unified system concept may support investment decisions in an ever more complex environment**

Scientific questions

- **Proof-of-concept**
  - Efficiency
  - Techno-economic feasibility
- **Market organization**
  - Convergence
  - Trade on low hierarchical levels
- **Operational principles**
- **Trade-off: Local balancing vs. energy transmission**
  - Investment in flexibilities, storages, and sector coupling or grid infrastructure?

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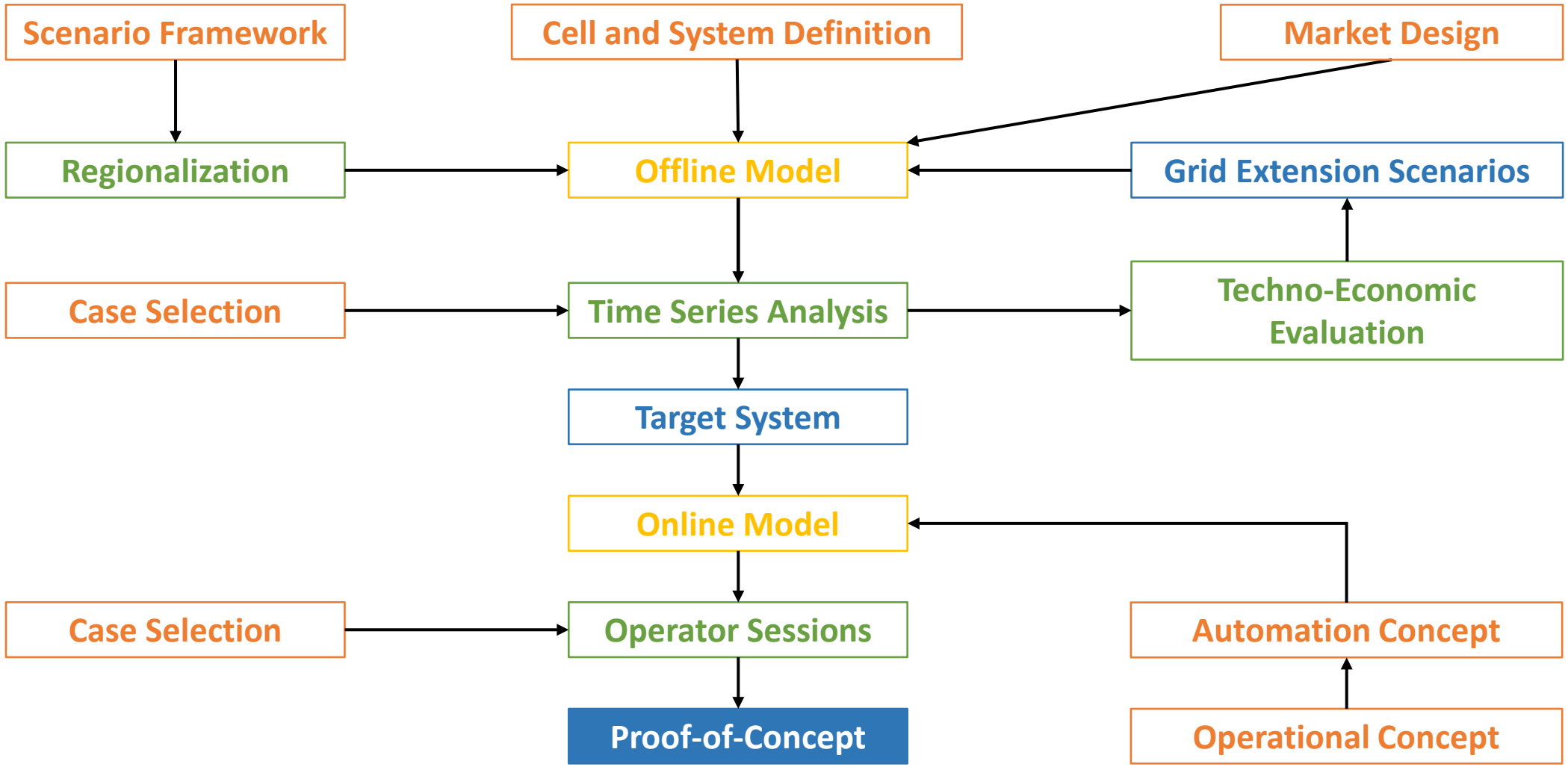
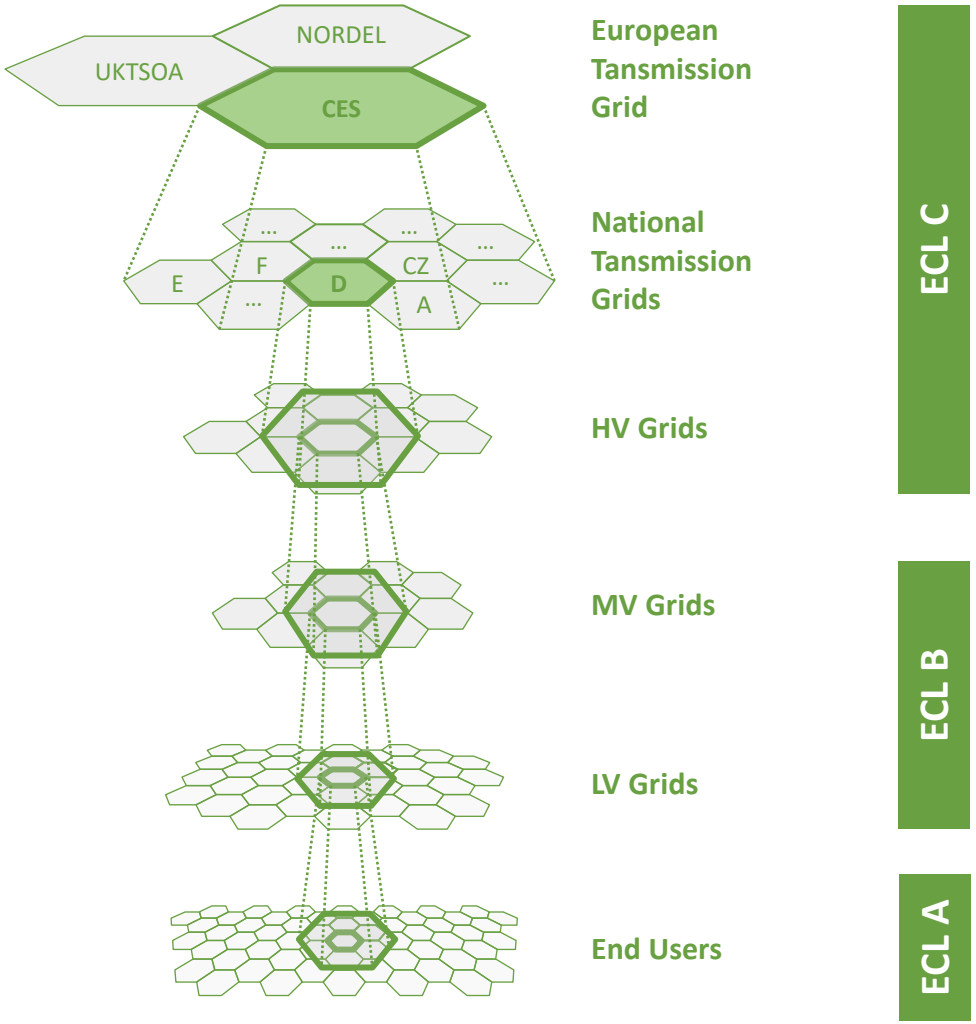
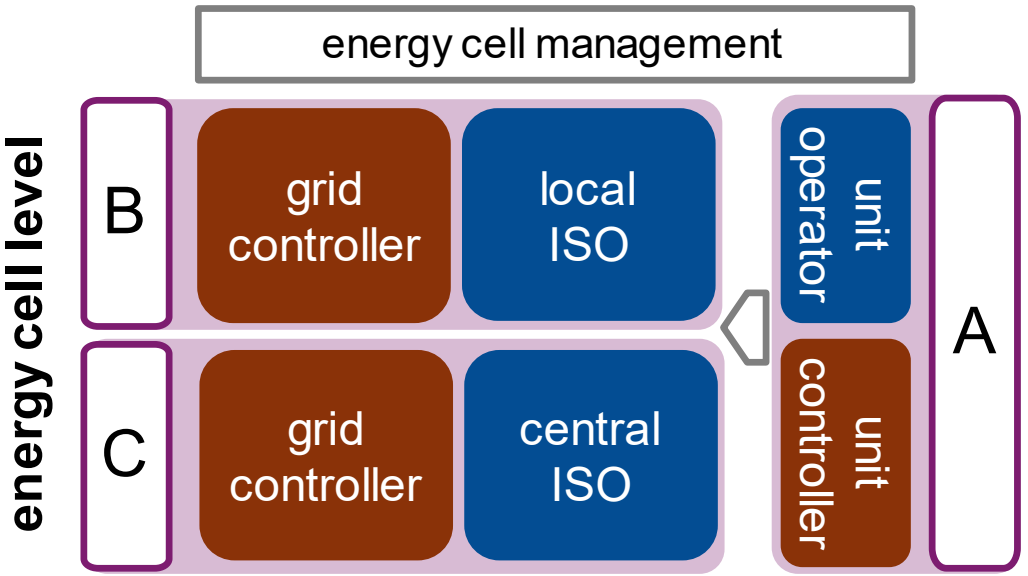
Project overview

Results from groundwork
Simulation model
Result
Workflow

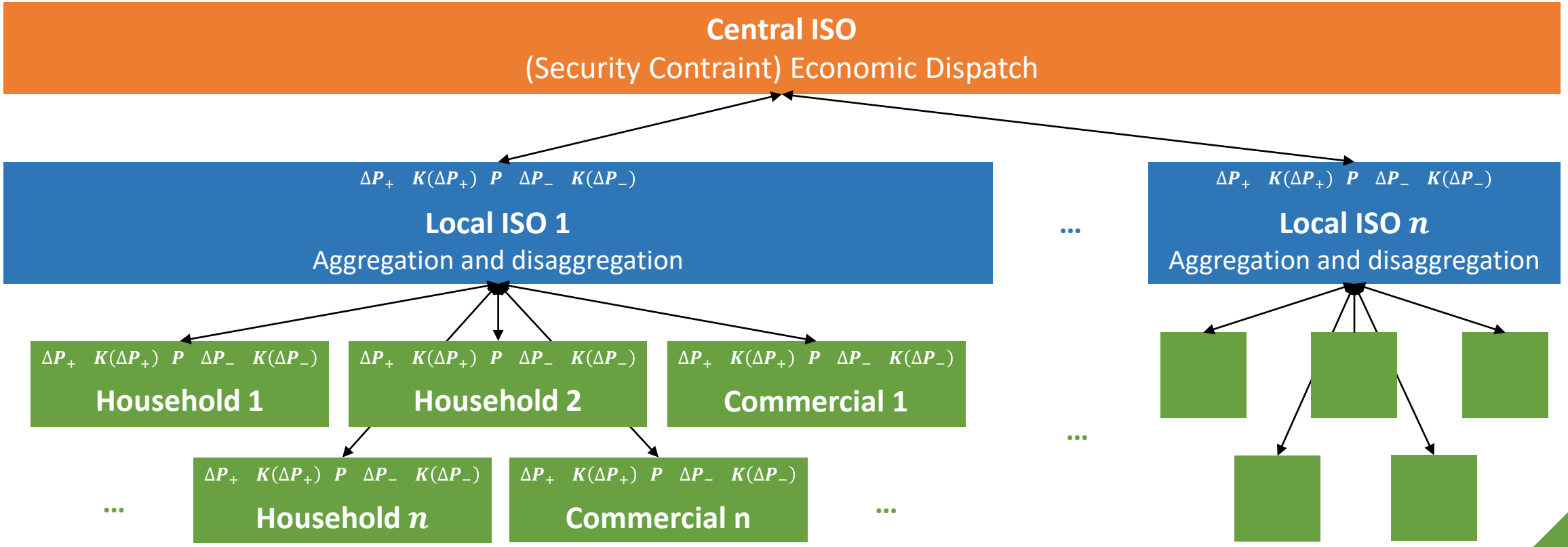


Delimitation & Cell Management

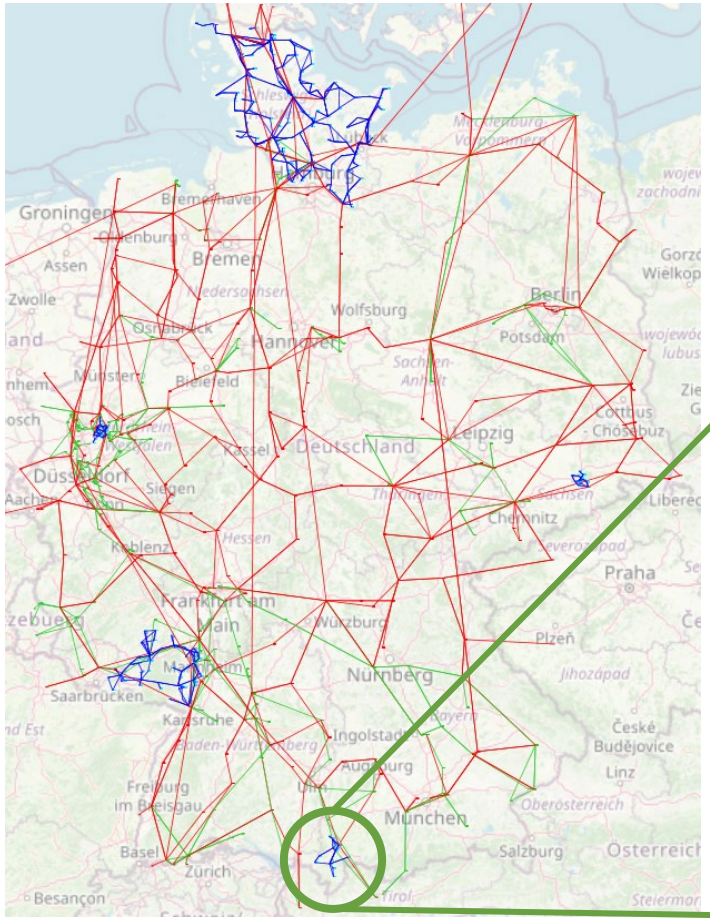


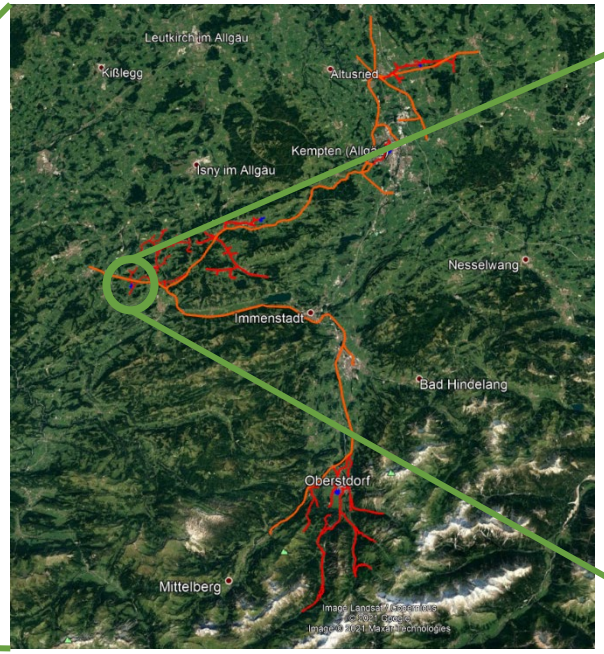


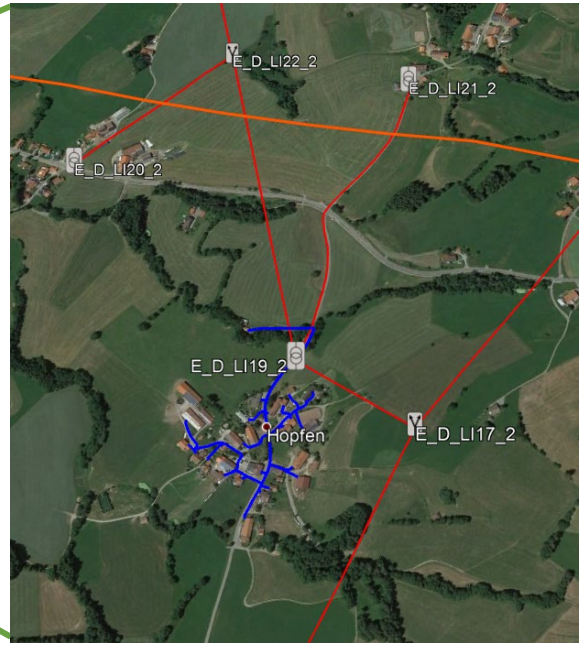
Market principle



Geoscope







TOTAL SYSTEM SCENARIO			
PV:	159 GW	Heat pumps:	120 GW_{th}
Wind onshore:	167 GW	BEV:	30 Mio.
Wind offshore:	28 GW	PtG:	53 GW
Biomass:	10 GW	El. Backup:	147 GW

380 kV/HVDC
220 kV
110 kV

110 kV
20 kV
0,4 kV

Map: Google Earth

Upcoming Presentations

- **Regulatory and Policy Aspects for a Cellular Design of Electricity Markets**
  - A. Schinke-Nendza, G. Blumberg, A. Khalid, C. Weber (University of Duisburg-Essen, Germany)
- **Initial Case Studies Conducted on Cellular Energy Systems on the District Level**
  - B. Uhlemeyer, M. Becker, J. Garzón-Real, T. Mueller, M. Zdrallek (University of Wuppertal, Germany)
- **The Problem of Resilience in Multi-carrier Cellular Systems: Responsibilities and Regulation**
  - G. Hawker, K. Bell (University of Strathclyde Glasgow, United Kingdom)

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