Decentral Energy Markets and Locational Price Signals

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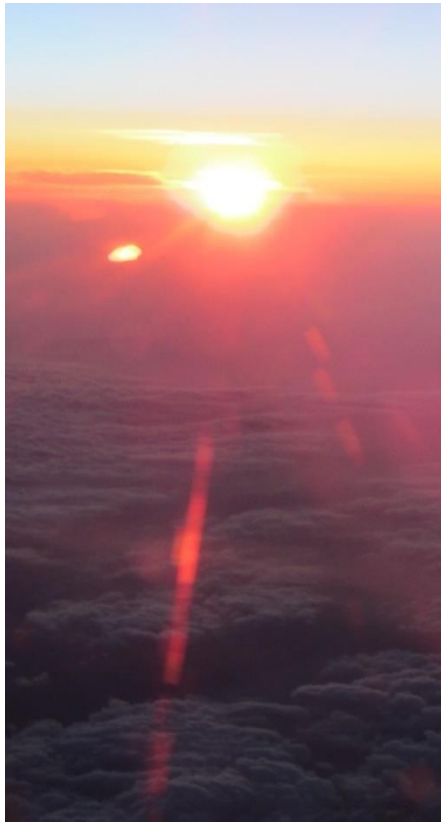
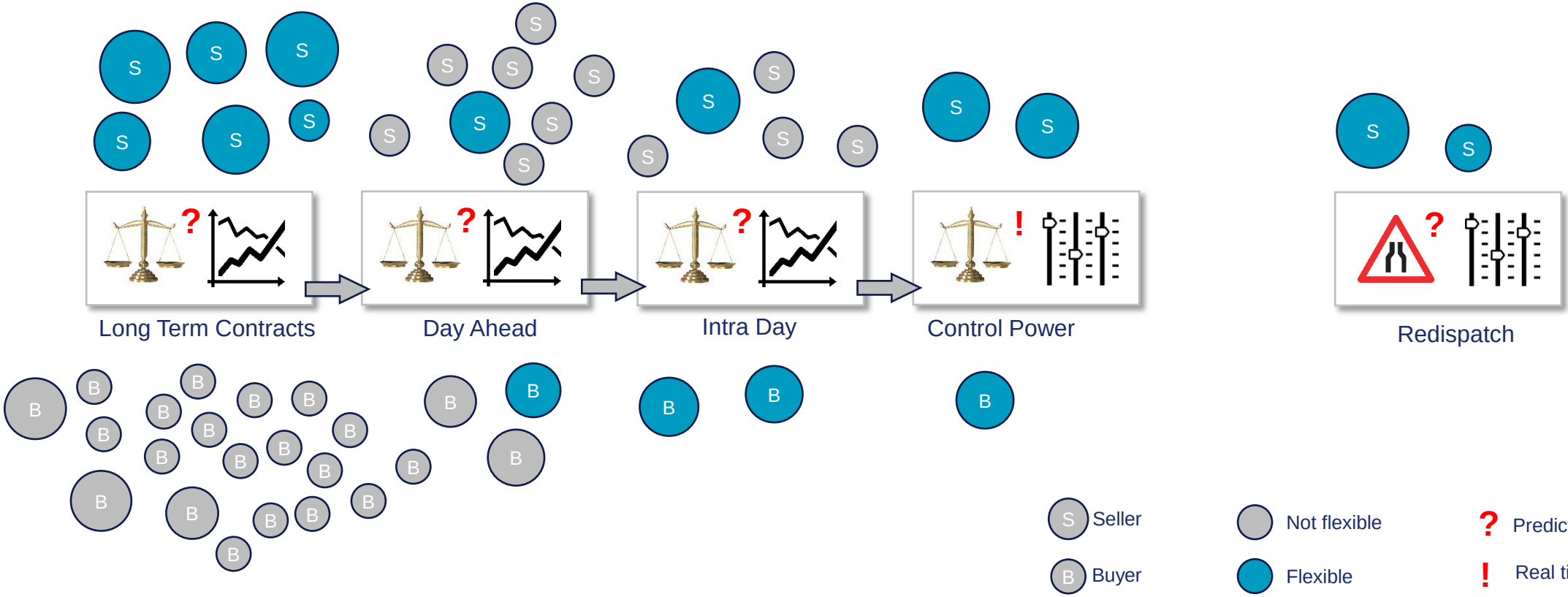


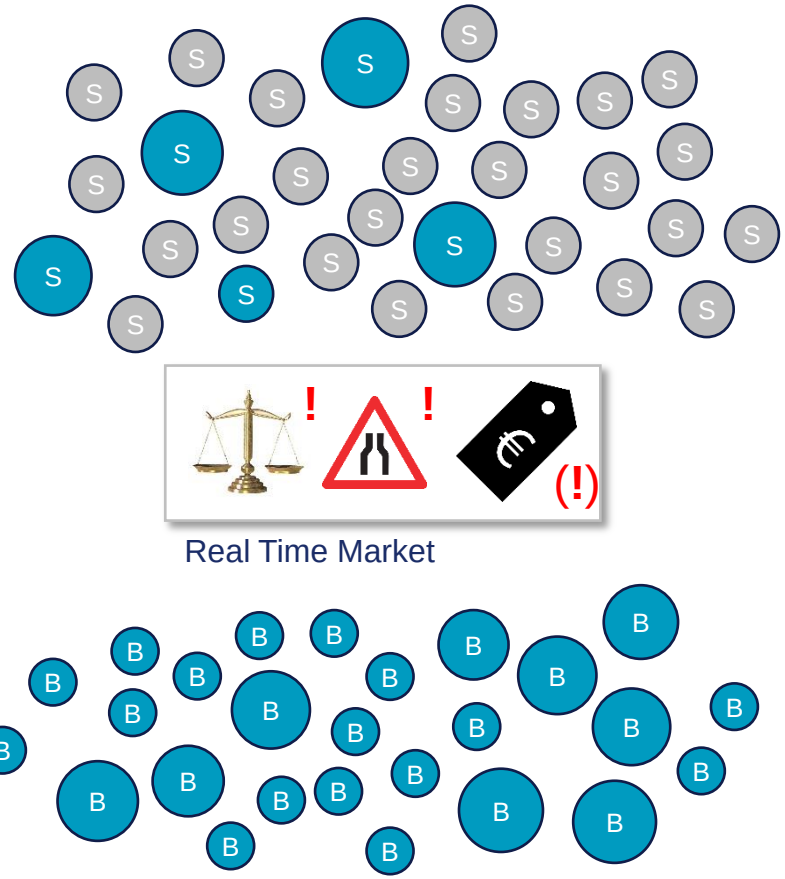
Agenda

1. ESG positioning and technology
2. Grid-supportive locational and temporal prices
3. Vision and opportunities

The Transformation Challenge
Market designed for „old“ actors



Our Answer to Transformation Challenge
Enable integration of „new“ market actors

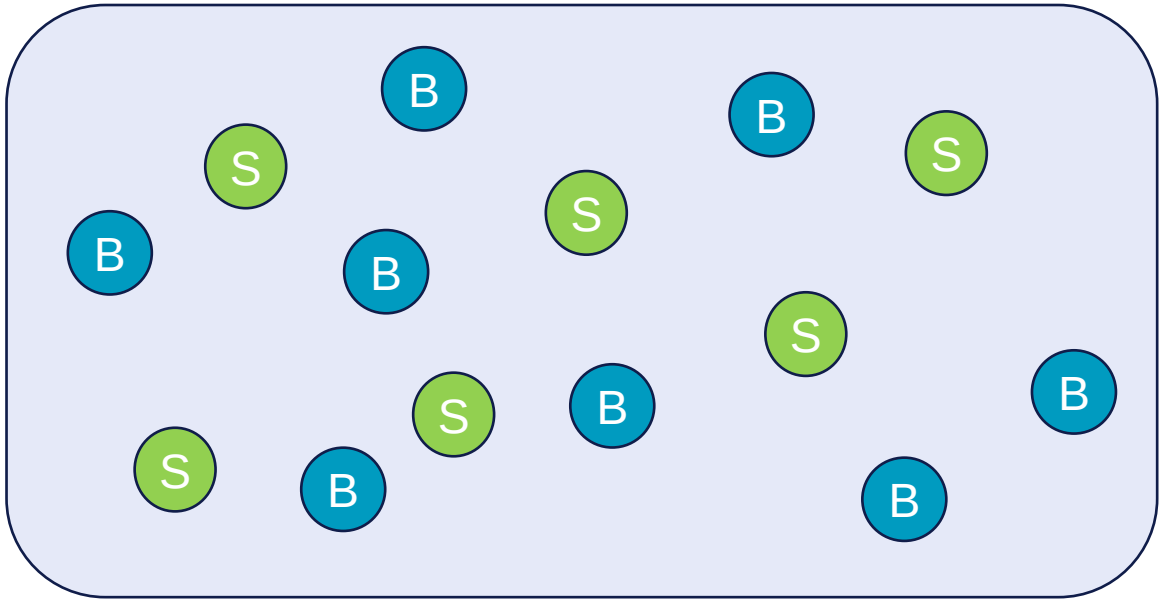


- ✓ Price signals reflect temporal and local grid state (overcome divergence market/physics)
- ✓ Market participants „trade“ by switching on or off
- ✓ Smart agents of buyers and sellers make predictions to optimize benefit:
  - ✓ Sellers go to high price times
  - ✓ Buyers go to low price times
  - ✓ Storage does market arbitrage
- ✓ Energy investments go to best match of temporal and locational profile
- ✓ Inc Dec gaming becomes impossible

S Seller
Not flexible
? Prediction
B Buyer
Flexible
! Real time value

A single measurement allows detection of market imbalance

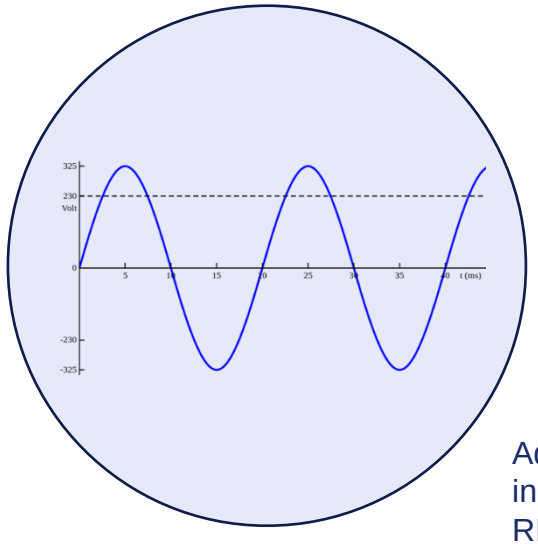
Sellers and Buyers in Decentralized Energy Market



Export energy:
P_n too high

Import energy:
P_n too low

Frequency changes by imbalance and inertia:
f up by exports,
f down by imports



Add virtual inertia in high RE scenario

Balance Indicator (BI) derived from power balance (coupled) or frequency (isolated market)

We combine four knowns components to build an efficient system

1. Walrasian Auctioneer

- Determine market balance by a „tatonnement process“ (TP)

2. Kirchhoff‘s Law (electricity markets only)

- The sum of all current flows in a grid node is zero

3. Maxwell‘s Equations (electricity markets only)

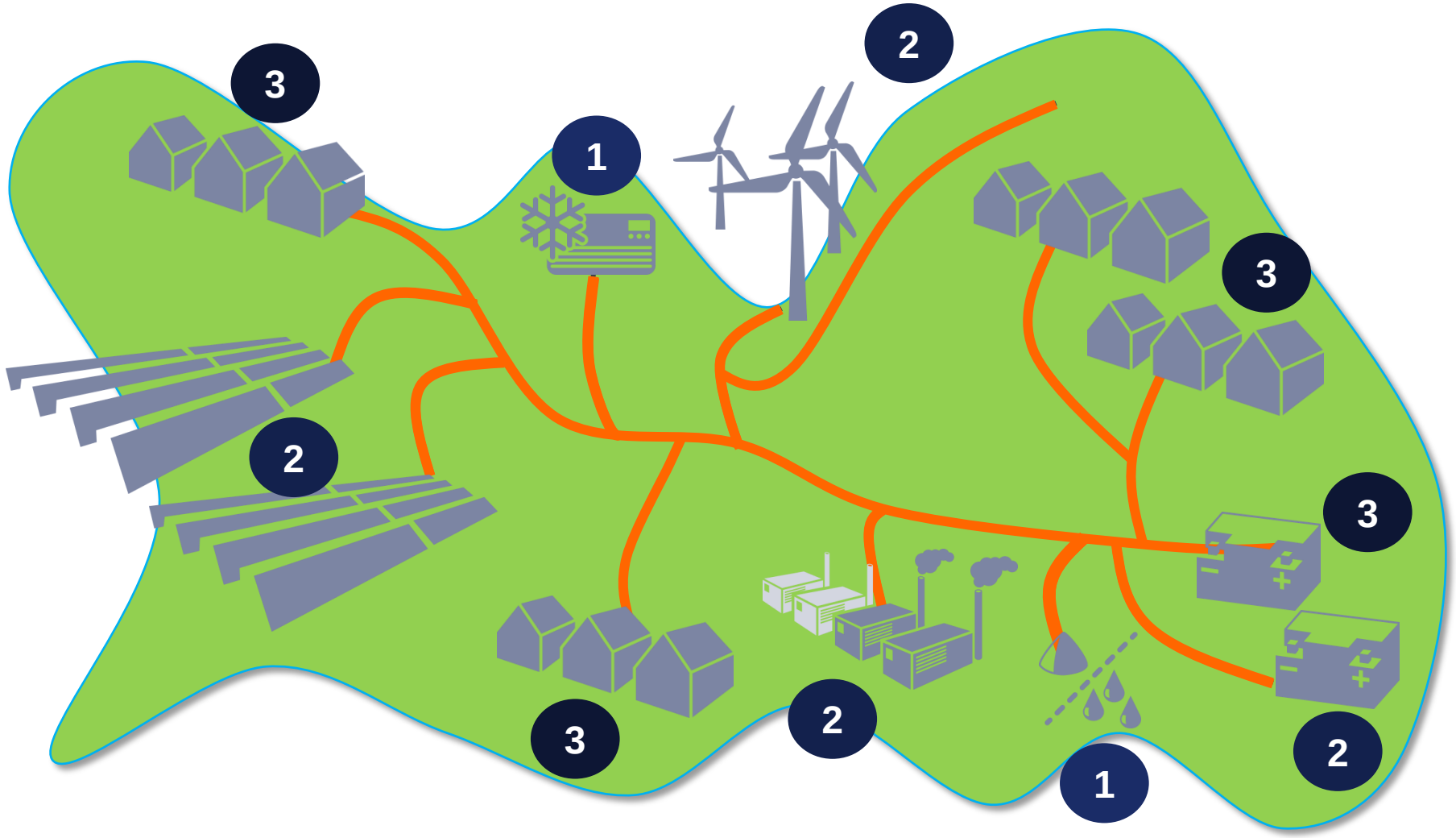
- Electro-magnetic field (= information) travels at c * speed of light

4. Successive Approximation (to implement TP)

- Compute P_{n+1} from P_n plus balancing error of last period n

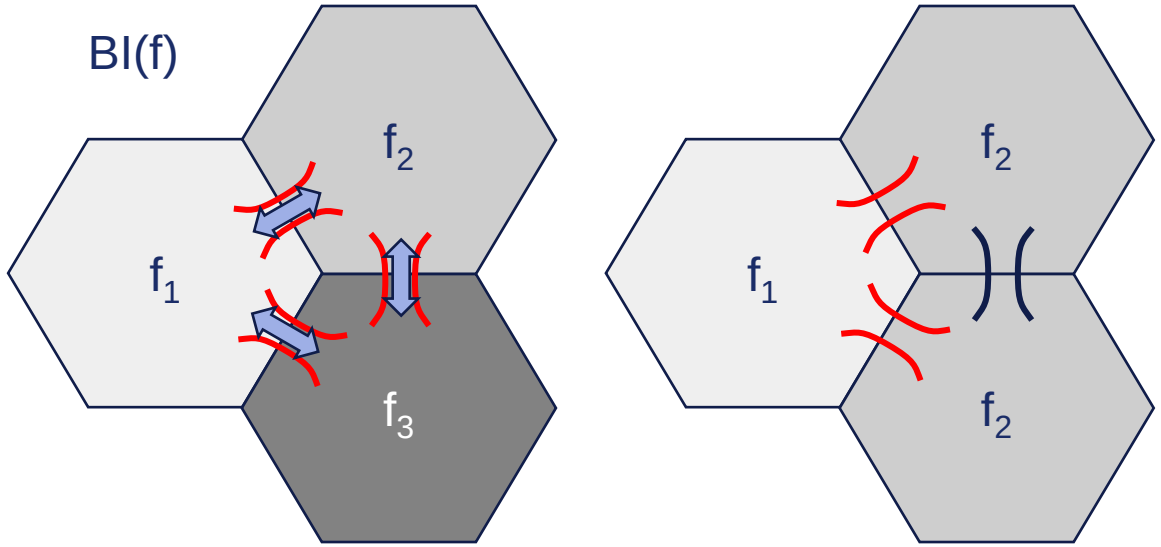
Update BI in real time!

Migrate Island or Isolated Grids
Less CAPEX and risk through RT market



1. **Implement BI(f)**
   - Integrate few large loads for less RE curtailment
2. **Increase RE share**
   - Install more RE and integrate more flexibility
3. **Full functionality**
   - Use all flexibility for stability and storage
   - No extra communication infrastructure, low cost agents, resilient and cyber secure

Construct „Cellular“ Grid by coupling several grid cells



Couple cells operating at different frequencies (prices)

Price (and frequency) differences disappear in absence of bottlenecks

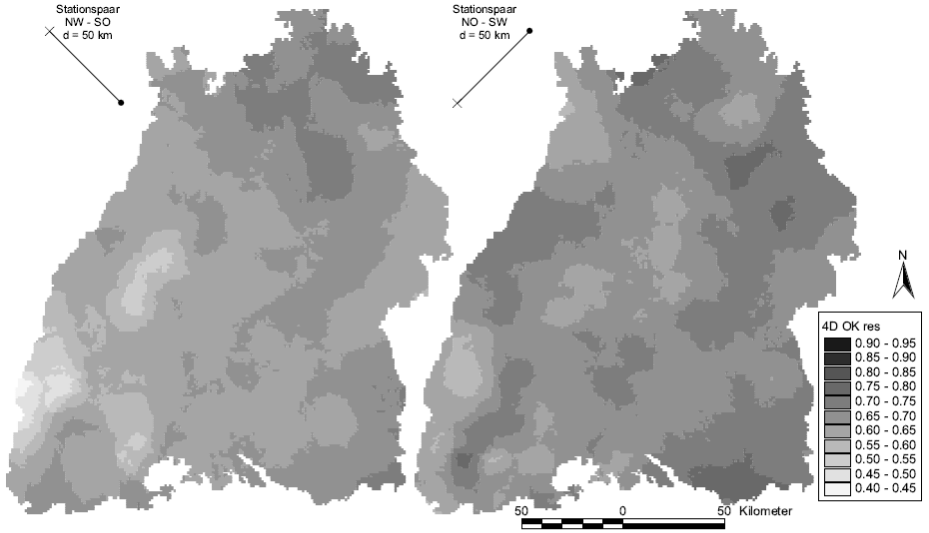


Abbildung 3.7.: Regionalisierte Korrelation zwischen Station und 50 km entfernter Station mit vierdimensionalem Ordinary Kriging der Residuen unter Verwendung eines dreiparametrigen exponentiellen und sphärischen Variogramm (Modell 7 in Tabelle 3.1.

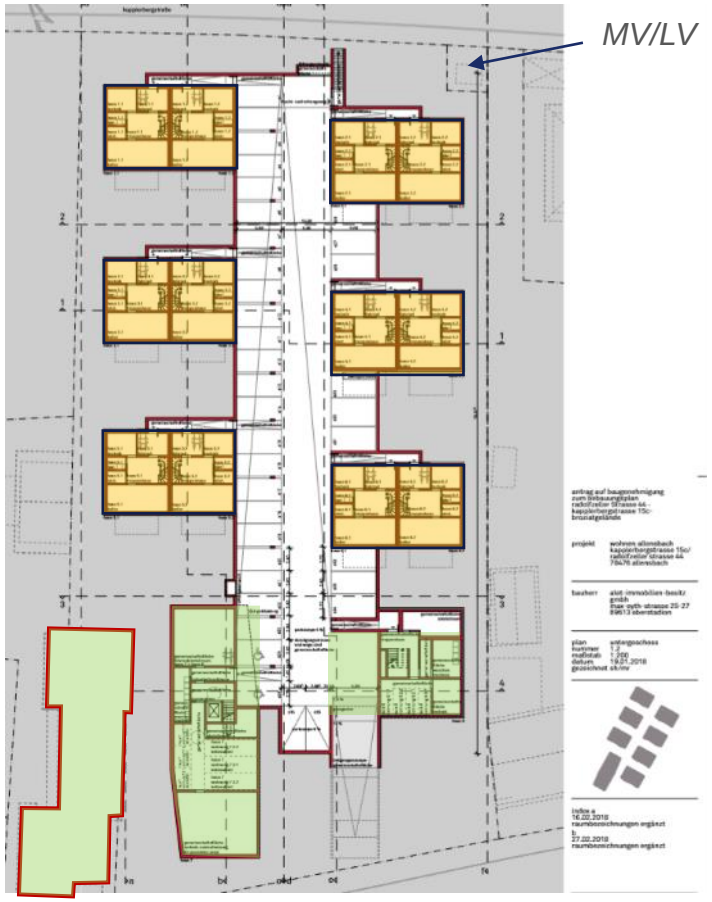
First estimate of cell size: weather correlation

Quelle Abbildungen: Dissertation Jürgen Brommundt, 2008 Institut für Wasserbau Uni Stuttgart, Download 20.08.2015, http://elib.uni-stuttgart.de/opus/volltexte/2008/3470/pdf/Brommundt_170_online.pdf
Wikipedia

Our „Real Lab“ Pilot
Site Outline Allensbach/D

MV/LV

North

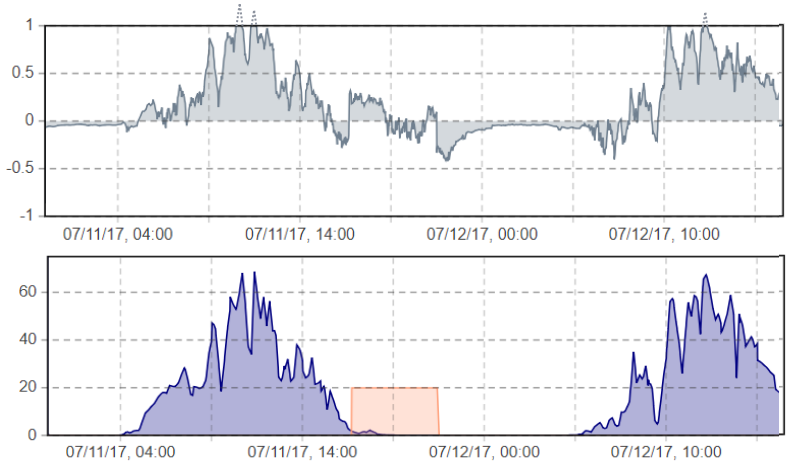


MV/LV

- 9 houses with 24 apartments
- insulation to KfW 40
- 14 PV plants (~70 kWp)
- 12 heat pumps
- 1 CHP
- up to 24 EV chargers
- batteries (KfW 40+)
- flexible household appliances (washing machines, dish-washers, dryers, fridges, freezers)

➔ up to 100 market participants

Simulated Results with “BI” as Price Signal
Summer Scenario

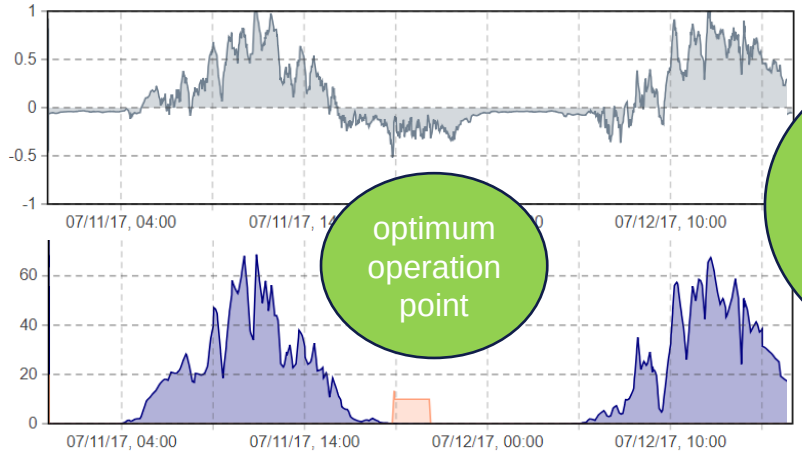


Balance Indicator BI

Calculated with **power** at grid connection point.
+1 = maximum feed
-1 = maximum supply

Generators

Electricity generation of PV plants ( ) and CHP ( )

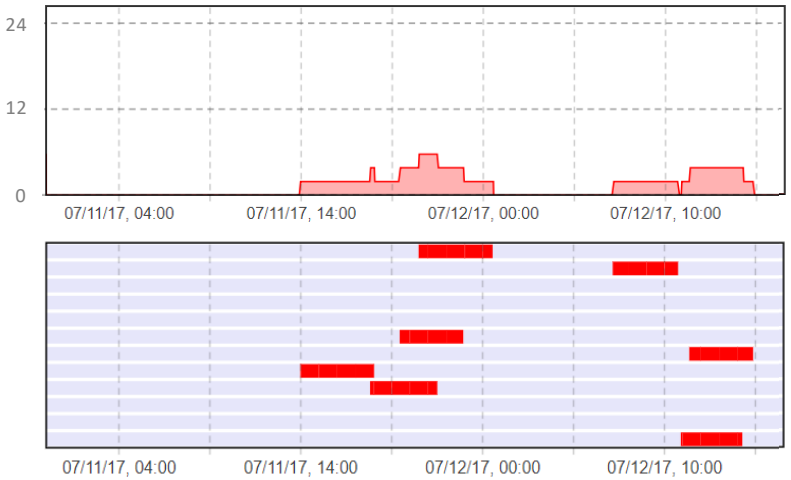


optimum operation point

CHP
100%
self supply

heat lead

Easy Smart Grid

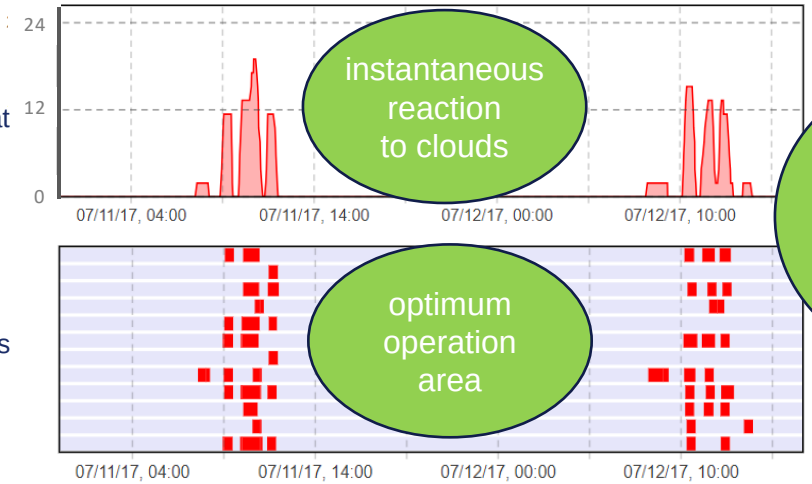


Σ Heat Pumps

Sum of power consumption of the heat pumps in 12 private houses

Heat Pumps

Switching decisions of the heat pumps in 12 private houses (warm water supply)

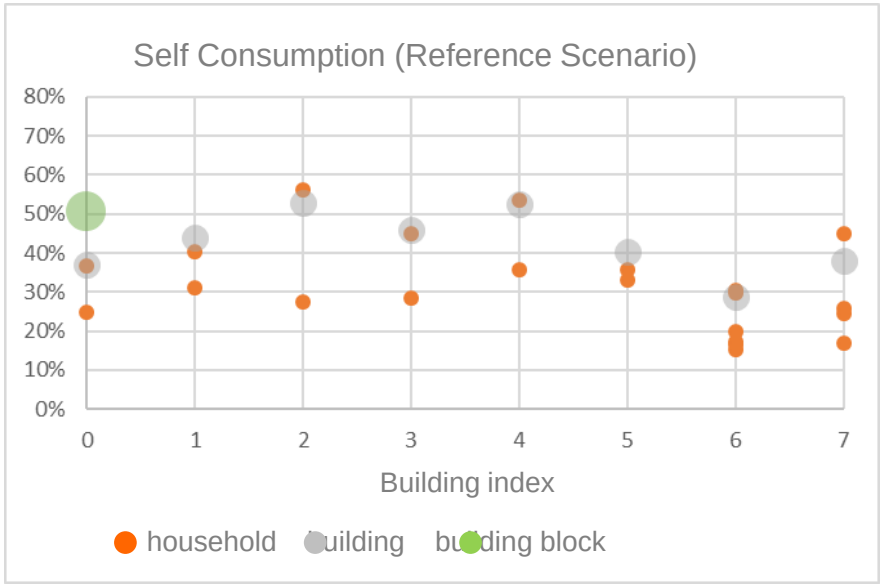


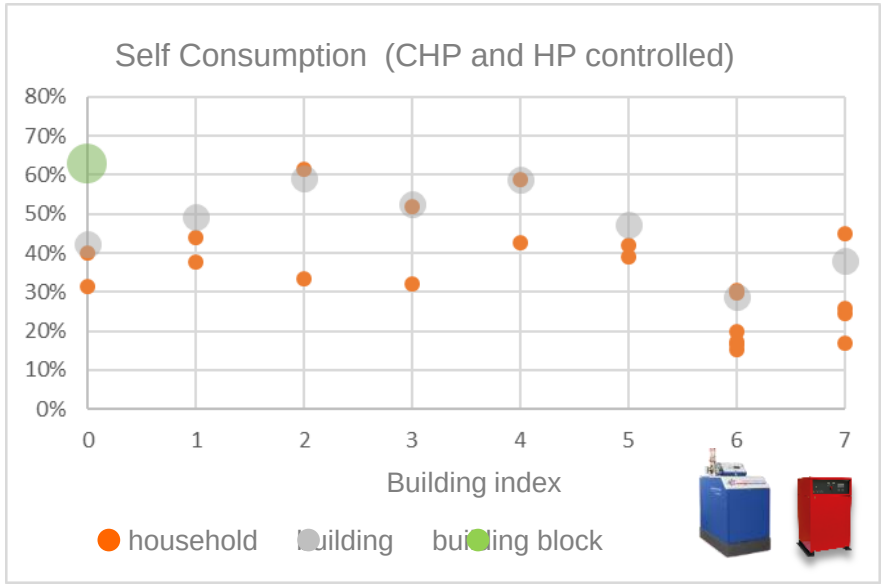
instantaneous reaction to clouds

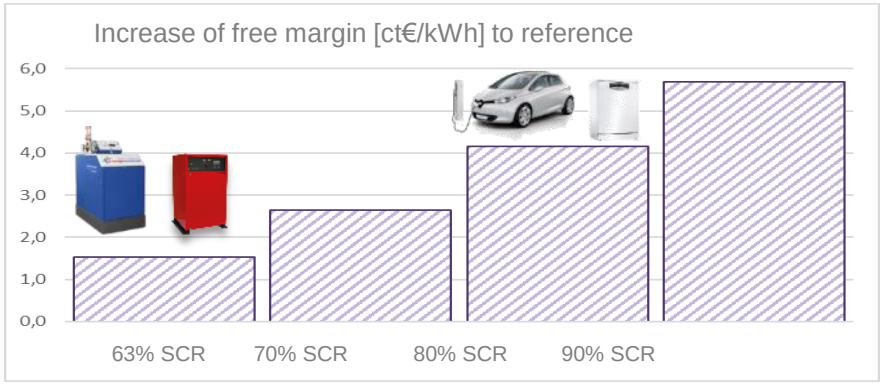
optimum operation area

heat pumps
100%
PV energy

Positive Effect for End Customers
Higher Self Consumption Rate and Margin







current
SCR increase
at LEM level
50% → 66%
(CHP and HP)

current
algorithm version
> 80%
of theoretical
optimum

project target
4 to 6 ct/kWh
free margin

target
technology cost
<< 1 ct/kWh

Virtual
Demonstrator

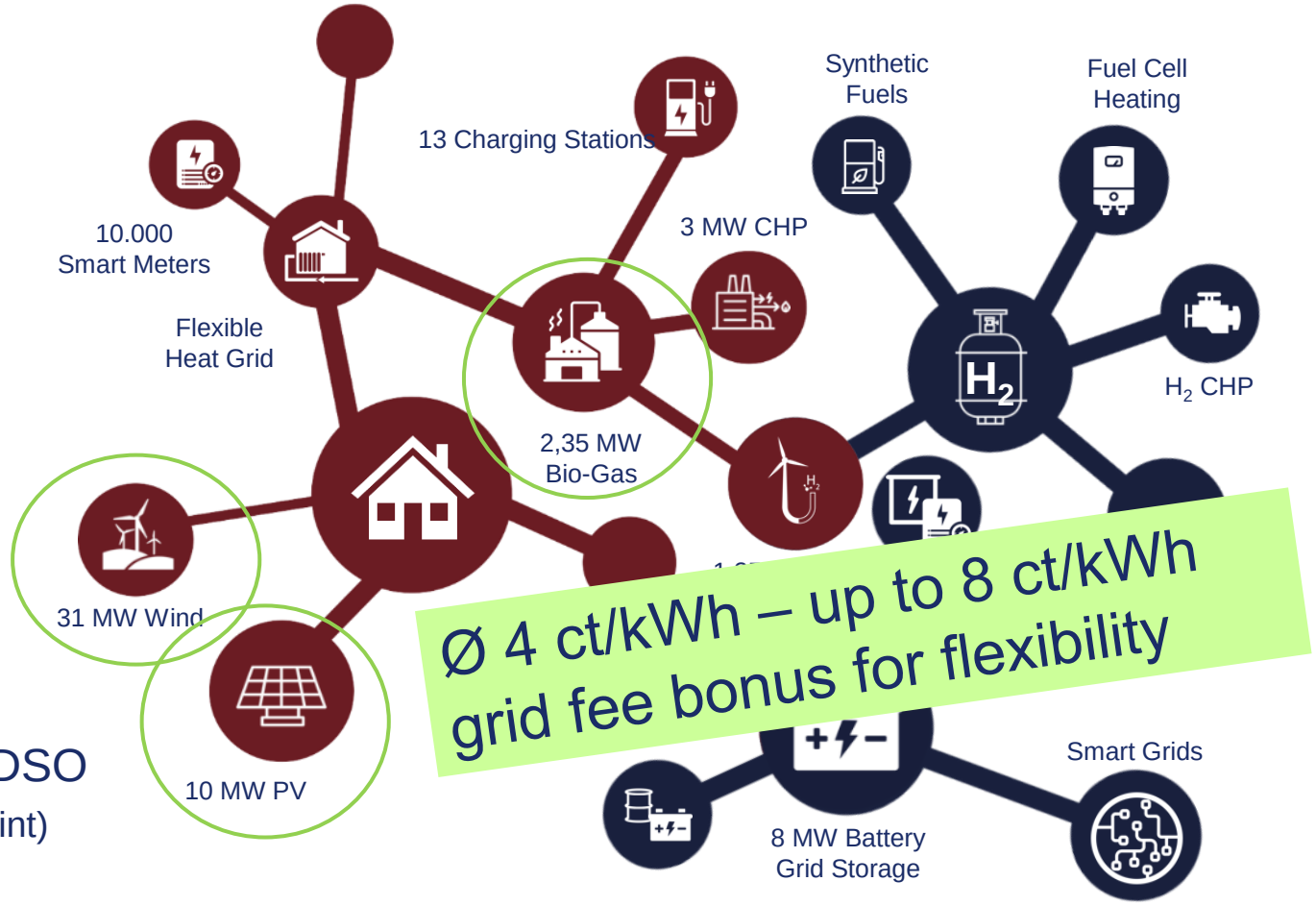
Result of
Simulation in
SoLAR Phase I

Next Step in Progress
Transfer to DSO Level

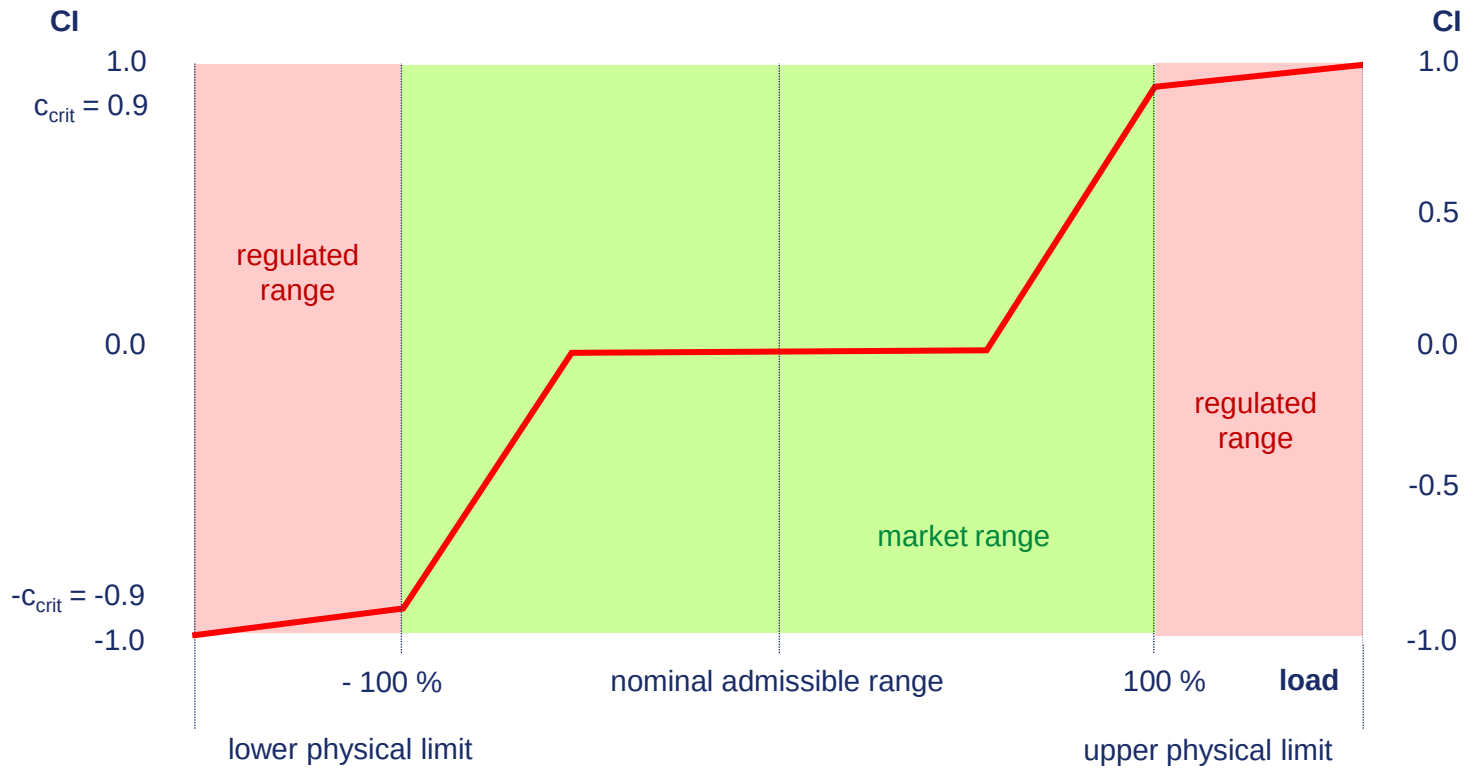
stadtwerk haßfurt

- 200% of annual demand served by local RE
- 38% of energy demand supplied by HV grid

➔ Reduce HV grid load and fees by matching supply and demand at DSO level (BI derived at HV/MV connection point)



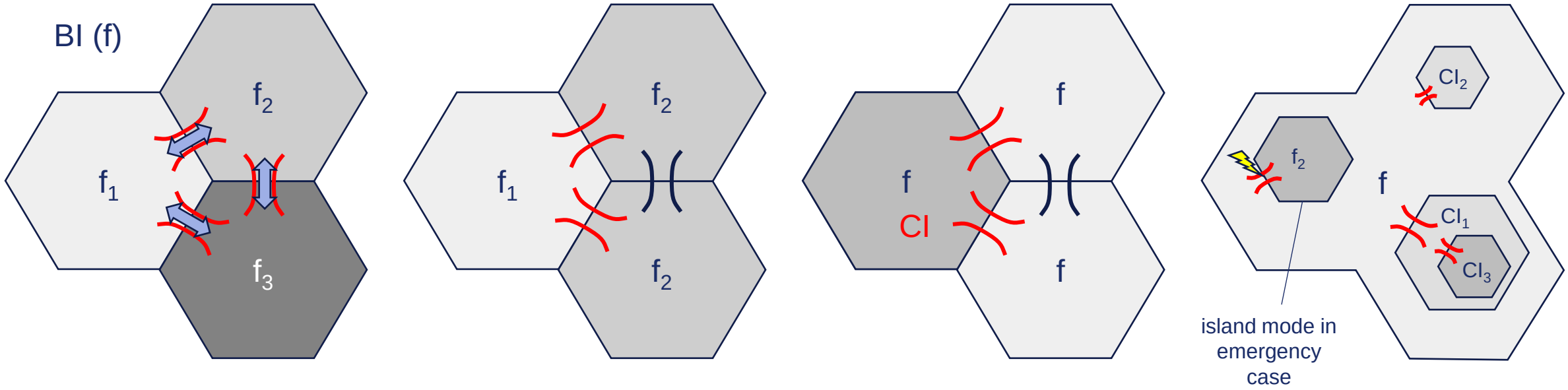
Participants empowered for dynamic prices can also counteract congestion (CI)



For the „regulated“ red zone grid operators may define behavioural characteristics for different classes of devices (such as LVRT for PV)

Options Towards Grid-Supportive Temporal and Locational Pricing

Note: BI based on frequency never,
CI always needs communication infrastructure



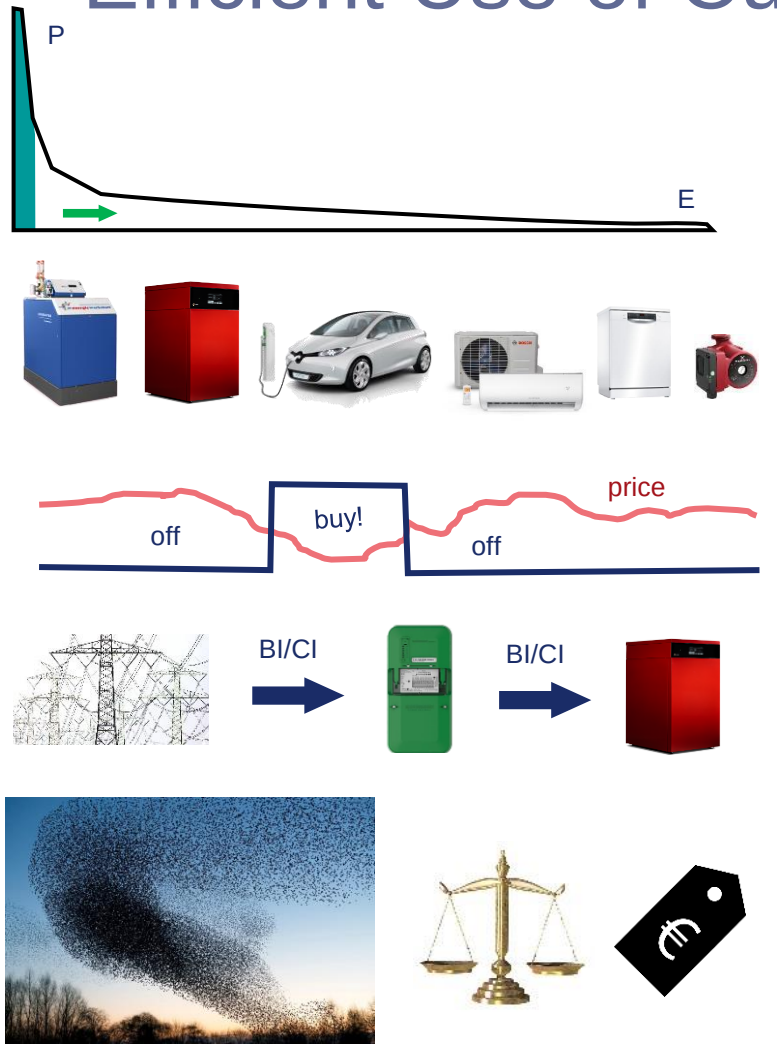
Coupling of cells operating at different frequencies

Price (and frequency) differences disappear in absence of bottlenecks

Combining universal frequency (BI) and local congestion (CI) signals

Polymorphous cells created by temporal bottlenecks

Decentral Energy Markets for Efficient Use of Customer Flexibility



- ✓ Use any flexibility (power, duration, availability)
- ✓ Huge and low cost storage (all-electric heating and mobility)
- ✓ Simple contracts (no bids or qualification)
- ✓ Unidirectional communication, data privacy (price takers)
- ✓ Resilient (failures, attacks)
- ✓ Fair and transparent (market mechanism)

Our Vision: A Real Time and Locational Tariff Element

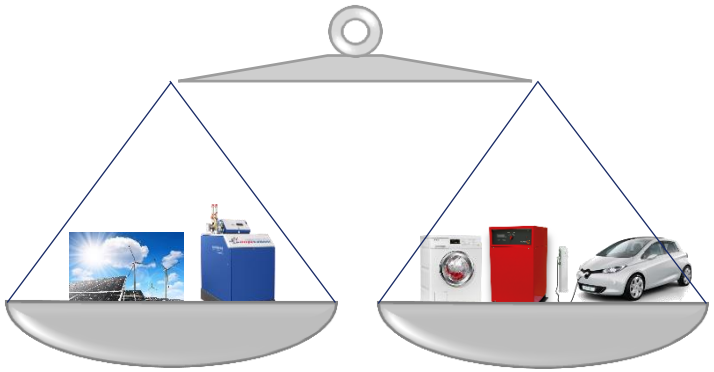
Utility 1

Utility 2

Utility 3

No need to balance utility every 15 mins

Ø Price for production and sales per utility



Flexibilities compensate imbalances and congestions

Cell 1

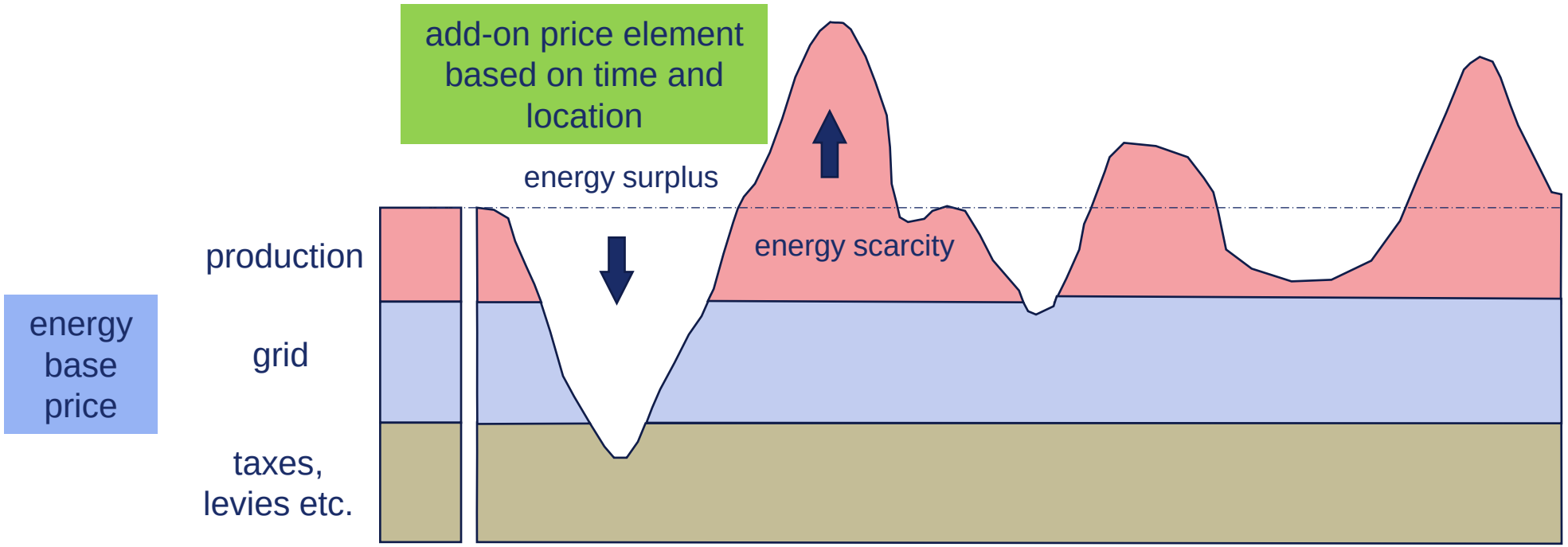
Cell 2

Cell 3

Ø Grid fee per cell

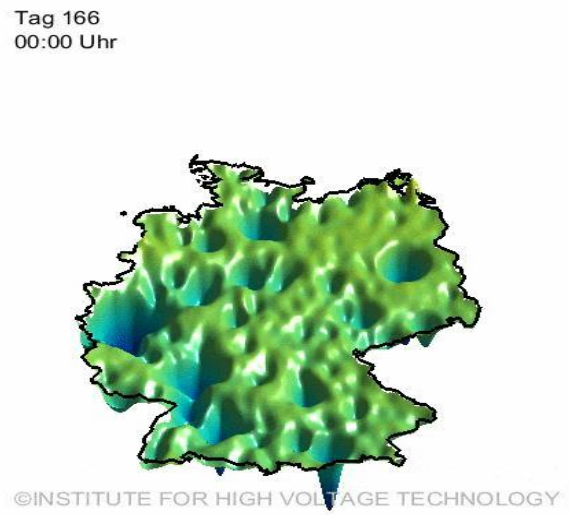
Dynamic price (deviation from Ø)

Our Vision: Add Platform for Real Time Price Element Based on ESG Technology



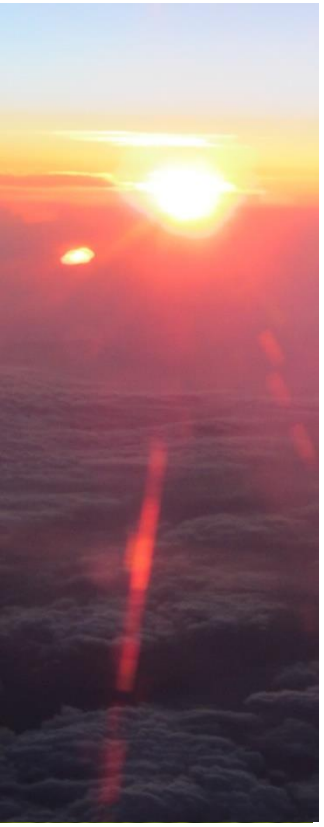
Dynamic tariff component may include dynamic energy prices and grid fees

The Opportunity: Create a platform for dynamic price components on grid infrastructure



Source of animated graphic control power 2025: RWTH Aachen

- Price signals reflecting spatial and temporal grid situation have large spread relative to energy market prices and represent the **complete** market
- Energy market prices reflecting **average** factor cost are basis for re-financing and related instruments (carbon tax, subsidies, capacity markets etc.)
- Price signals reflecting spatial and temporal grid situation **co-ordinate** renewable-dominated energy systems
- Grid operators are well positioned to develop and provide the platform necessary for this co-ordination



Thank you
for your interest
and our exchange!

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