SuMoCoS

Sustainability and Mobility in the Context of Smart Cities

Energetic Neighbourhoods & In-house Energy Management

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Agenda

- Transition of Energy Supply System
- Ancillary Services Delivered by Renewables
- Challenges of Necessary Aggregation Scheme
- Energetic Neighborhoods as Special Use Cases

Smart City Definition (EU)

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Environment	• Reduction of CO_2 emissions • Use of renewable energy • Monitoring on energy consumption
Living	• Co-working cultural initiatives • Living-lab • Crowd-sourcing co-design
Mobility	• Development of technologies to improve urban mobility • Low environmental impact
Governance	• Starting of processes for the involvement of citizens about topics of public relevance
Economy	• Cooperation among public and private actors • development of social incubators and of small and medium enterprises
People	• Sharing data • Security and protection of sources • Monitoring and communication

Smart City Definition (EU)

Environment

- Reduction of CO_2 emissions
- Use of renewable energy
- Monitoring on energy consumption

- Climate change and environmental pollution demand a change in energy provision towards cleaner resources
- Use of renewable energy entails some challenges to cope with

Change in energy provision

Source: E-Energy, BMWi

Past: Fossil generation close to consumers

Future: Decoupling in time and space of generation and consumption in renewable smart grid

Challenges for Renewables‘ Integration

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- In the long run and if all traditional (fossil) plants are replaced, the renewables will have to assume responsibility for grid control and ancillary services:
  - Planning energy provision day-ahead
  - Frequency control (provision of reserve power, balancing power)
  - Voltage control (local provision of reactive power)
  - Black start capabilities
  - ...
- Problematical because renewable energy is
  - volatile and hard to predict (medium- and long term)
  - hard to control
  - small in size and flexibility
  - decentralized
- Aggregation scheme for bundling needed
  - must include consumption side

Virtual Power Plants

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- Well established aggregation scheme: virtual power plant (VPP)
  - group of distributed energy resources (generator/ consumer/ battery)
  - drawn together by some communication means
  - today often still controlled by central control
  - acts like a single (larger) power plant

- Agent-based control is seen as a promising future approach for control
  - Copes well with scalability
  - Automation
  - Self-* properties

- Centralized as well as decentralized control entail new algorithmic challenges

Challenges of Agent-based Control

- Example use case: predictive scheduling (simplified)
  - given:
    - A virtual power plant
    - A schedule for the VPP that has to be operated (e.g. from some market)
  - problem:
    - Find a schedule for each generator/ consumer in the VPP such that the aggregated schedule resembles the wanted (market) schedule

$$\delta\left(\sum_{i=1}^{n} \boldsymbol{p}_i, \zeta\right) \rightarrow min$$

such that

$$\boldsymbol{p}_i \in \mathcal{F}^{(U_i)}\ \forall U_i \in \mathcal{U}.$$

- Tricky part: how does the algorithm know what schedules can be operated by which energy resource within the VPP?

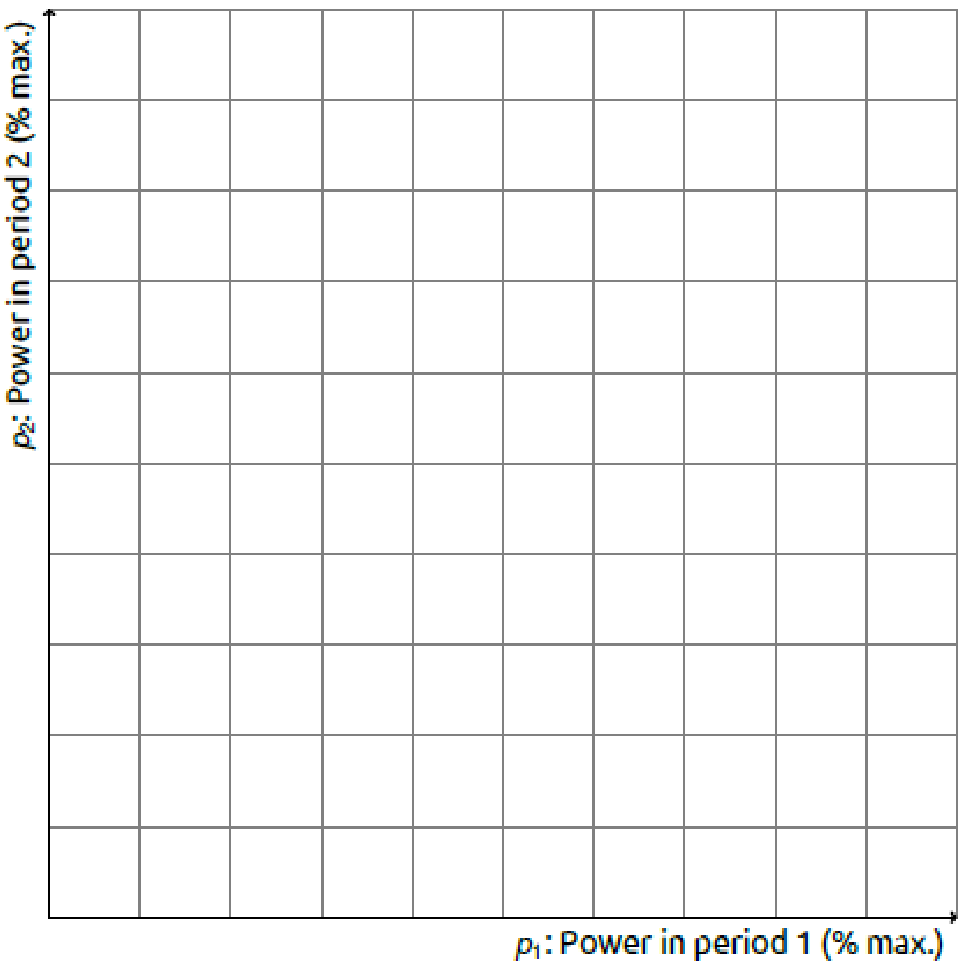
Constraints

- What kind of constraints do we have to deal with?

- Operability of schedules (for given time frame) . . .
  - . . . is restricted by technical constraints (min/max power output, state of charge of buffer, etc.)
  - . . . may depend on economical or ecological limiting factors (start-up cost, primary energy cost, user profiles, etc.)
  - . . . depends on current operational state

- let’s have a look at a single unit first. . .

Constraints (Example: μ-CHP)

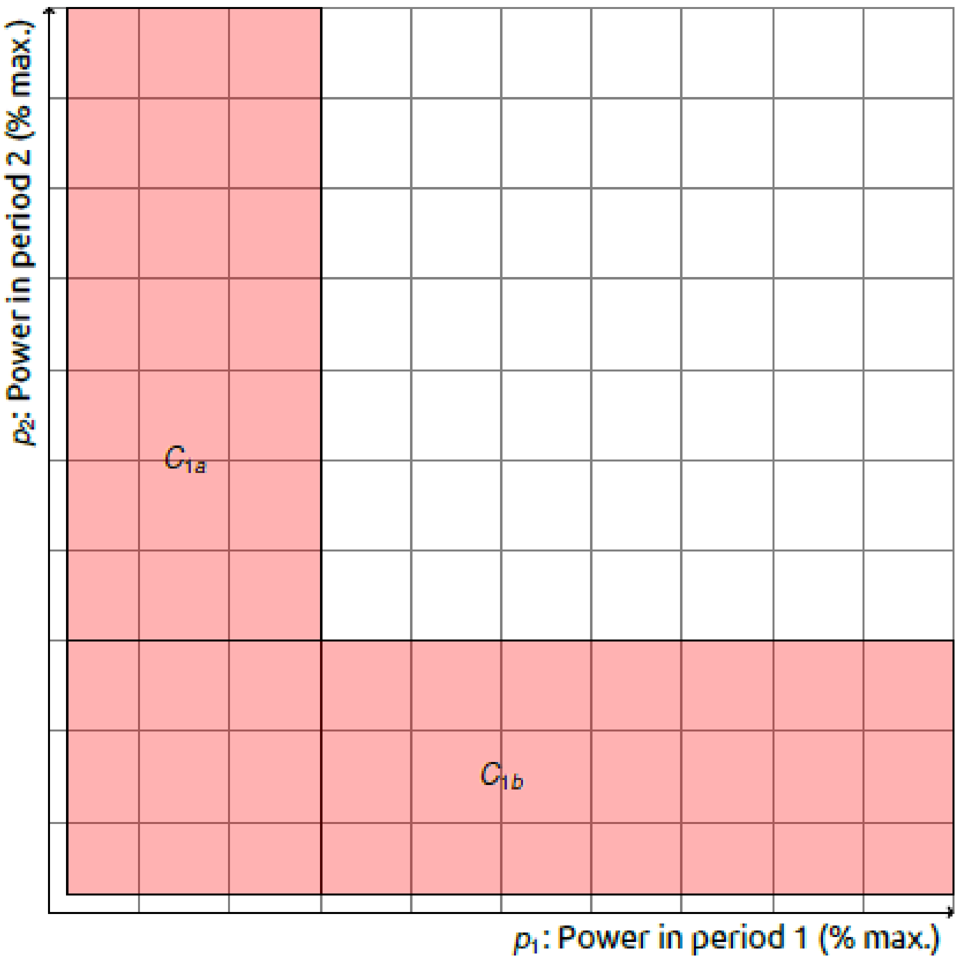


Illustrative example

- Each point in plane is schedule for 2 time periods

  X-axis: Mean active power during period 1
  Y-axis: Mean active power during period 2
- Output always between 0 and 100%
- Without further constraints: each schedule operable

Constraints (Example: μ-CHP)



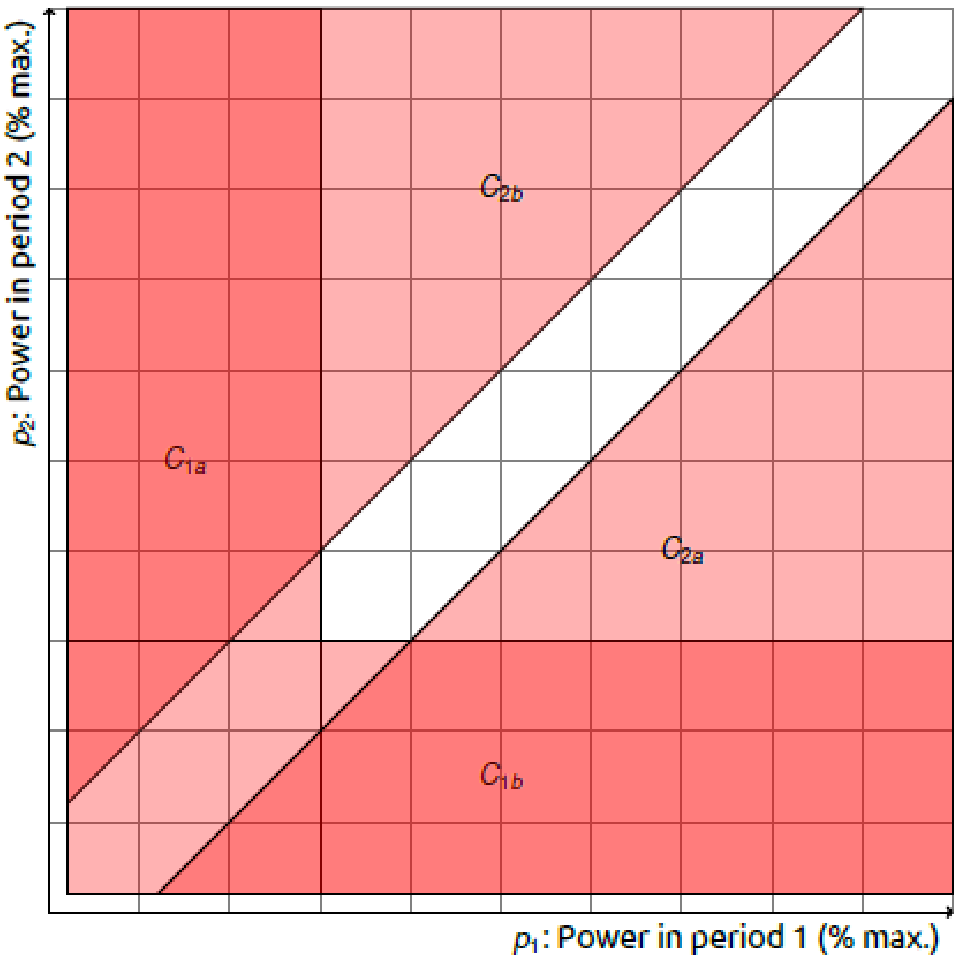
Constraint C_1: Modulation

- Only within given range
- OFF is additional option

(exaggerated depiction)

⇒ Red area drops off the solution space

Constraints (Example: μ-CHP)

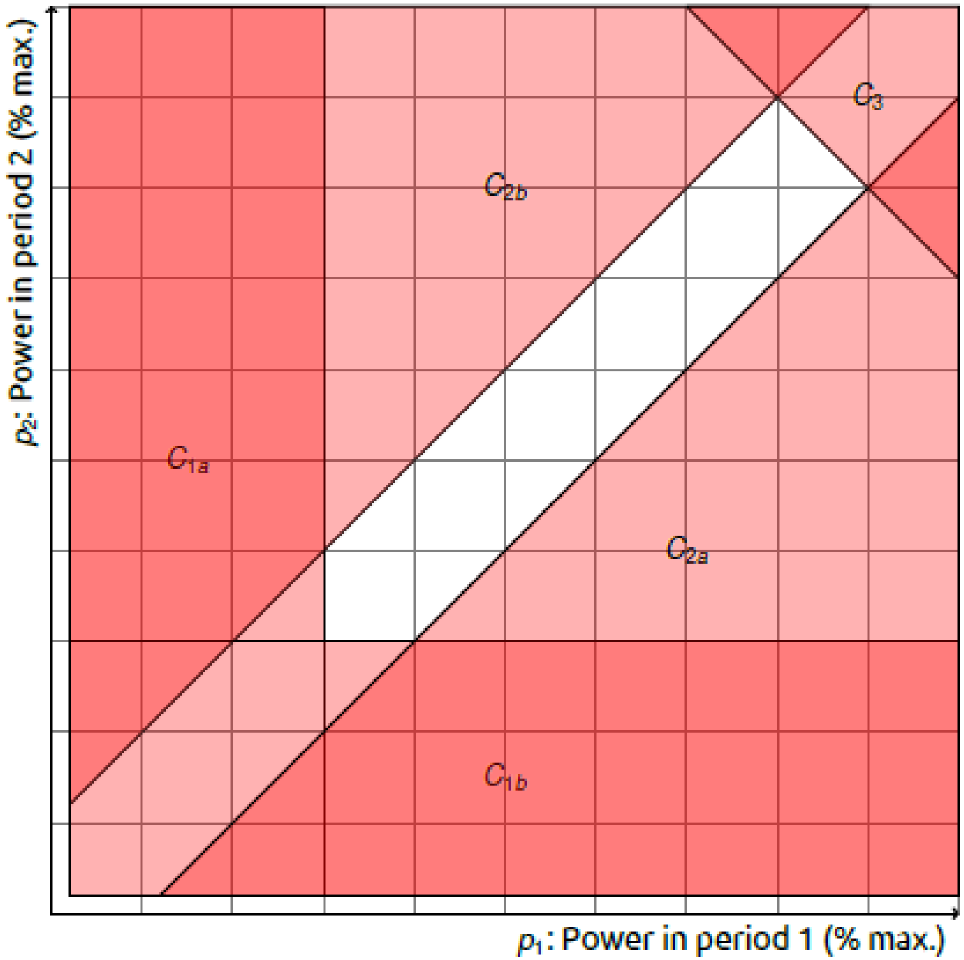


Constraint C_2: Inertia

- No instantaneous changes

⇒ Additional areas drop off

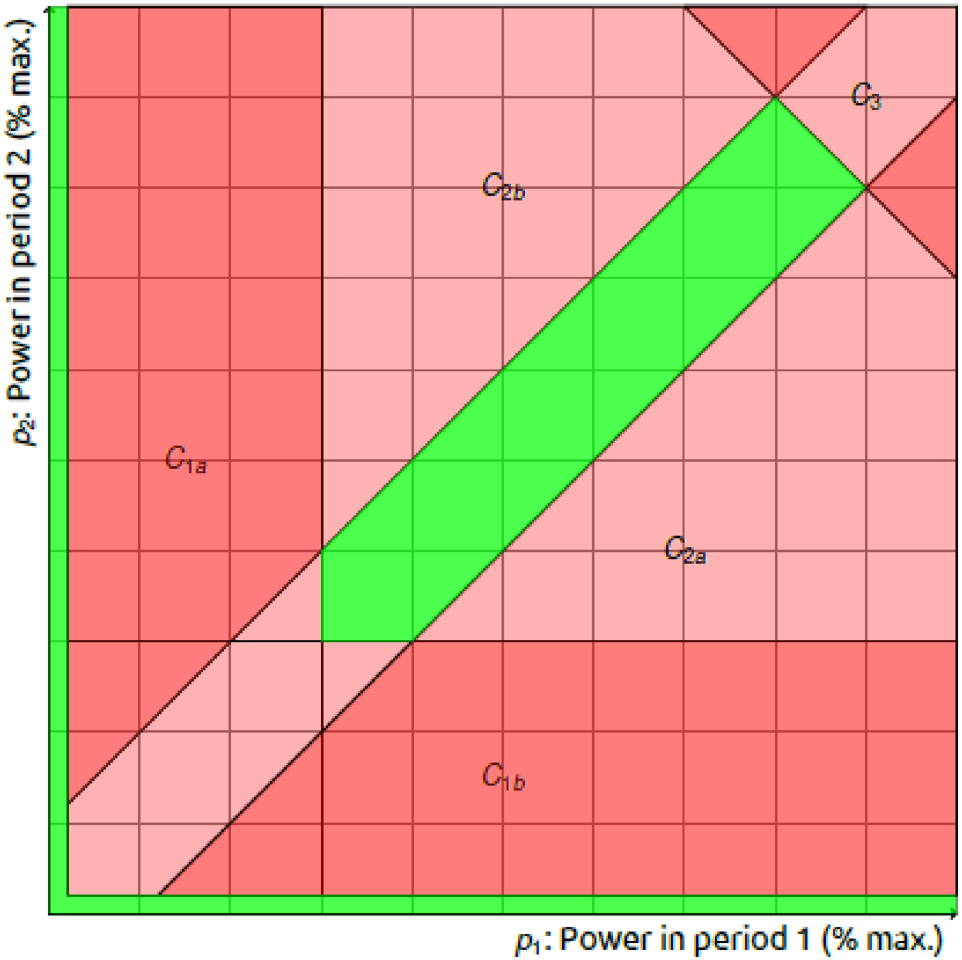
Constraints (Example: μ-CHP)



Constraint C_3: Buffer capacity

- Use or store concurrently produced thermal energy
- But: Buffer store has limited capacity

Constraints (Example: μ-CHP)

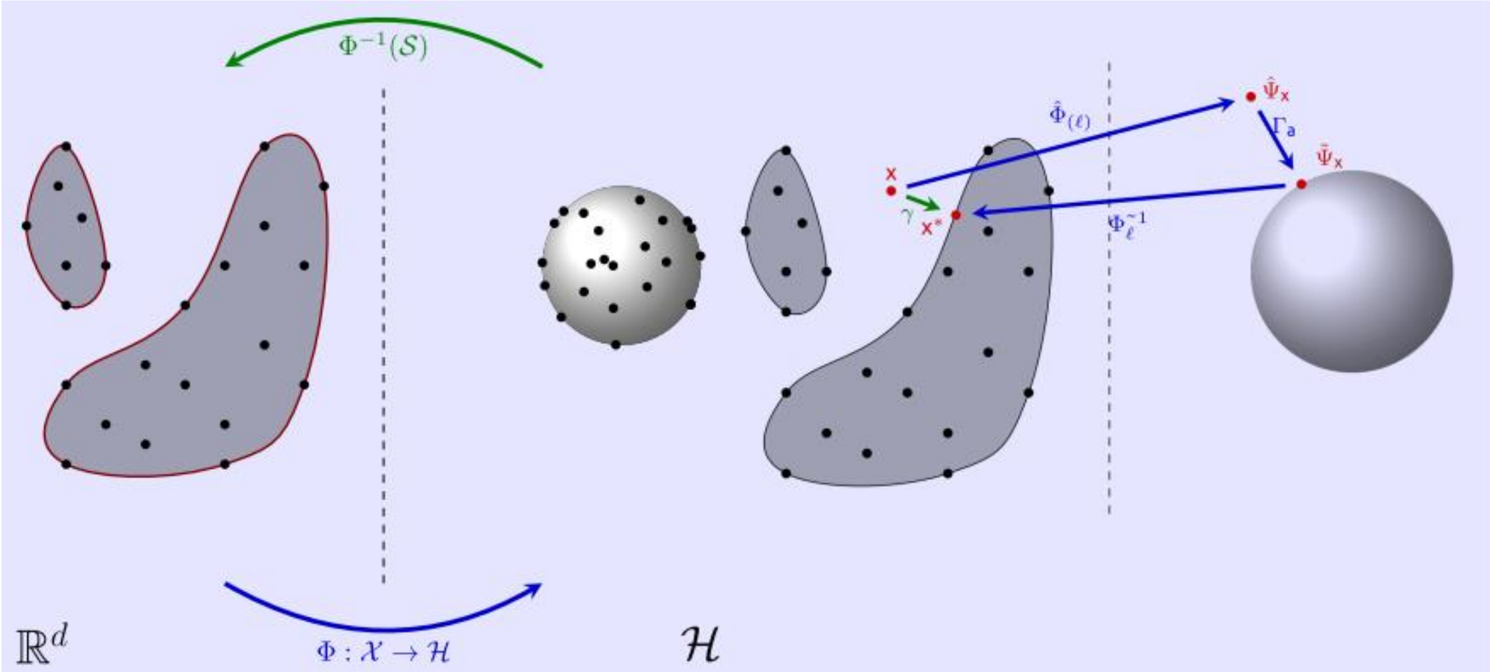


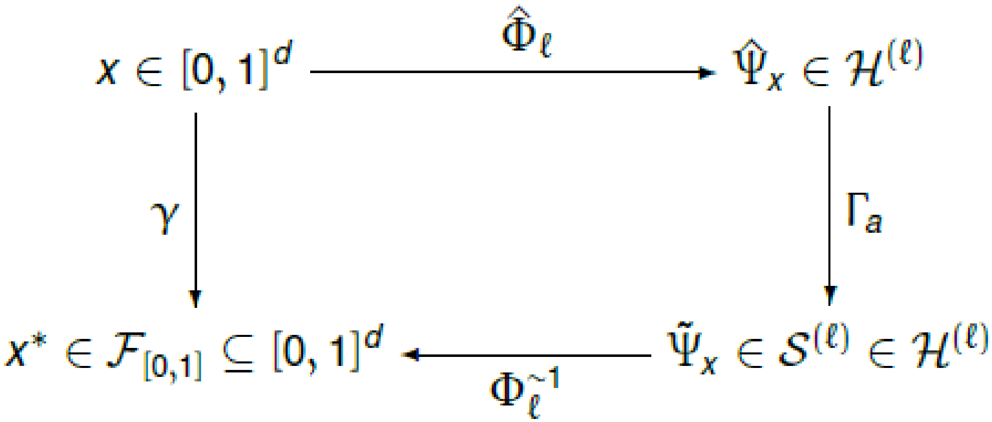
Superposition of all constraints

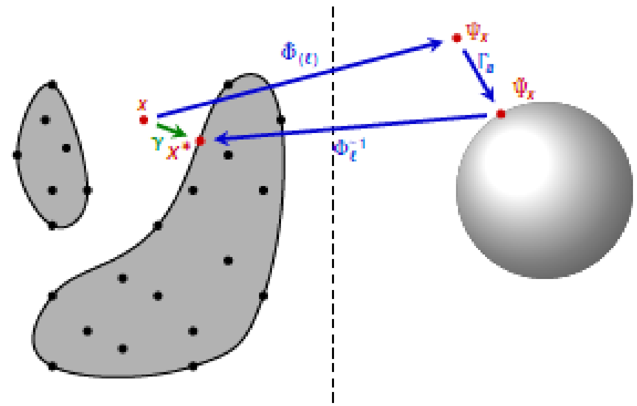
- Remaining region is solution space
- Only take schedules from this region
- Dimension: *96 and more* not unusual!

Flexibility models

- Flexibility modeling generates a surrogate of the feasible region of an energy unit; the phase space
  - A schedule for an energy unit can be seen as a real valued vector
  - *i*-th value denotes power during respective time interval
  - Surrounding envelope of the feasible region is learned
  - Decoders systematically generate feasible schedules without domain or situational knowledge







$$\delta\left(\sum_{i=1}^{m} \sigma_i^{-1} \circ \gamma(x_i), \zeta\right) \to min,$$

such that

$$x_i \in [0,1]^d.$$

In-house Energy Management

- In-house many small sized devices of renewable generation are operated
  - roof top PV, co-generation, batteries (e.g. from electric vehicles),...
- These have to be integrated efficiently into the grid
- Operating all these devices isolated leaves many degrees of freedom unused
- Integrated operation on the other hand allows e.g. for a maximization of the fulfilment of the own demand
- Fulfilling ones own demand for energy in-house causes less demand for control power within the grid

- Can be solved by means from VPP concept

- Integrated operation usually comprises more than just electricity:
  - integrated view on heat and electricity
  - e.g. co-generation, thermal storages, heat pumps, ...

Energetic Neighborhoods

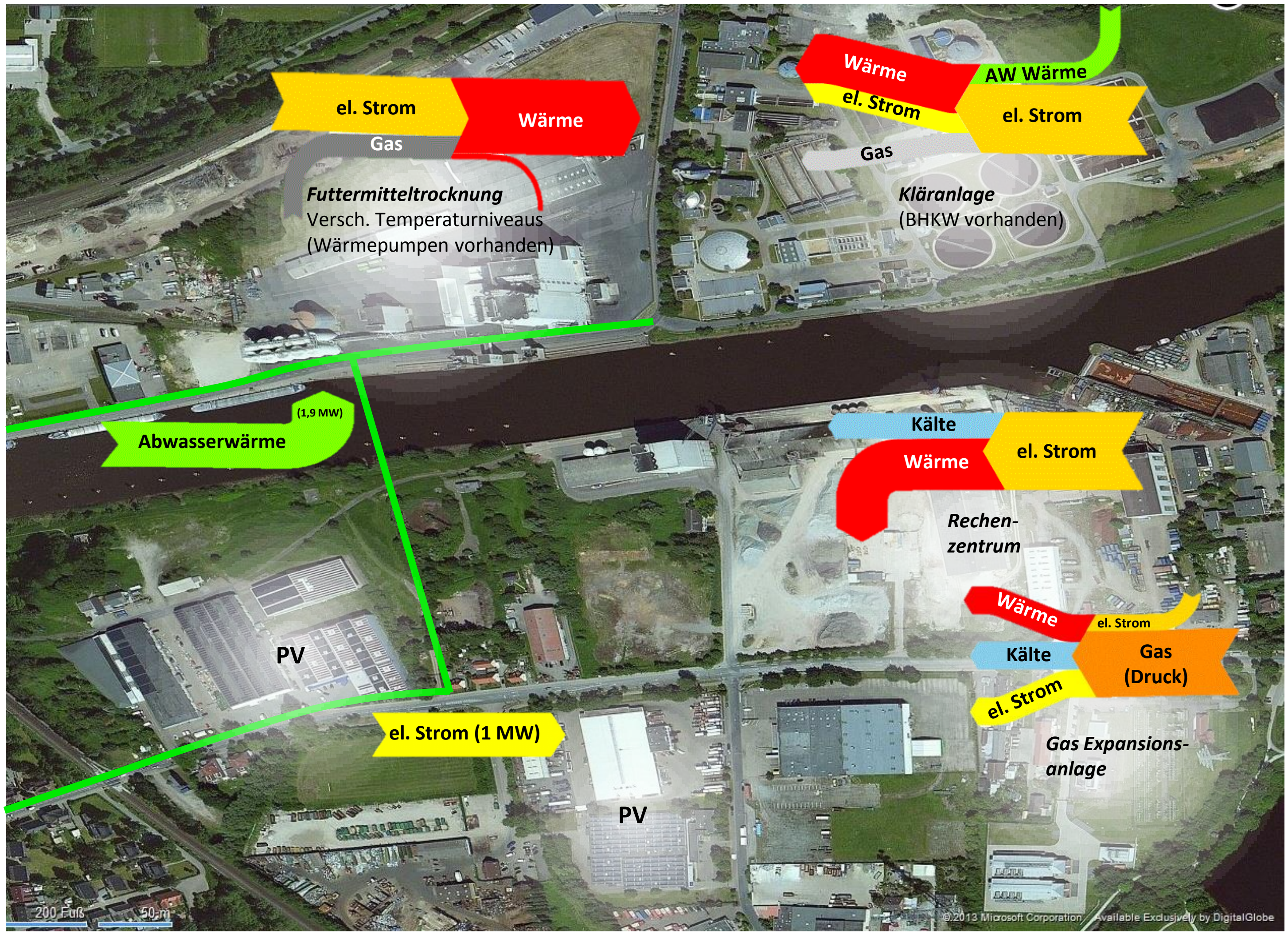
- From a hierarchical point of view, the in-house concept can be extended to a quarter
  - Balancing energy on quarter level reduces reversed energy flows within the grid
  - and entails less control energy demand on higher grid levels
  - and thus unburdens lines and allows for cheaper dimensioning
- From an algorithmic point of view, concepts from the virtual power plant can be adapted
  - But an energetic neighborhood is more

Energetic neighborhoods (cont‘d)

- Industrial estates with single companies with specific, separated energy conversion processes
- Internal efficiency is usually well-established (saves cost!)
- But, there is a potential for more efficiency regarding unused energy emissions (heat)

- Inter-process and -company coupling of processes needed to harness these emissions
- Examples for direct coupling
  - Joint use of common (thermal) buffers store (e.g. for district heating)
  - Joint marketing as virtual power plant
- Example for market- or platform organized based coupling
  - Increase internal consumption of in-house PV generation by finding a neighbor who wants to charge electric vehicle

Preliminary Work



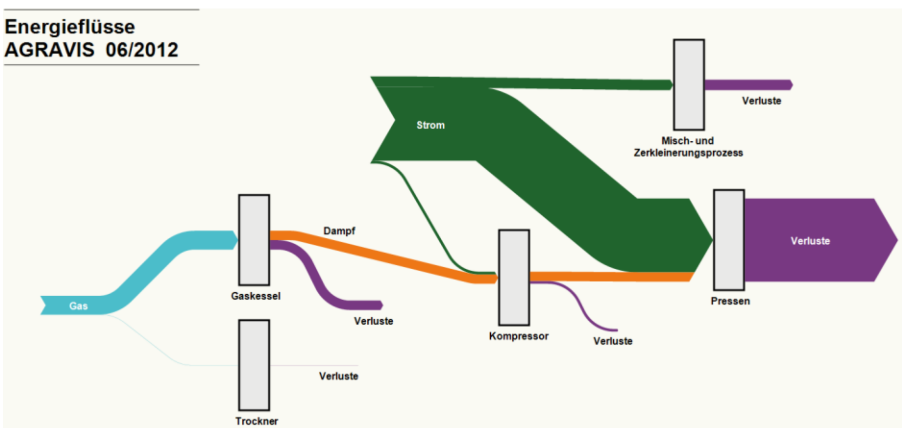
[Lehnhoff et al., 2014 – *Ergebnis stud. Projektgruppe*]

Preliminary Work (cont'd)

Ex.: industrial estate Drielake

- High (theoretical) synergy potenzial from static viewpoint
- But: dynamic/seasonal process characteristic

summer



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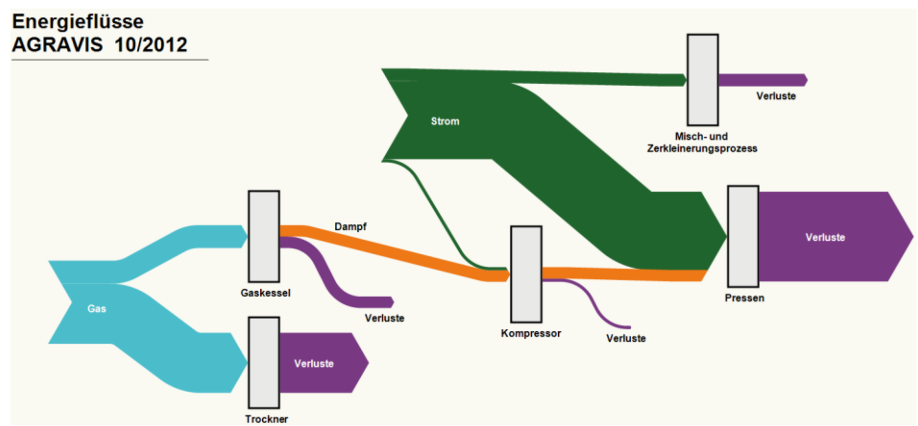

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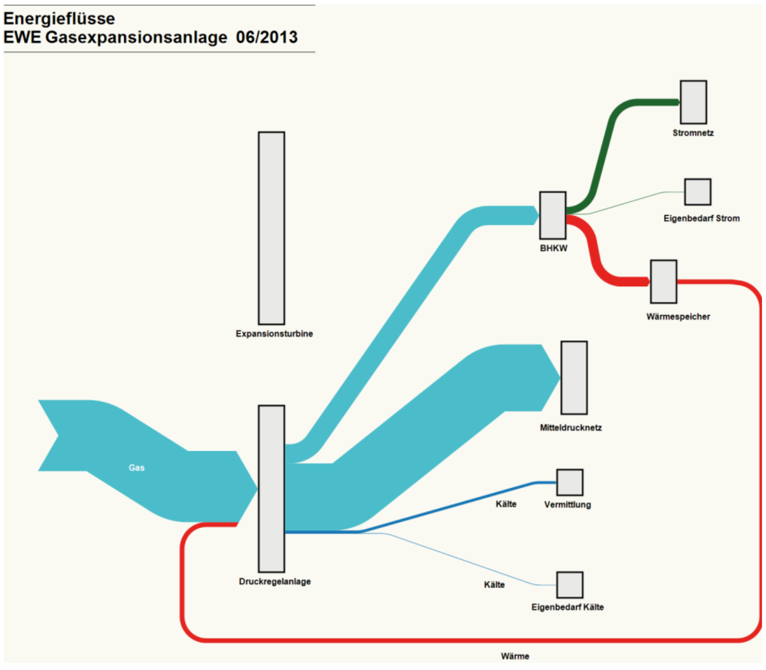

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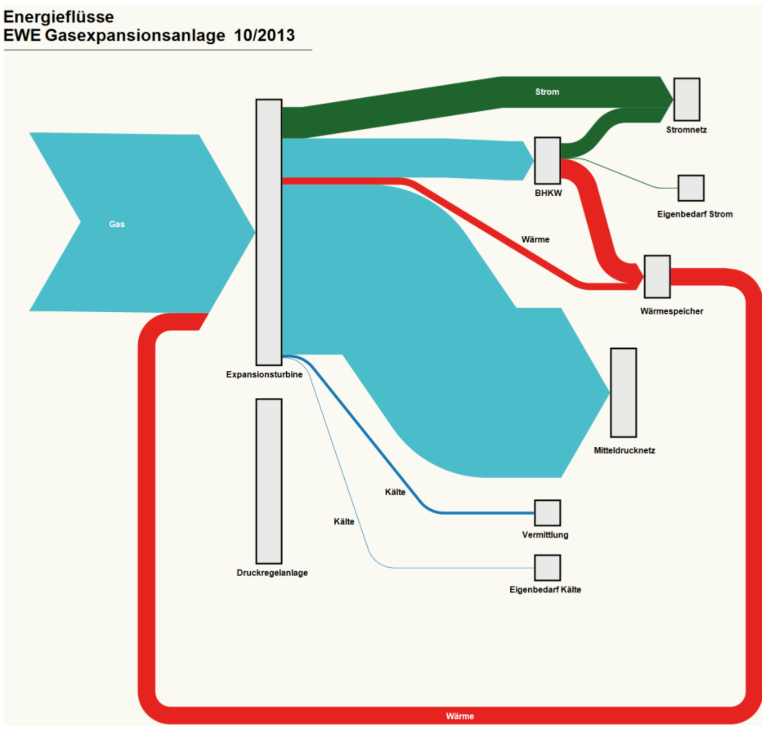

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Smart City lab Oldenburg

Smart City lab Oldenburg (cont'd)

Provision of an **experiment and testbed for experimental living environments for different topics**, especially for

- technical and non-technical innovations
- joint building and living projects
- new supply and mobility concepts on residential quarter level

Stepwise extension of the Smart City Lab Oldenburg by **„medium-sized" project development and organizational structure** as public private partnership

- **Cooperation of industry- and research projects** on different topics of a Smart City for **interdisciplinary exchange among experts**
- **Development of pilot projects** and pooling of partners from administration, research and business

ENaQ

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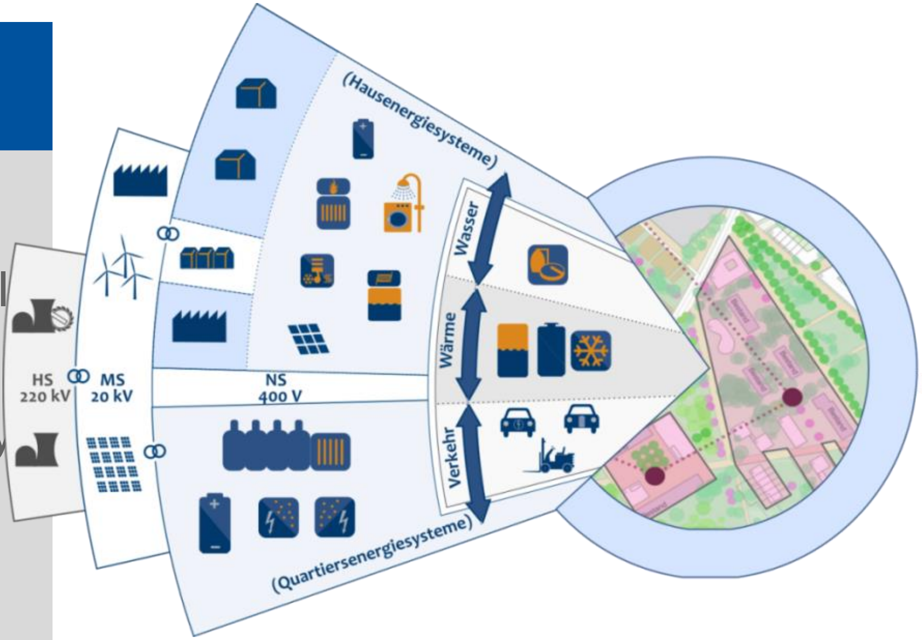
ENaQ: Energetic neighborhood quarter on former Oldenburg air base

Funding:	6. Energieforschungsprogramm : Förderinitiative „Solares Bauen / Energieeffiziente Stadt“

Goals & Approach

- Develop multimodal provision system for electricity and heat
- Participation of house owners in social and financial incentive system (cooperative)
- Develop business case for local energy cooperatives and added value chains
- Conceptualize and develop digital platform for automating energy exchange and marketing



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