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Smart Hybrid Energy Grids for Smart Regions

Prof. Dr. Sebastian Lehnhoff – acatech Project Group „Hybrid Energy Grids“

OFFIS – Institute for Information Technology
R&D Division Energy

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Energy Supply Challenges

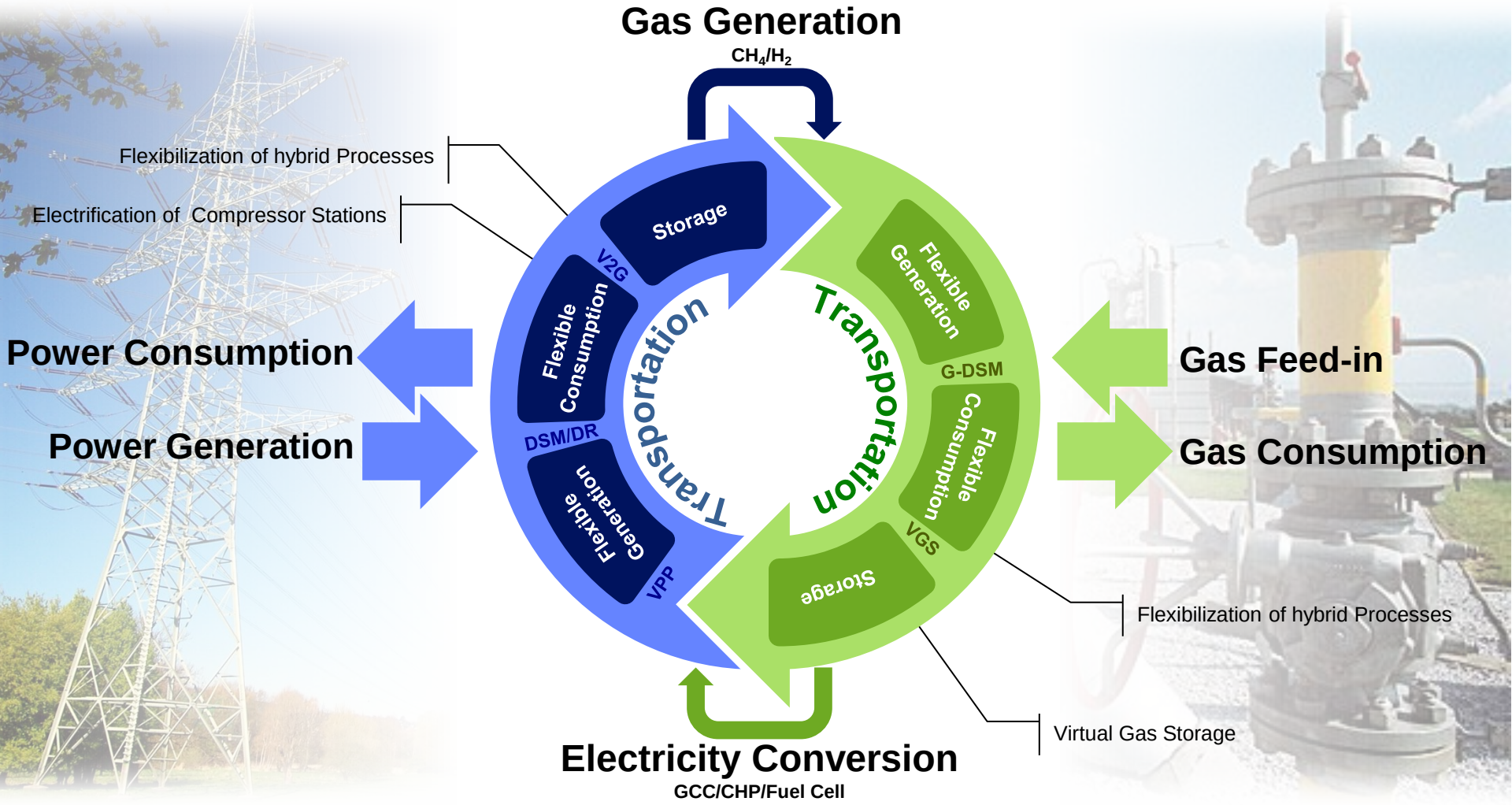
Smart Grids, Smart Cities, Smart Regions

- Increasing energy feed-in from volatile decentralized sources
  - Increase in storage and transportation requirements
- Flexibilization of power demand and supply (Smart Grids)
  - Timely (and regionally) coupling of demand/supply processes
- Multi-domain flexibilization in Smart Cities → Smart Regions
  - Coupling of infrastructures (power/gas/heat/transportation)
  - Adequate coupling of processes?
- acatech project group „Hybrid Energy Grids“
  - 30 representatives from industry, government and R&D
  - Technical Report „Hybrid Energy Grid for the Energy Turnaround – ICT-Challenges“

→ Modeling of multi-domain process coupling…

Power-to-Gas(-to-Power)

Process Coupling

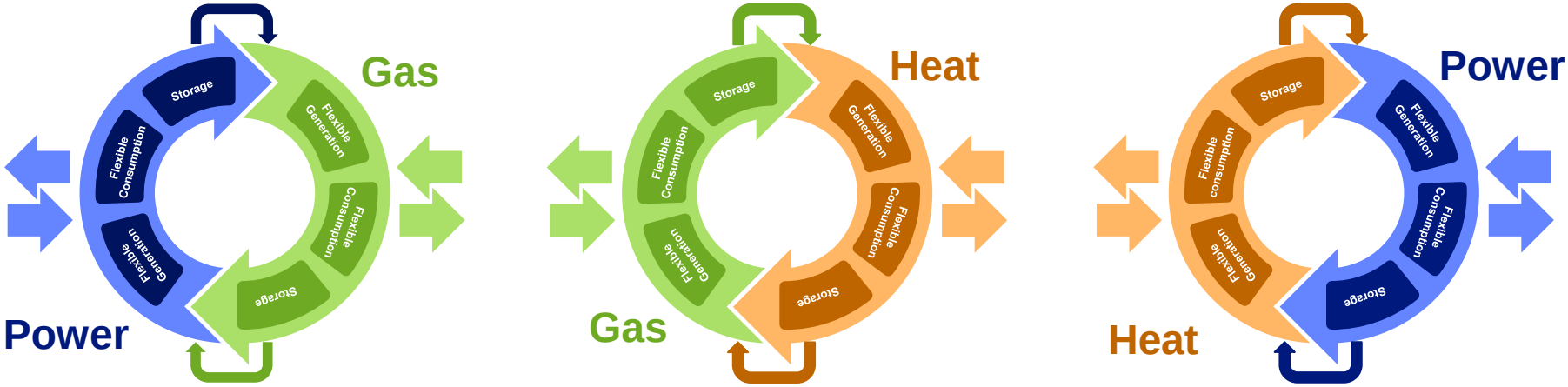


Multi-Domain Process Coupling

Increase in Degrees of Freedom

Smart Cities: integration of power-, gas-, heat- and transportation-systems

> Number of 1-dimensional process couplings
  - 3 Domains: 3
  - 4 Domains: 6



> Multi-dimensional process couplings

Minimization of process distances in hybrid energy systems utilizing Smart Grid methods, complementary methods in gas/heat/transportation-systems, process coupling...

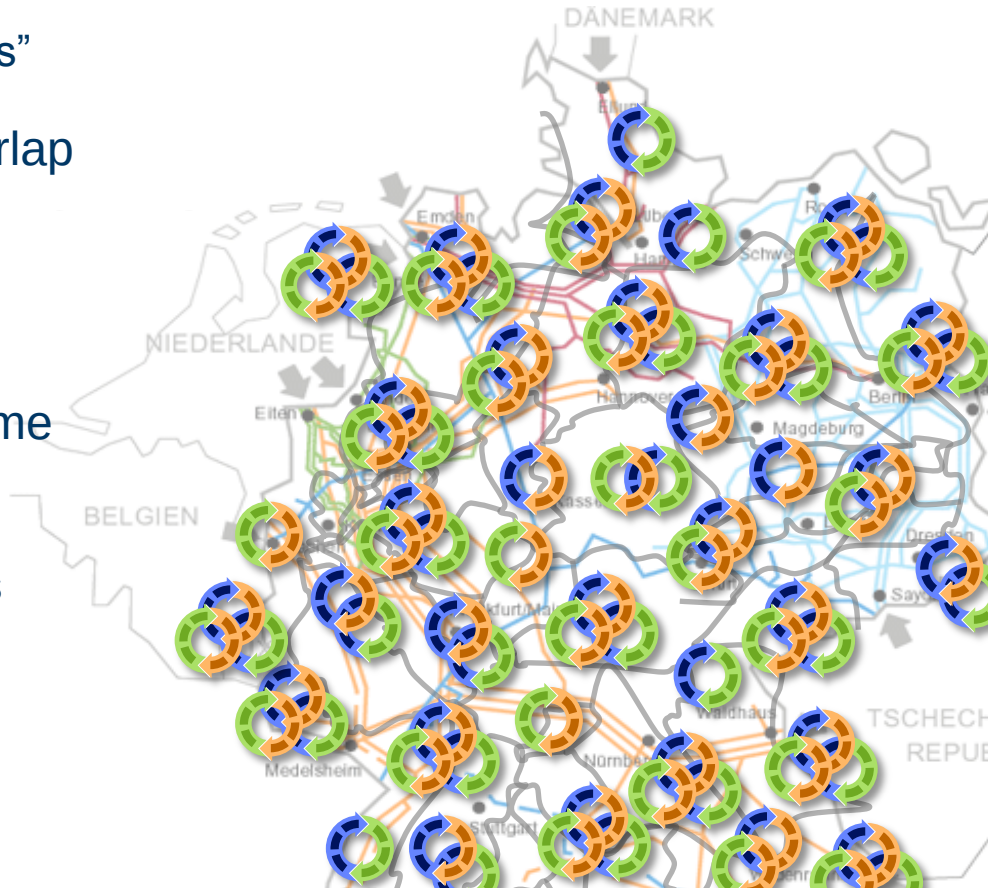
Multi-Domain Process Coupling

Timely differentiated Availabilities in Smart Regions

Utilizing regional alternatives for fulfilling energy demands

- E.g.: heat can be produced from solar/electric energy or by combustion (biomass/gas)
  - Timely differentiated “process costs”
- Where energy infrastructures overlap process coupling is possible
  - Conversion processes
  - „Bivalent consumers“
- Energy demand fluctuates over time and space!
  - Spontaneous switching between energy sources and infrastructures

➡ Automated solutions required!



Multi-Domain Process Optimization

Beware of complexity trap

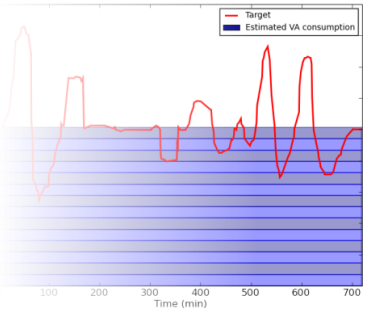
Design challenges:

- Where do existing infrastructures support process coupling?
- Where is the biggest potential for process coupling?

Operational challenges:

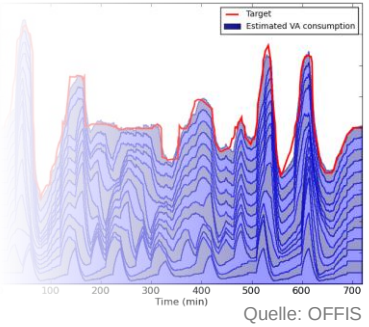
- Conversion processes
- Automation of process couplings (e.g. bivalent consumers)
- Timely and spatially flexibilization along the Power(-to-{*Gas*;*Heat*;*Mobility*;*Power*})* process chain

Quelle: TU Braunschweig



Beware of complexity trap! [FEG2012]

- fragmented, single-purpose, heterogeneous ICT
- Inhomogeneous systems (high integration costs)
- (High-)potential options for flexibilization will not be considered
- **Missing incentives for development/hybridization!**



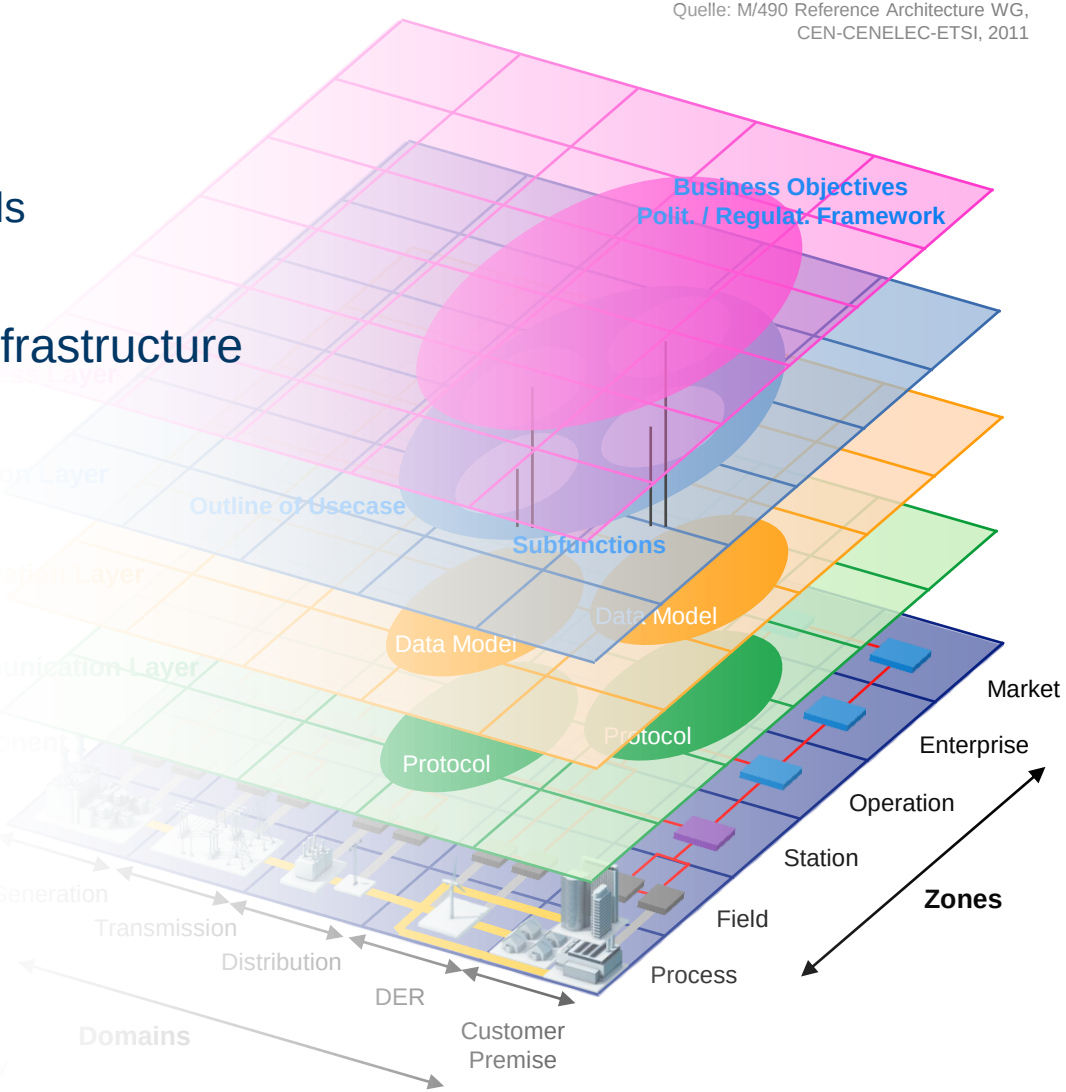
Quelle: OFFIS

Integrated Energy Information Systems

Overall System Optimization

- Established ICT-concepts:
  - Decentralization/hierarchies
  - Reference architectures/models
- Adequate design of the ICT-infrastructure necessary
  - Data exchange platform
  - „Internet of Energy“
- Standards for communication and automation
  - Definition of profiles
  - Tool development and support
  - Security!

Quelle: M/490 Reference Architecture WG, CEN-CENELEC-ETSI, 2011



Regulation Framework for Hybrid Energy Grids

- Timely and spatially differentiation of coupling and storage processes
- Identification of „relevant“ domains
  - Storage and transport capacities (timely and spatially differentiable)
  - Comprehensive area-wide infrastructure
  - Decentralized (bidirectional/two-way) access
- Energy systems in Germany (ordered by total end user consumption)
  - Mineral oil
  - Gas
  - Power
  - Heat

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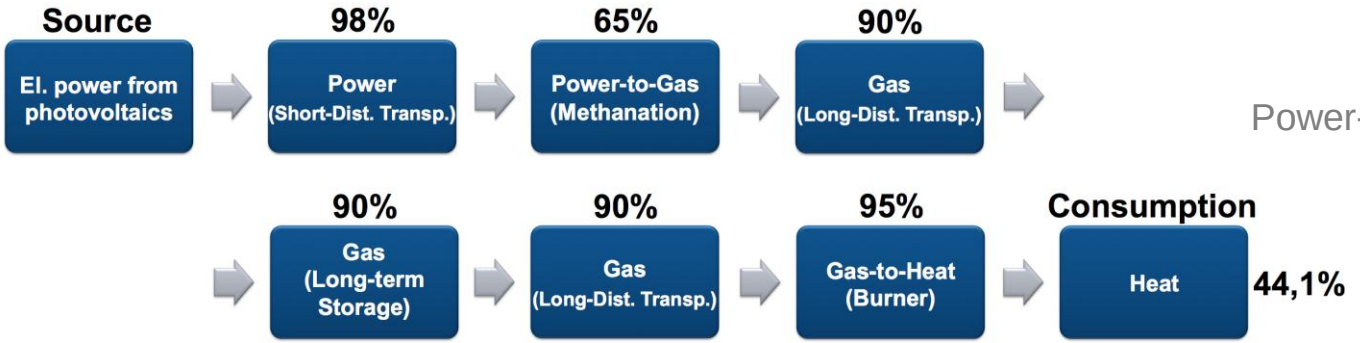
Regulation Framework for Hybrid Energy Grids (cont'd)

	Power	Gas	Heat
Power	**Short-Term Storage** Efficiency: 90% Costs: high **Short-Dist. Transp.** Efficiency: 98% Costs: medium **Long-Term Storage** Efficiency: 40% (Compr.-Air) 75% (Pumpstorage) Costs: high **Long-Dist. Transp.** Efficiency: 93% Costs: medium	**Power-to-Gas** Efficiency: 75% / 65% (H_2, CH_4) Costs: medium	**Power-to-Heat** Efficiency: 100% / 300% (Resistance, HP) Costs: low / medium HP: Heat-Pump
Gas	**Gas-to-Power** Efficiency: 40% / 60% (CHP, GaS & FC) Costs: medium (GF, GuD, FC) GF: Gas Furnace, GaS: Gas and Steam, FC: Fuel Cell	**Short-Term Storage** Efficiency: 100% Costs: low **Short-Dist. Transp.** Efficiency: 95% Costs: medium **Long-Term Storage** Efficiency: 90% Costs: low **Long-Dist. Transp.** Efficiency: 90% Costs: low	**Gas-to-Heat** Efficiency: 95% (Burner) Costs: low
Heat	**Heat-to-Power** Efficiency: Costs:	**Heat-to-Gas** Efficiency: Costs:	**Short-Term-Storage** Efficiency: 95% Costs: low **Short-Dist. Transp.** Efficiency: 90% Costs: medium **Long-Term Storage** Efficiency: 75% Costs: medium **Long-Dist. Transp.** Efficiency: 85% Costs: high

Caption			
	Technically and economically irrelevant	Efficiency and costs with respect to the cross-domain coupling between the two domains	Storage and transport within the energy domain

Evaluation of Process Chains in Hybrid Energy Grids

- Identification of promising business/use cases



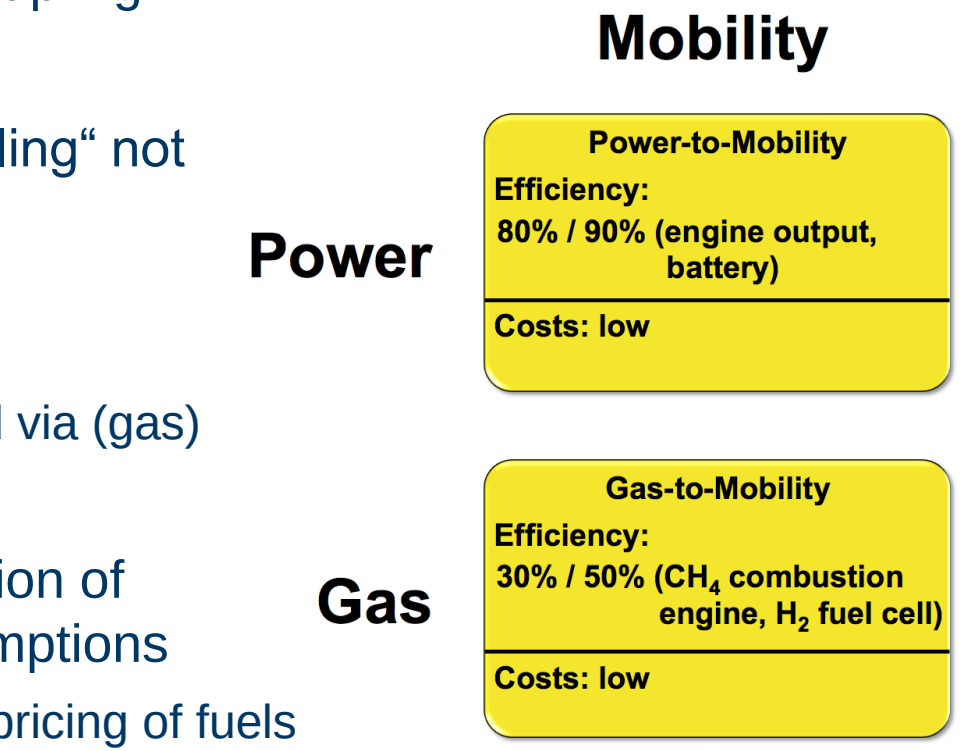
Power-to-Gas-to-Heat

- Additional energy sectors/domains?
  - What about mobility/public transportiation?
- Alternative (more efficient) coupling processes?
  - „Virtual“ coupling processes
  - Compressor stations
  - Thermal industrial (melting) processes
  - Multivalent coupling processes (data centers, Smart City concepts etc.)

„more electric power, less gas“ (and vice versa)

Virtual Coupling into the Mobility Domain

- Multivalent, highly available coupling process
- But: coupling process is „refueling“ not „driving“
  - Tightly knitted, public/private stations/charging points
  - Coupling of power and gas grid via (gas) filling stations
- Timely and spatially flexibilization of domain specific energy consumptions
  - Timely differentiable, dynamic pricing of fuels
  - Dense public/private stations/charging points



Hybrid Energy Grids for Smart Regions and the Energy Turnaround

- Hybrid energy grids exhibit a highly increased complexity compared to “conventional” Smart Grids
  - Power, gas und (district) heating, supply systems for fuels
- Automated operation only feasible with integrated ICT-concepts
  - *„Energy information systems with distributed intelligence“*
- Design/optimization: regional approaches
  - Energy supply and demand fluctuate over time and space!
- Identify adequate/efficient system architectures
- Highlight migration paths

http://www.acatech.de/publikationen-hybridnetze

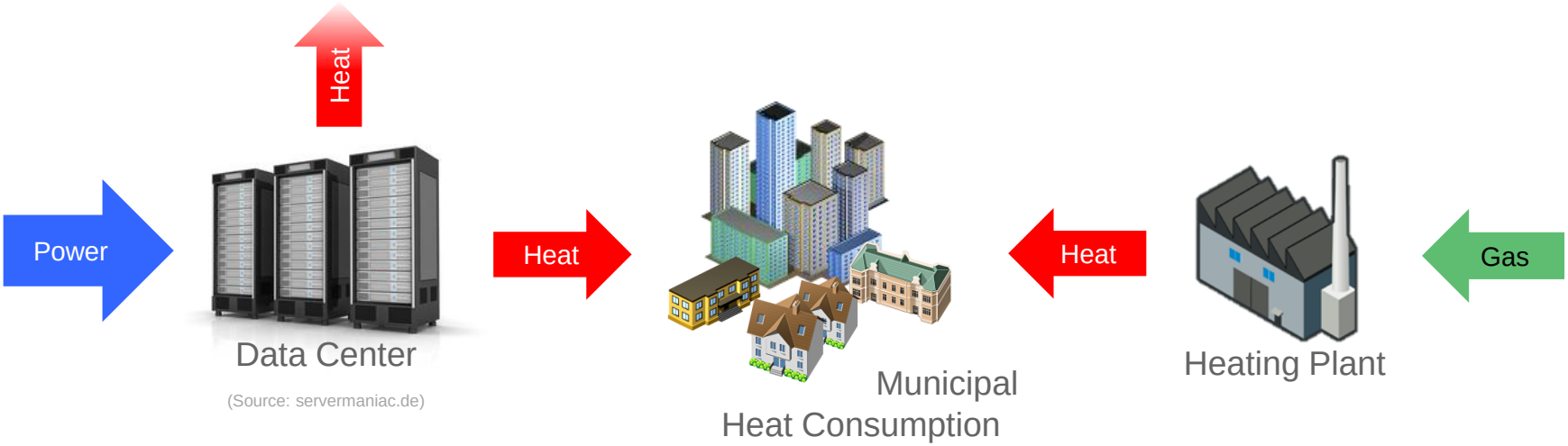
S. Lehnhoff, S. Rohjans, H.-J. Appelrath: *ICT-Challenges in Load Balancing across Multi-Domain Hybrid Energy Infrastructures*. In: it – Information Technology, 2/2013, ISSN 1611-2776.

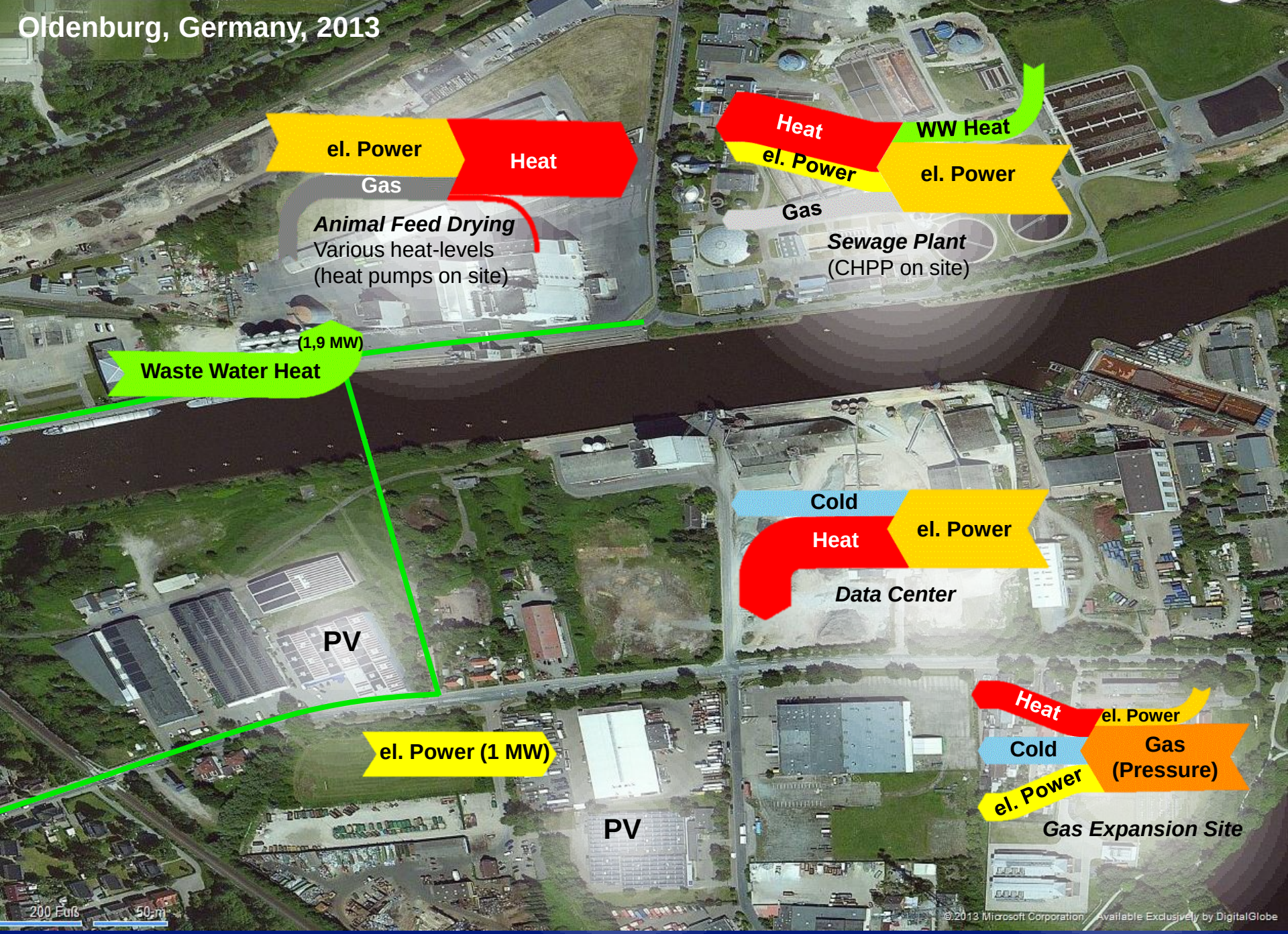
http://www.acatech.de/publikationen-hybridnetze

Data Center as Multivalent Process Coupler

Smart City-Component

- Data center as energy conversion process:
  - Power-to-Heat: „very efficient heater with its own cooling system“
  - Large amounts of waste heat dependent on the cooling concept
  - Power grid connection point dimensioned for the maximum projected ICT-performance
  - Increasing energy density




Oldenburg, Germany, 2013
el. Power
Heat
Gas
Animal Feed Drying
Various heat-levels
(heat pumps on site)
Heat
WW Heat
el. Power
el. Power
Gas
Sewage Plant
(CHPP on site)
(1,9 MW)
Waste Water Heat
Cold
Heat
el. Power
Data Center
PV
el. Power (1 MW)
PV
Heat
el. Power
Cold
Gas
(Pressure)
el. Power
Gas Expansion Site
200 Fuß
50 m
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Thank you!

Prof. Dr. Sebastian Lehnhoff
R&D Division Energy
lehnhoff@offis.de