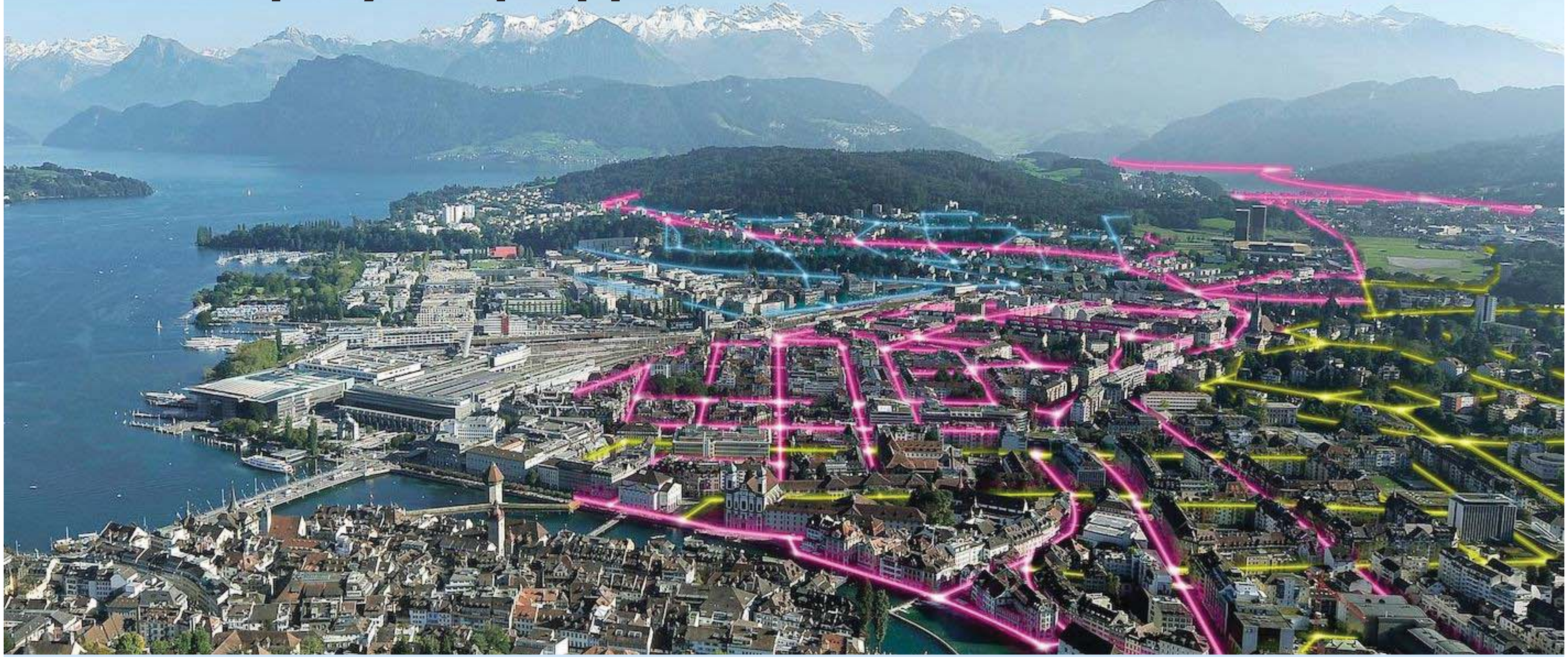
An entire CO_2 neutral region? Transitioning to decentralized energy systems – A step-by-step approach

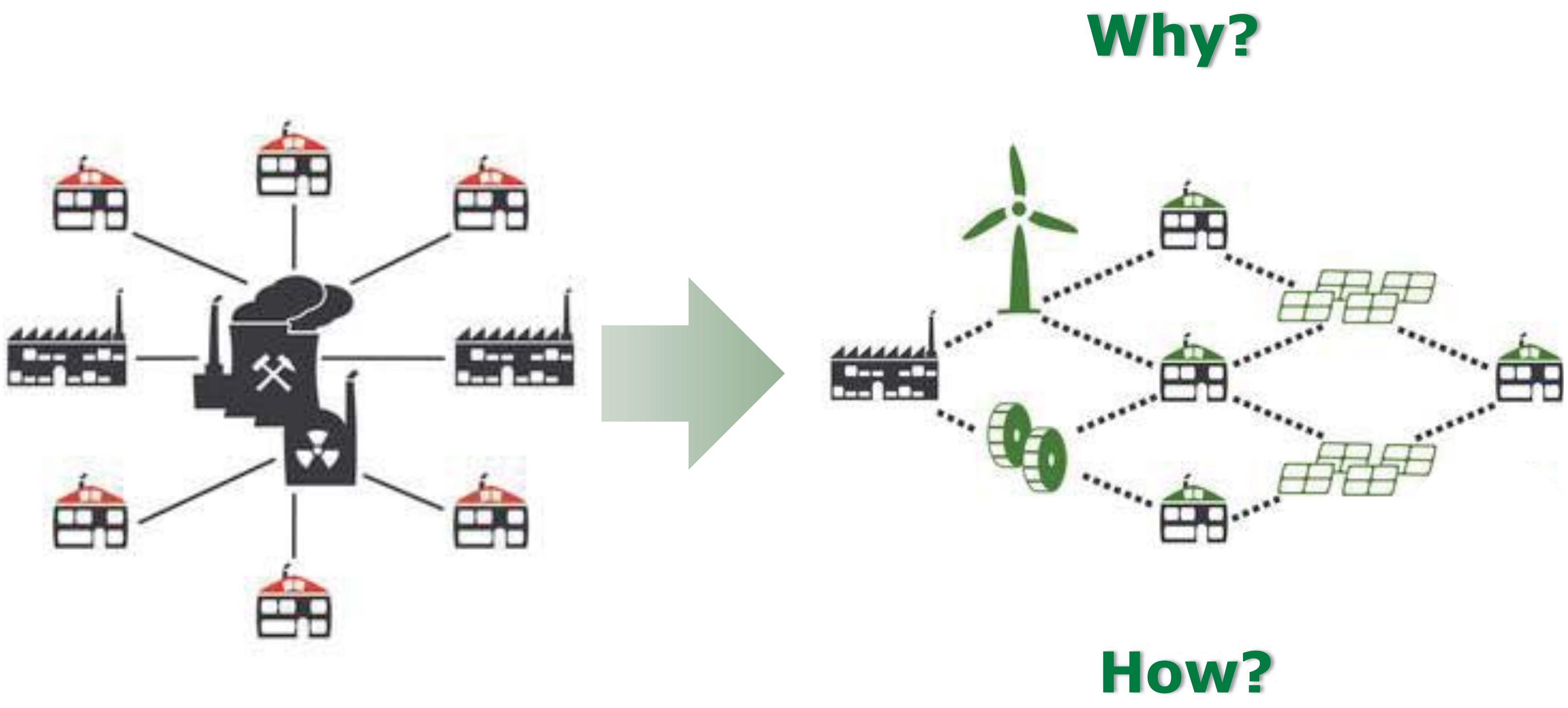


Lucerne School of Engineering and Architecture
Prof Dr Uwe W Schulz
Head of International Relations
Head of the Bachelor's Program in Energy Systems Engineering
T direct +41 41 349 32 37
uwe.schulz@hslu.ch

Agenda

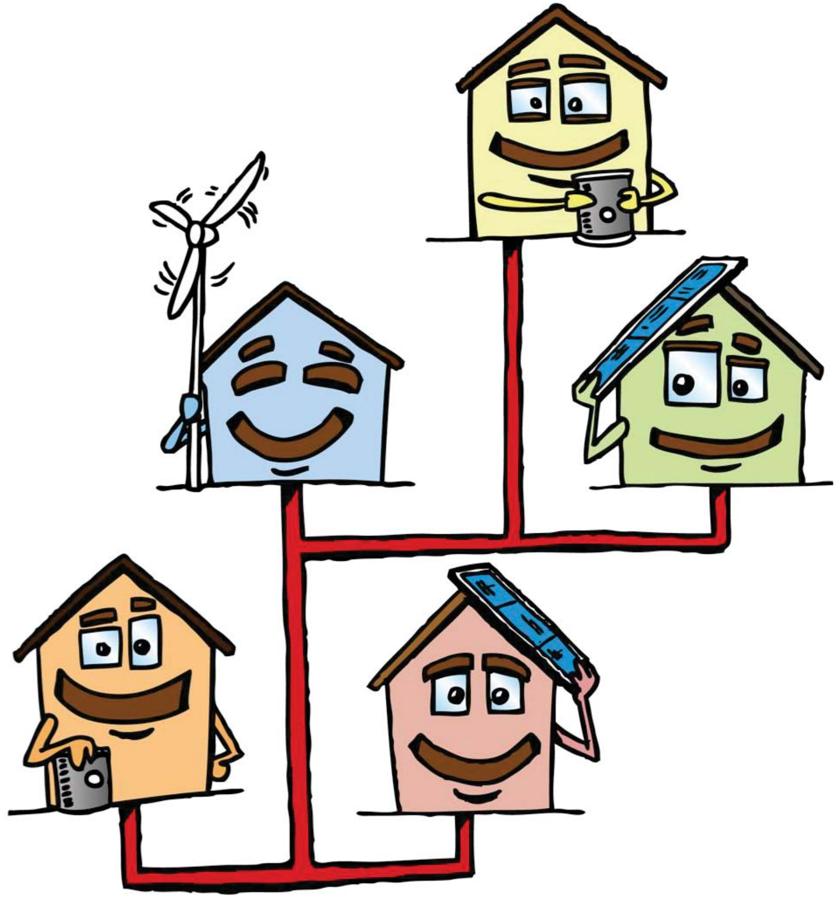
1. Introduction	- Decentral energy systems
2. Collaboration	- Zernez Energia 2020
3. Techn. implementation	- Suurstoffi district
4. Operational optimization	- NODES Laboratory

1. Introduction
Transitioning to decentralized energy systems



Hochschule Luzern
Engineering and Architecture

Decentralized Energy Systems: From a Building to a Region



2. Collaboration

Image from https://www.collaborativedrug.com/wp-content/uploads/2012/07/ubuntu_collaboration_large.jpg

1. CO_2 Emission manager
2. Energy manager
3. Financial manager

} Municipal council

4. Representative of the inhabitants
5. Energy supplier

Zernez Energia 2020

Source: ETH Zürich

- Zernez, located at an altitude of 1’440m above sea level
- In 2011: decision to become 100% energy self-sufficient and CO_2 neutral by 2020
- 2013 – 2015 Research project:
  - ➢ reduce building-related energy demand
  - ➢ potentials for renewable energy production in the area
  - ➢ strategies for locally generated heat and electricity
- Inhabitants were directly involved in the process

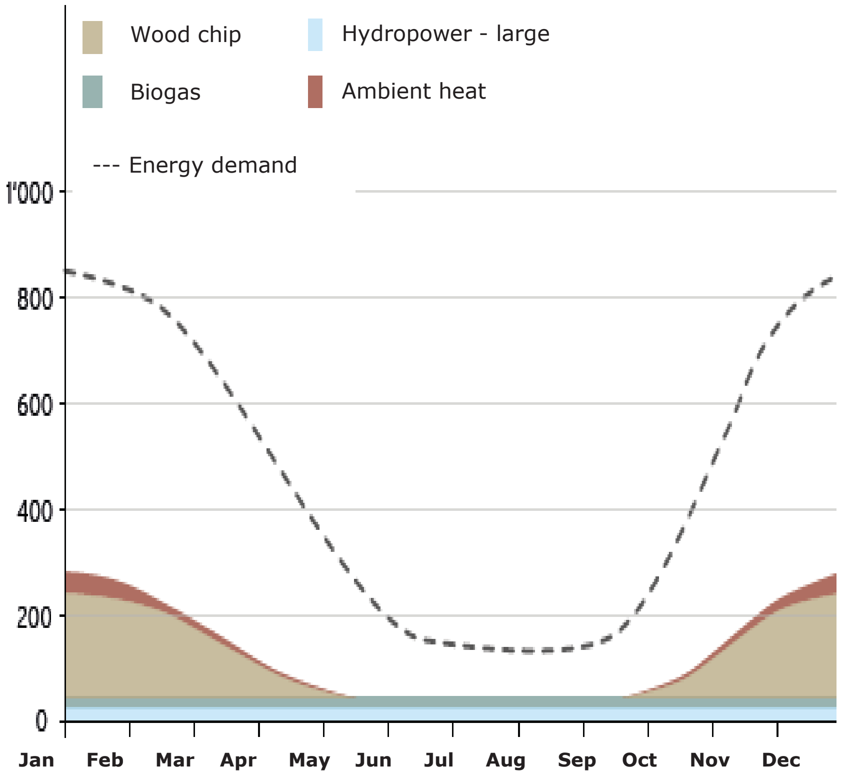
Zernez Energia 2020 –
Energy zones today and in the future

Source: ETH Zürich

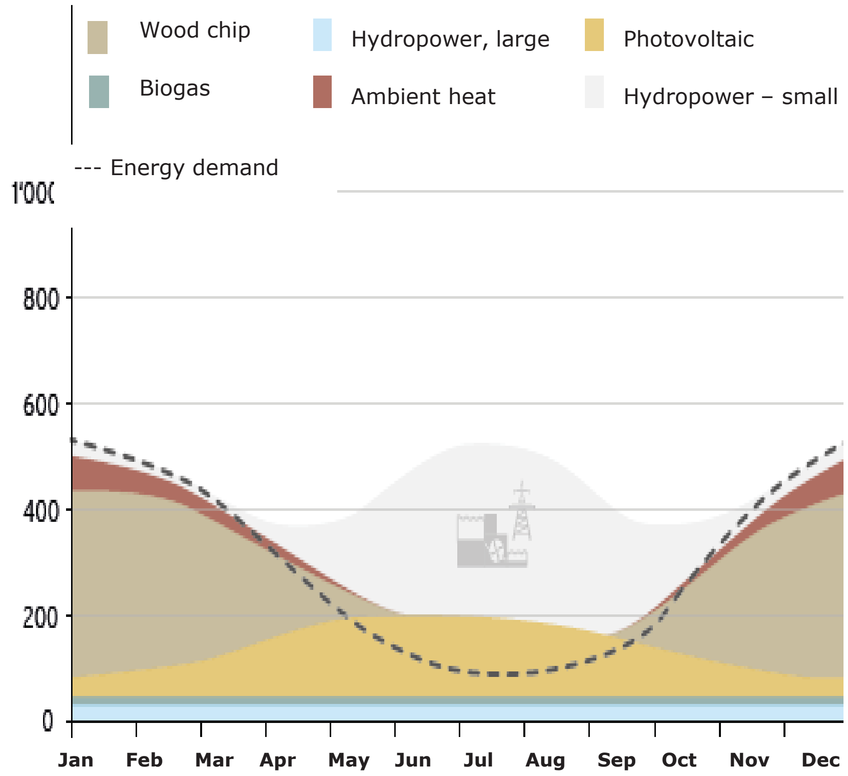
- Existing connection to district heating grid
- Potential connection to district heating grid
- Potential connection to extended district heating grid
- Potential area for local heating network
- Individual heating systems

Zernez Energia 2020 – Outlook

Energy supply/demand (MWh) - today



Energy supply/demand (MWh) - future



Source: ETH Zürich

Simulation of Zernez*

* As developed by ETH 2015, Wagner at all.

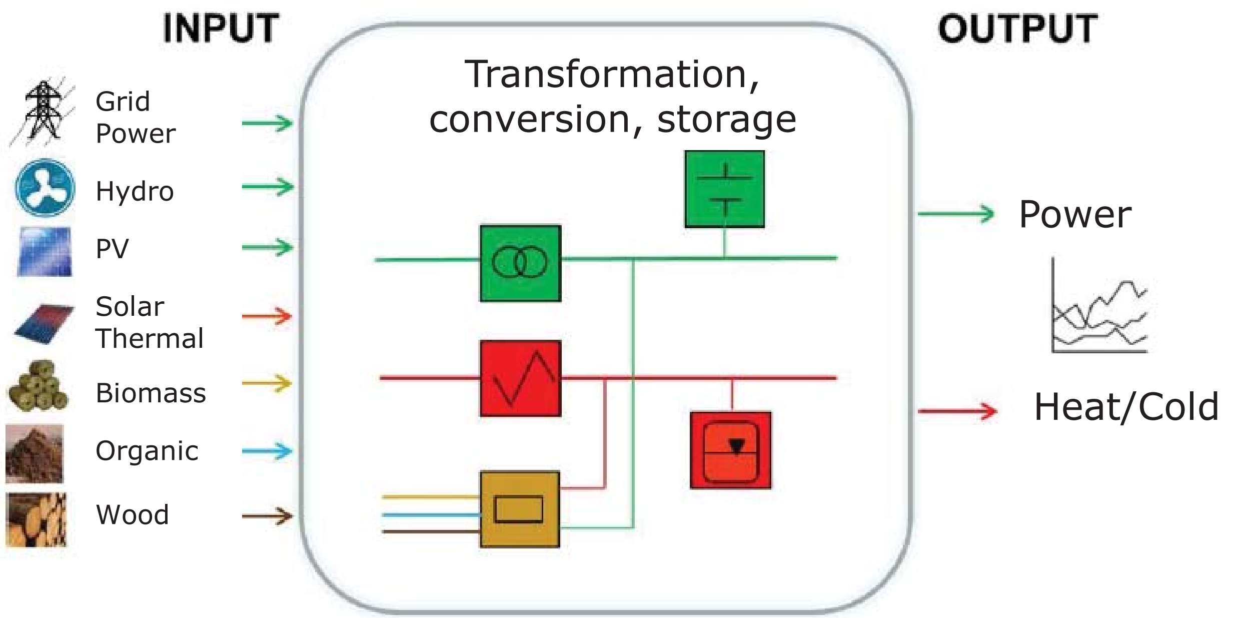
2. Technical Implementation
Suurstoffi district Switzerland

Source: Zug Estates

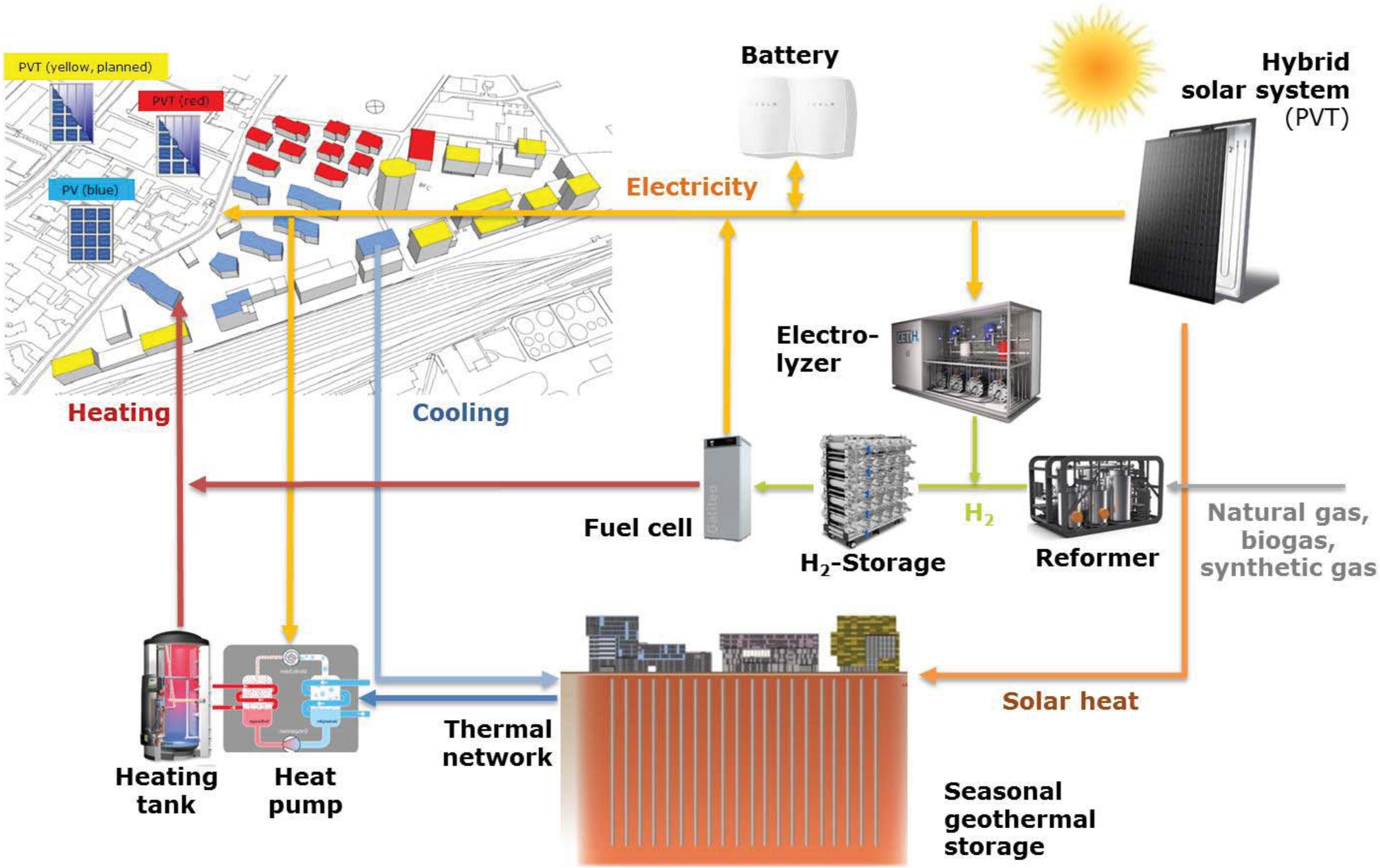
- In operation since 2012
- Low temperature district heating and cooling network **(LTN)**
- The LTN connects residential buildings, offices and industrial buildings (= consumers and producers) to a **borehole heat exchanger** (215 pieces à 150 m depth), which acts as a geothermal storage.

Suurstoffi district – An Energy hub concept

Energy hub: Combination of different technologies for generation, transformation, conversion and storage of energy

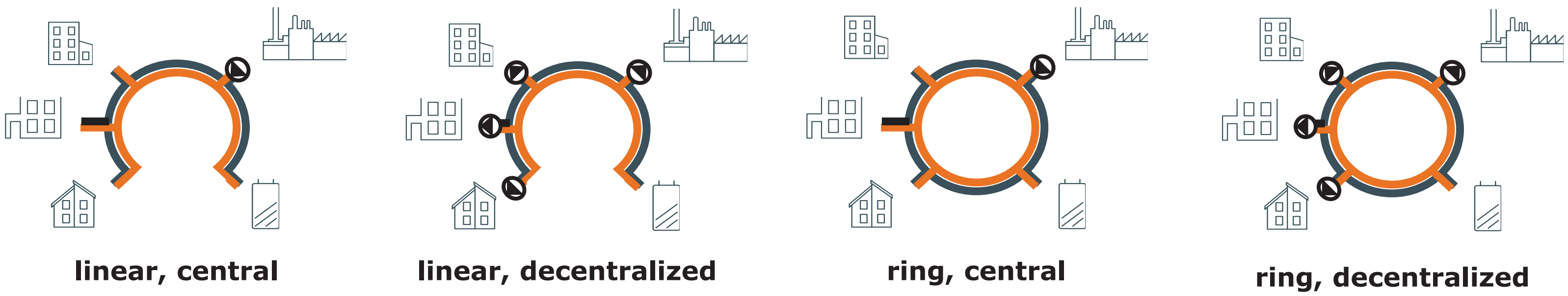


Suurstoffi district – Energy concept



Suurstoffi district - Various issues for LTN design

Bidirectional, meshed network layout
Planning and design guidelines, different scenarios and network-topologies:



Intelligent control systems
Control strategies, z.B. predictive control in order to ensure efficient and steady operation

In addition
Development of simulation models

3. Optimization
Suurstoffi district – LTN design with NODES Laboratory

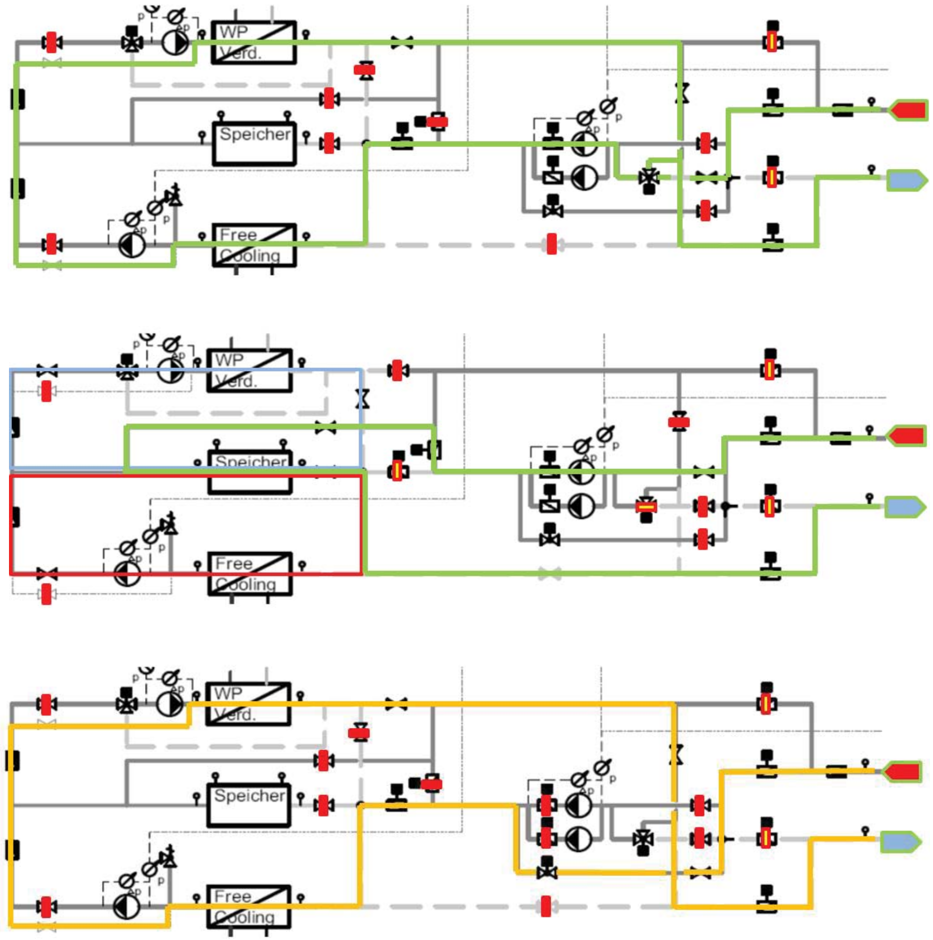
New **O**pportunities for **D**ecentralized **E**nergy **S**ystems

NODES Laboratory

LTN with ring structure

- Power grid: Thermal smart grid of a simple district
- Temperature range: 4 -25° C
- Network topology: two-pipe system (heating/cooling pipe)
- Temperature difference: ΔT = 4K
- Maximum heating capacity: 40 kW
- Network participants act as "prosumers"

NODES Laboratory - Operating conditions



- High-pressure network (with storage)
- Low-pressure network (without storage)
- Directed network (with external main pump)

Source: ZIG

References

Wagner, M. et al. Zernez Energia 2020 - Leitfaden. **ETH**-Zürich (2015)
http://dx.doi.org/10.3929/ethz-a-010577816

Prasanna A., Vetterli N., Dorer V., Sulzer M. **HSLU**; Modelling the Suurstoffi district based on monitored data to analyse future scenarios for energy self-sufficiency. Status Seminar, Brenet Zürich, 8-9 Sept 2016

Messmer C. et al. Virtual Test Bench by Linking the HSLU-NODES Lab and the **FHNW**-Energy Research Lab. Status Seminar, Brenet Zürich, 8-9 Sept 2016

Summary

- Decentral Energy Systems are our future
- It all starts with a good collaboration between all parties

- …..to have an entire CO2 Neutral Region

Thank you for your attention!

Backup

Zernez Energia 2020

Initial situation:

- 304 buildings connected to the power grid 100% hydropower (partially imported)
- 91 oil heaters, mainly in the village center
- 33 buildings supplied with district heating from an outdated wood-chip heating
- 113 buildings equipped with wood and electric heating

Potential analysis:

- showed that 90% percent of total CO_2 emissions caused by oil heating
- wind in village inefficient; bigger wind turbines in exposed higher locations difficult to develop and alteration of landscape → touristic value
- hydro power plants → nearly all potential locations already exploited
- Forest area has potential for enhanced usage of wood → advantage: time-independent availability
- Over 50% of buildings in Zernez renovated → but mainly only windows and doors

Zernez Energia 2020

Implementation Plan:

- Extention of district heating (25 buildings); new cogeneration plant (wood)
- Merging of separate buildings to local heating network (e.g. wood heating or heat pumps if already floor heating)
- Solar thermal for single buildings
- small hydropower plants
- Private and municipal photovoltaic on rooftops and freestanding (parking and industrial area)
- heat pumps combined with borehole heat exchanger
- Prohibition of all electric heaters
- Renovation of building envelopes: of all 309 buildings, 89 were identified to cause 90% of all CO_2 emissions for heat demand;

  Priority:
  → 1. replacement of all oil heaters by heat pump or district heating
  → 2. building envelope (37 buildings)

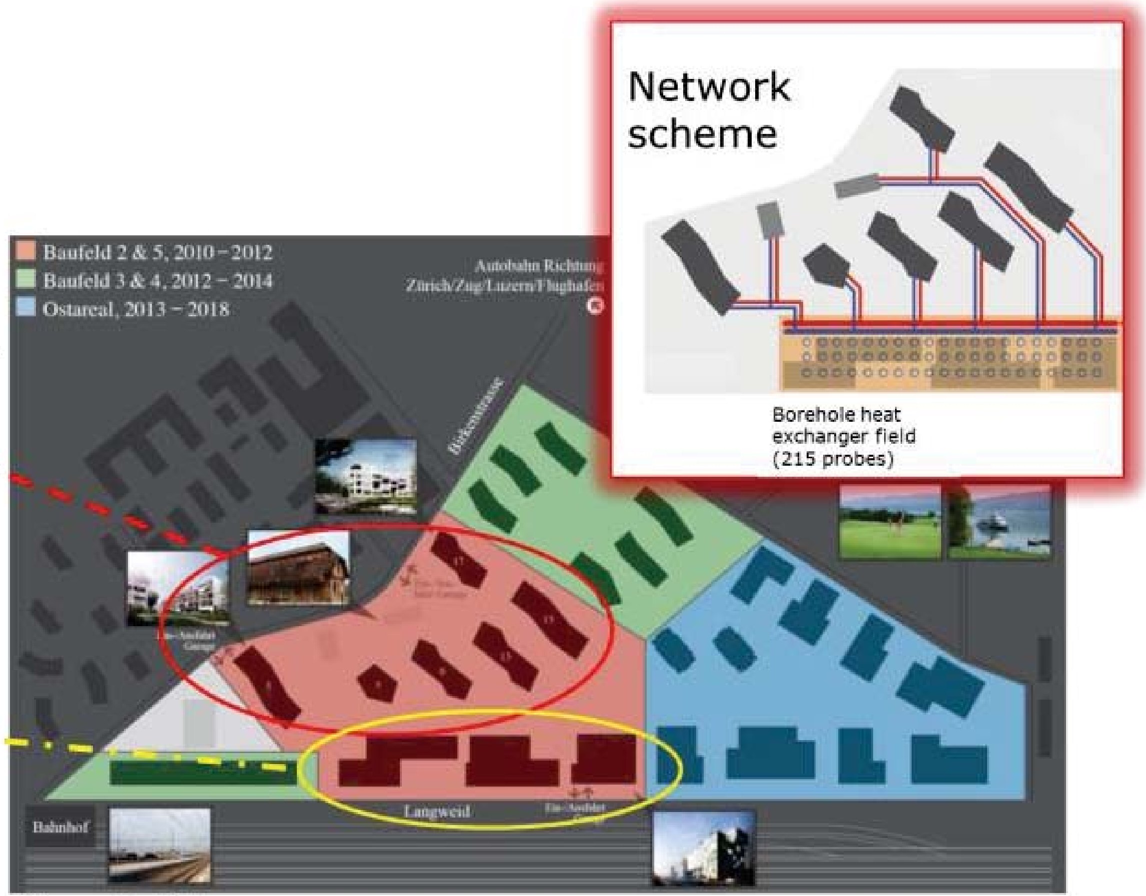
Suurstoffi district – Energy concept

Building field 2:
19’540 m²

In operation since
2012

Building field 5:
27’250 m²

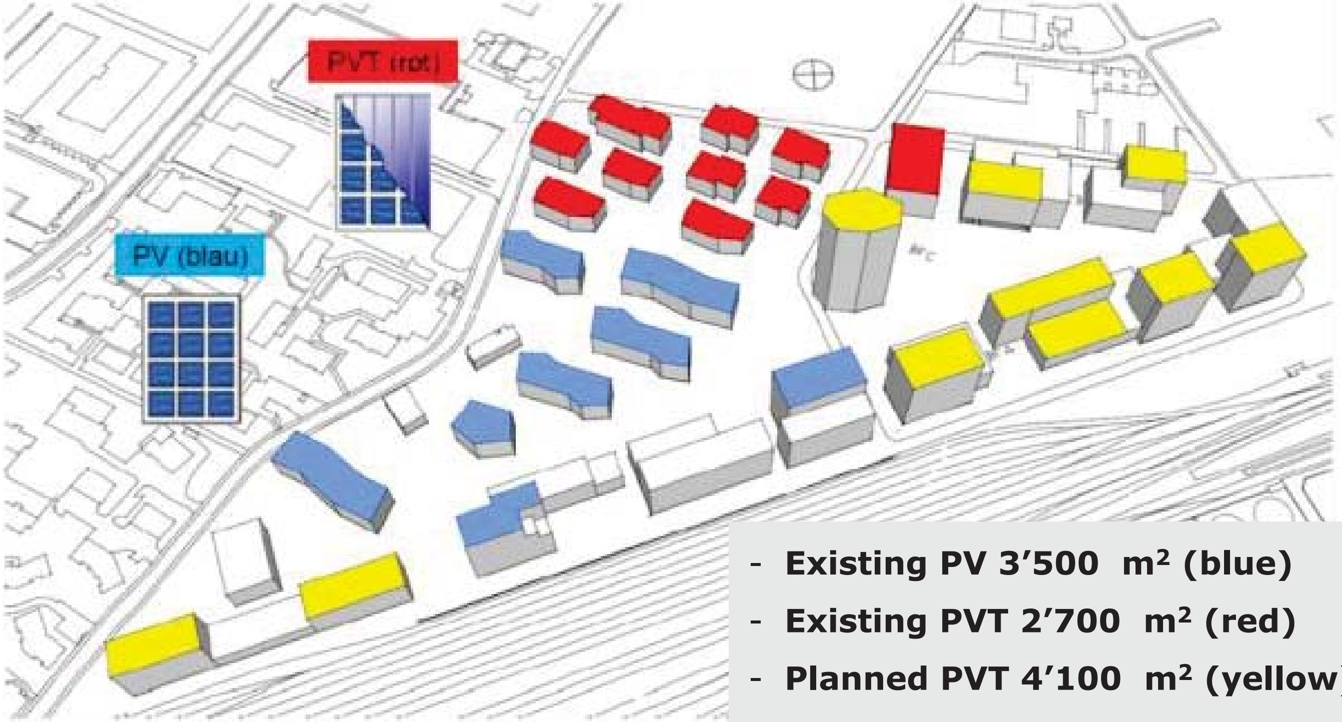
In operation since
2013



Source: Zug Estates

Final state (2020): 165’000 m²

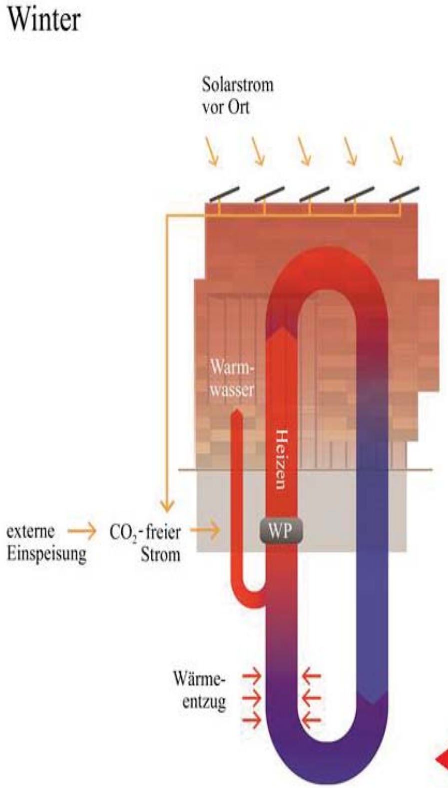
Solar energy integration in the system

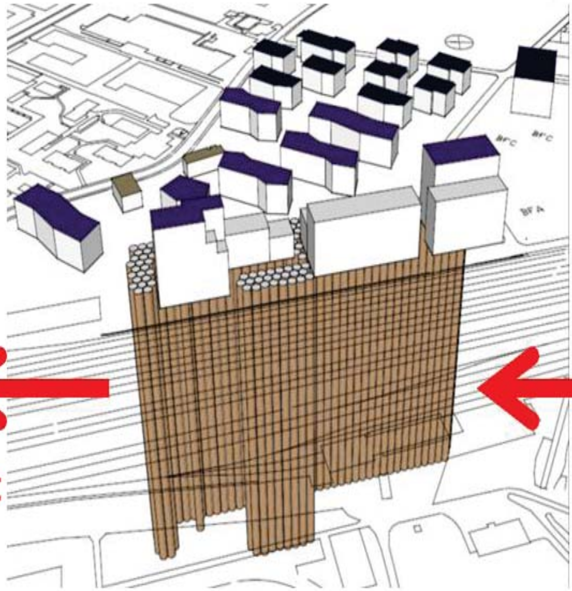


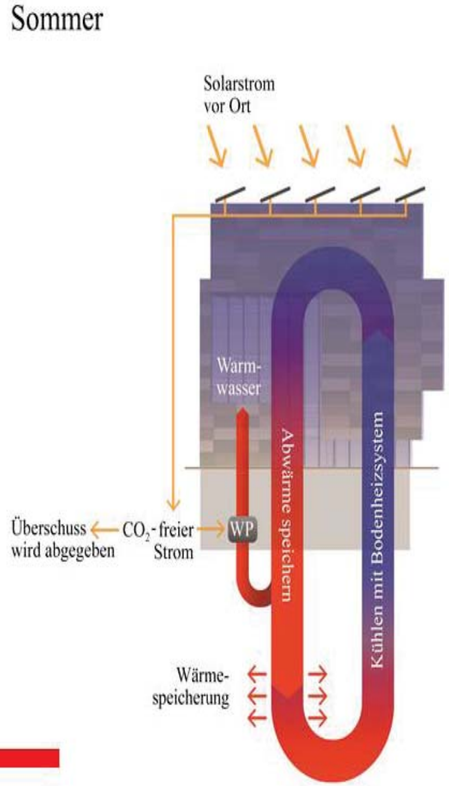
- **Existing PV 3’500 m² (blue)**
- **Existing PVT 2’700 m² (red)**
- **Planned PVT 4’100 m² (yellow)**

Source: Hans Abicht

Source: Hans Abicht / Zug Estates







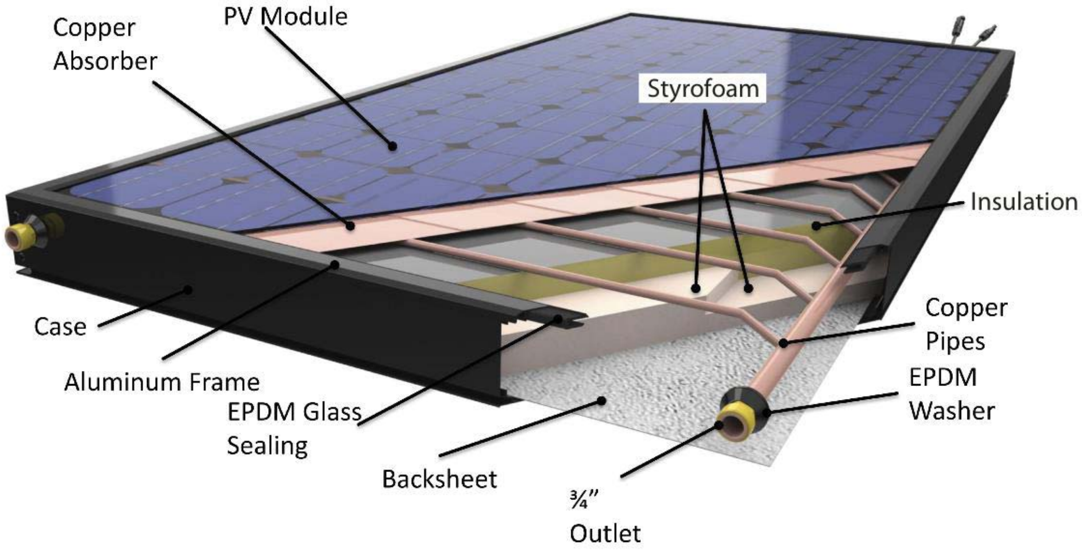
Uptake of heat through heat pumps

Field West: 215 boreholes 150 m depth

Heat supply through freecooling

Field East:
180 boreholes 280 m depth

Hybrid (PVT) solar collector



Source: solar choice

Monitoring & Results

- LTN Suurstoffi is being monitored for at least five years and the Lucerne University of Applied Sciences has been analyzing the monitoring data since 2012
- Heat and power flux as well as temperature change are measured in a 15 minute interval resulting in a total of about 400 data points over the existing building fields 2 and 5
- Results have been regularly compared with original calculations -> high correlation but still some optimization potential for network operation-> use of optimization model/software

Suurstoffi district – Installed PV and PVT capacity

	Total installed area [m^2]	Total installed capacity [kWp]	Electricity production [kWh per year]	Thermal production [kWh per year]
PV panels [BF2+BF5]	3484	595	345	0
PVT panels [BF3]	2704	424	401	1367
Total	6188	1019	746	1367

PV Efficiency:18%

PVT Thermal efficiency: 30%-50%

Electrical efficiency: 13%

Suurstoffi district – Heating/cooling demands and borehole fields capacity

	Space heating [MWh/y]	Hot water [MWh/y]	Cooling [MWh/y]	Total heating [MWh/y]	Total Cooling [MWh/y]
BF2	629	283	56	912	56
BF5	797	380	533	1177	533
BF2+BF5 [measured]	1426	663	589	2089	589
BF3	507	213	64	720	64
BF2+BF5+BF3	1933	876	653	2809	653
Whole site [estimate]	5624	1828	2117	7452	2117

	Number of boreholes	Depth[m]	Capacity [GW]
Borehole field 1	220	150	2
Borehole field 2 [in construction]	180	300	3

Monitoring & Results – Total measured heat demand vs. model input demand

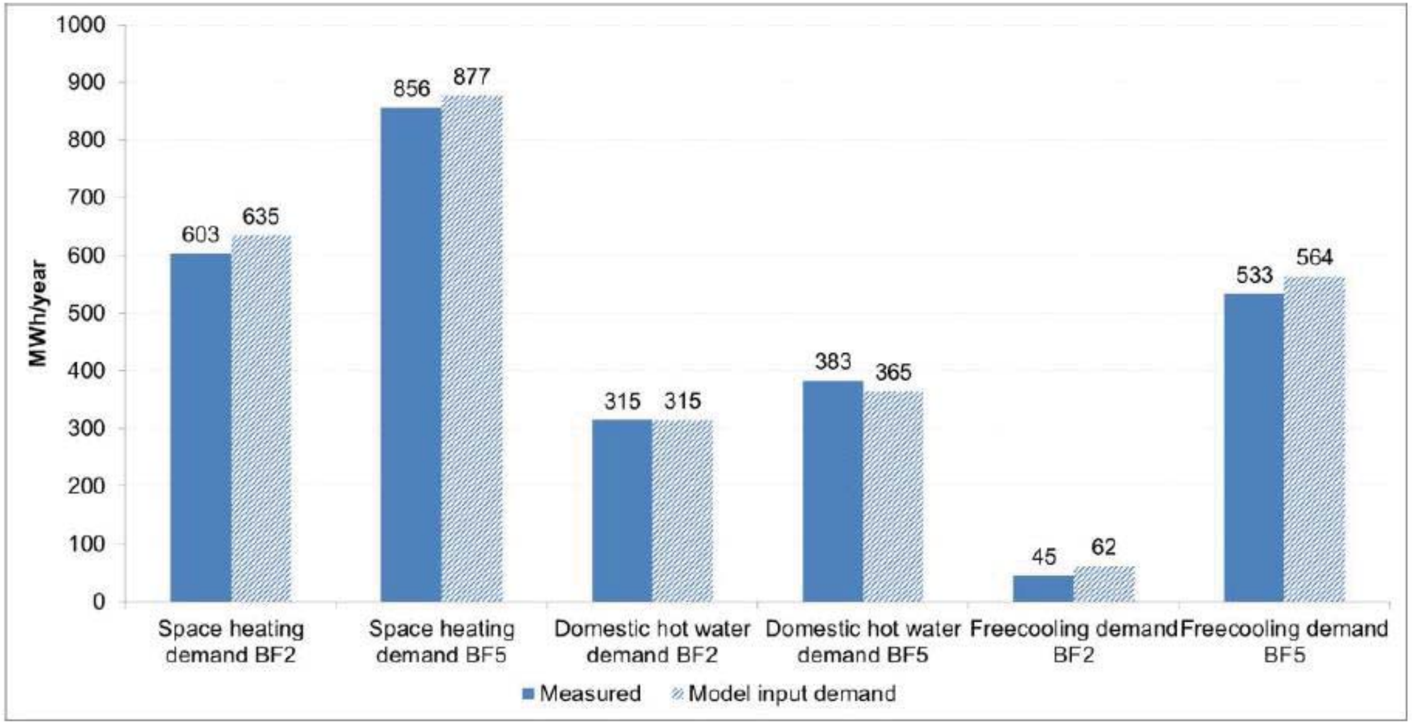


Figure 4a. Comparison of measured demand with model input demand

-> Small deviation of measured and modelled data

Monitoring & Results – Total measured electricity demand vs. model input demand

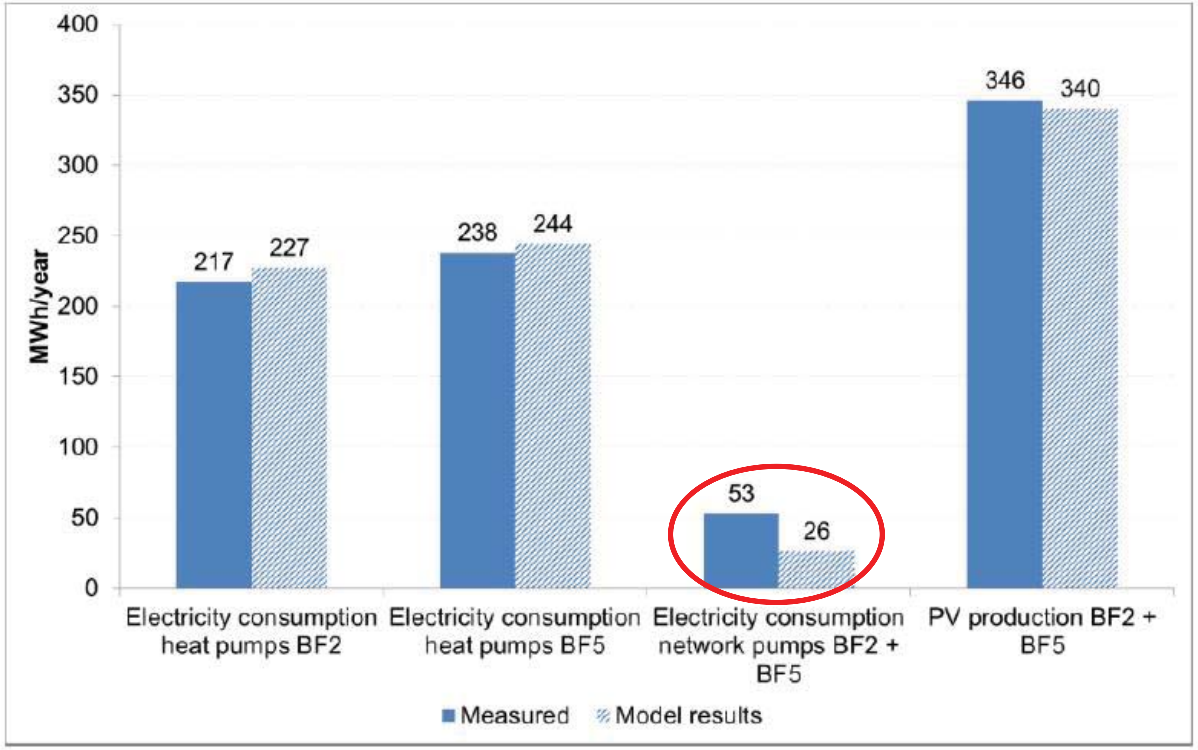
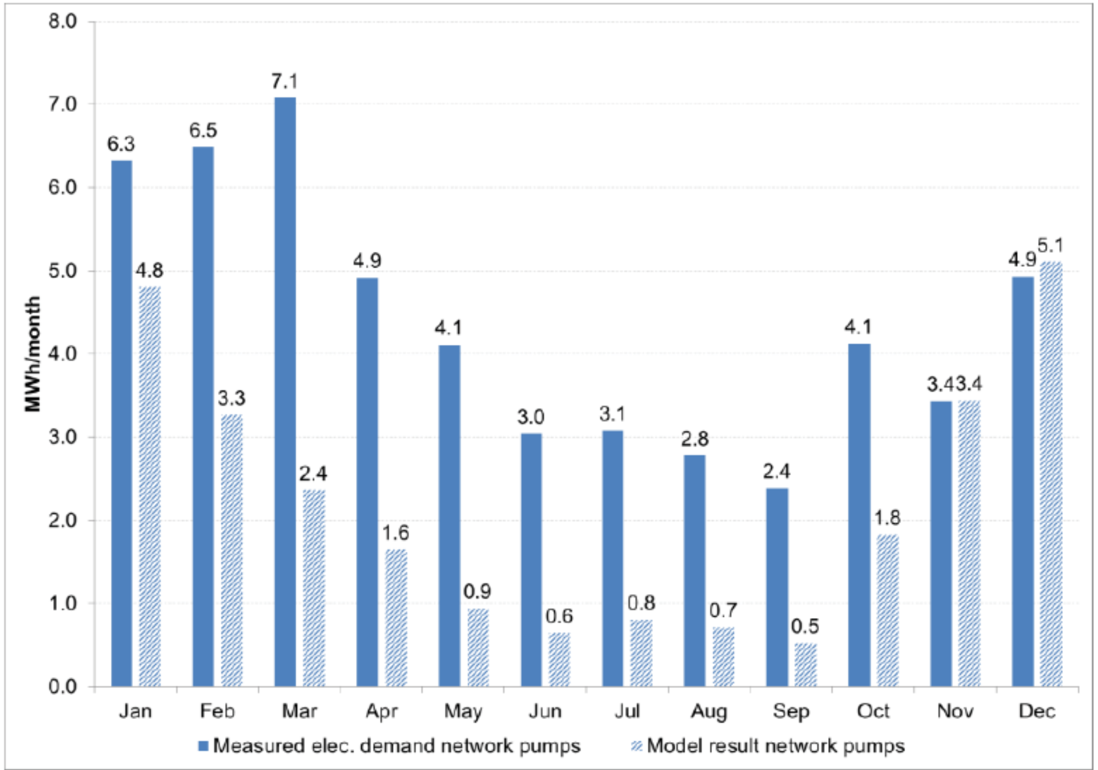


Figure 4b. *Comparison of measured electricity demand with model results*

-> Small deviation of measured and modelled data, except network pumps

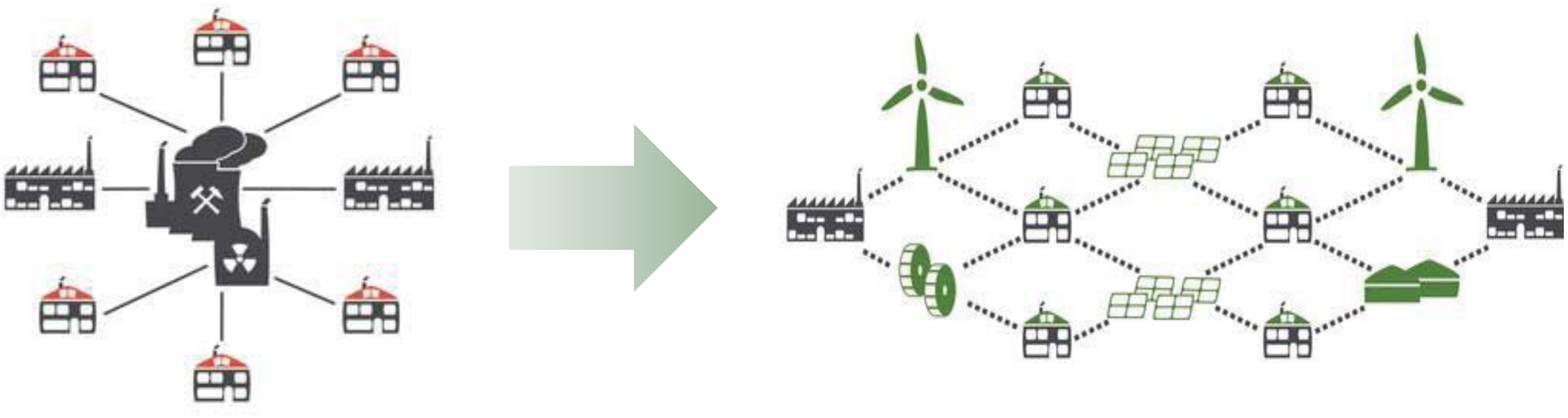
Monitoring & Results – Total electricity demand vs. model input demand network pumps



Comparison of measured electricity consumption of network pumps with model results

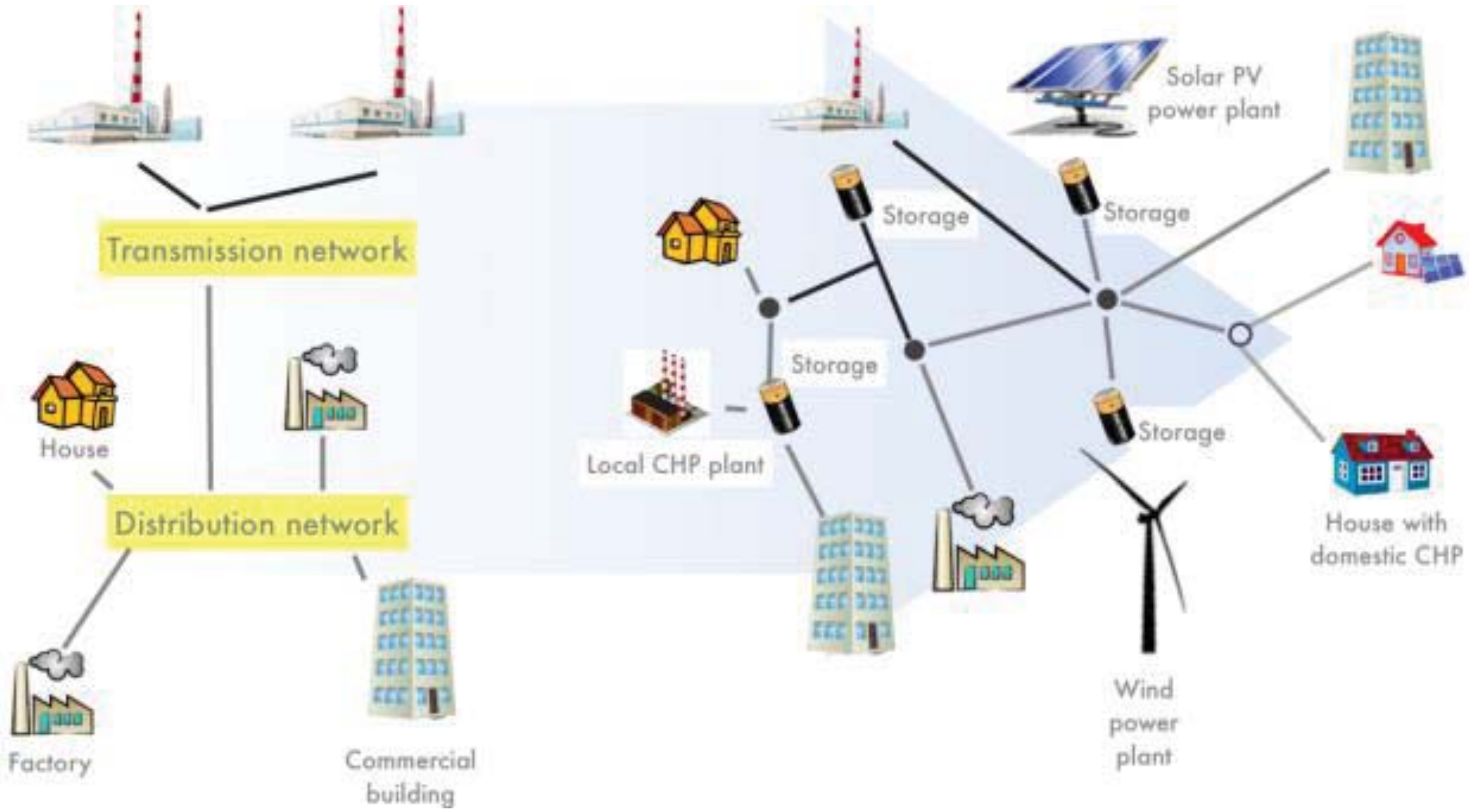
-> Optimization potential for network operation
-> More detailed simulation model

Transitioning to Decentral Energy Systems



https://www.naturstrom.de/ueber-uns/die-naturstrom-ag/vision/

Transitioning to Decentral Energy Systems



https://ilsr.org/challenge-reconciling-centralized-v-decentralized-electricity-system/