2nd International Conference on Smart Energy Systems and 4th Generation District Heating
Aalborg, 27-28 September 2016

Modelling, design and evaluation of decentralized energy systems for districts and neighborhoods

Ashreeta Prasanna, Viktor Dorer
Empa, Urban Energy Systems Laboratory

Distributed multi-energy systems (DMES)

Example: Suurstoffi Areal, Risch Rotkreuz

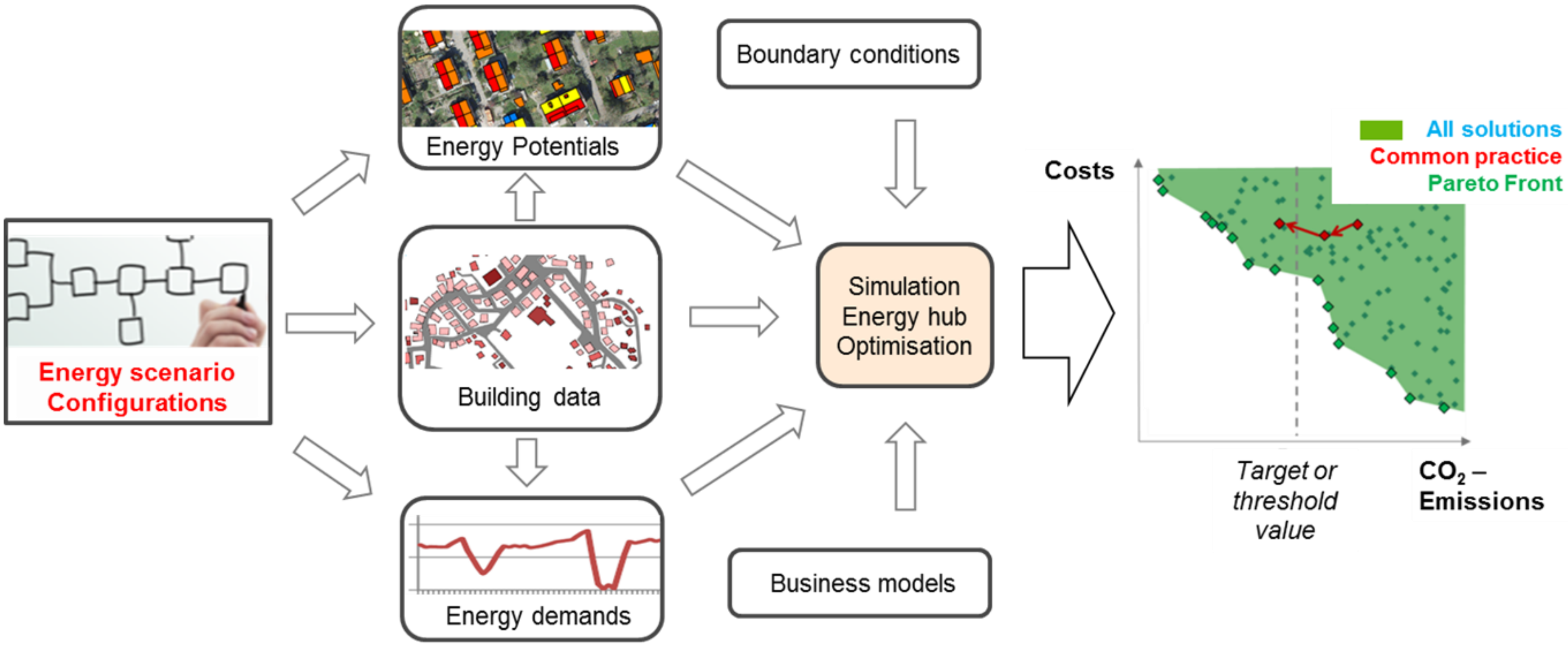
Questions:

1. What are the benefits of a multi-energy system?
2. How can DMES be optimally designed?
3. How can DMES be optimally operated?

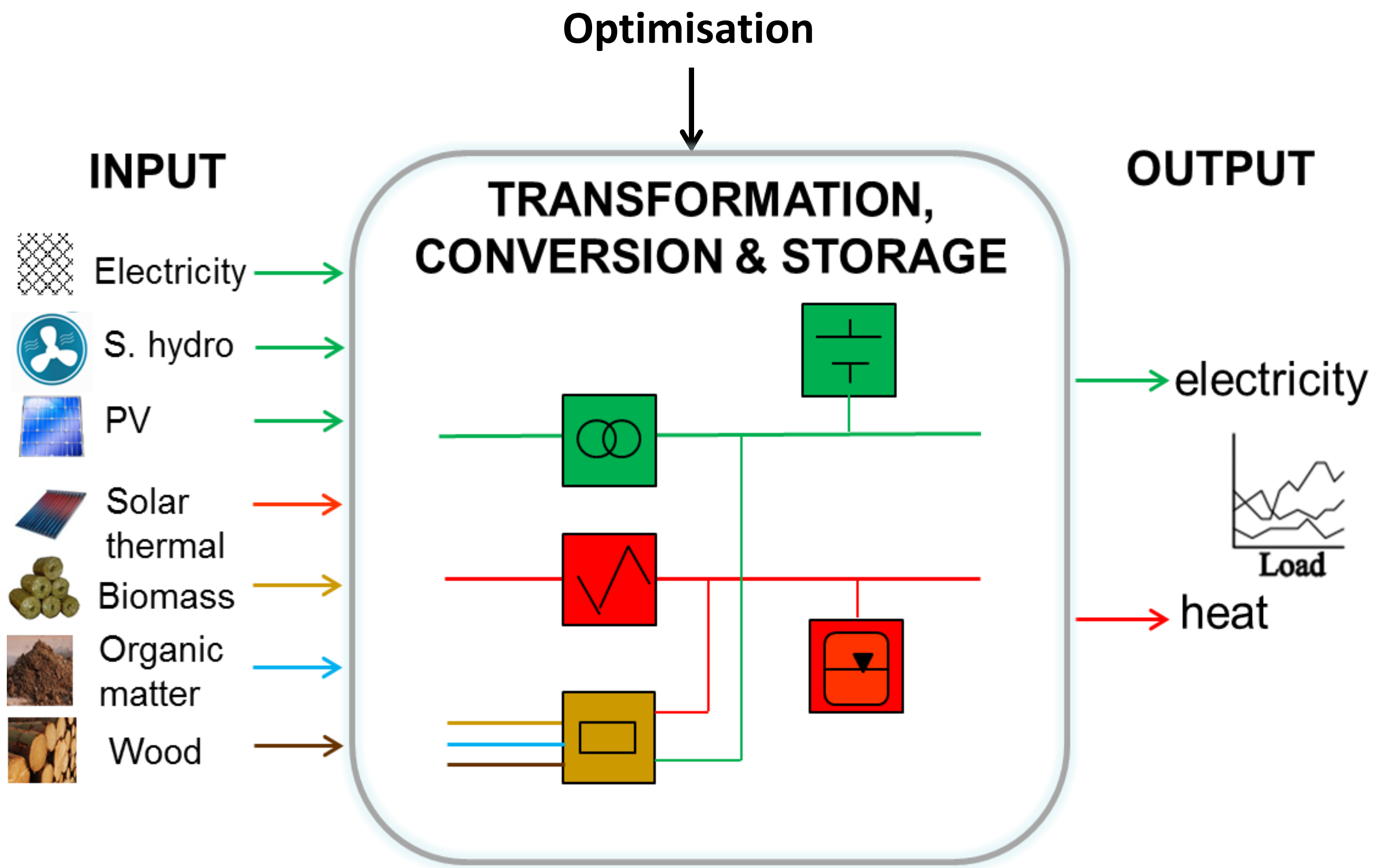
Given:

- Time-varying resource availability
- Multi-energy demand patterns
- Technical & economic constraints
- Regulatory/policy environment
- Uncertainties regarding fuel prices, energy demand, policy

Optimisation model – Energy hub approach

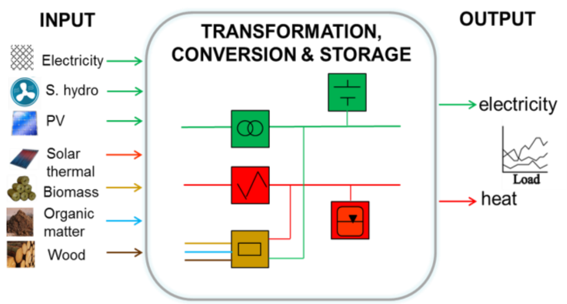


Energy hub approach



Optimisation vs. Simulation

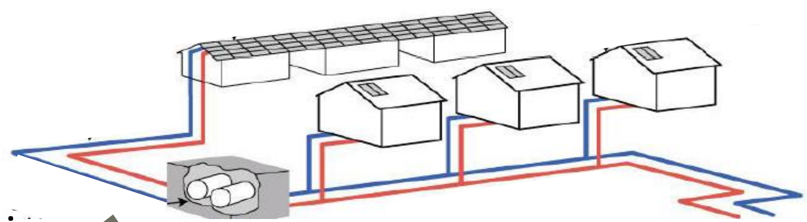
Optimisation (Energy hub approach)



Validation, Constraints

Detailed analysis

Simulation



- Simplified representation of components (linear equations)
- Analysis of complete system with individual building loads
- Global optimisation of system, over time horizon
- Objectives: Dimensioning of systems and operation strategy

- Detailed description of the components (temperature, pressure, partial loads, etc.)
- Analysis of a specific system configuration
- No global optimisation
- Objectives: Understand dynamic system behavior, and energy performance

Case study : Low energy district in Switzerland

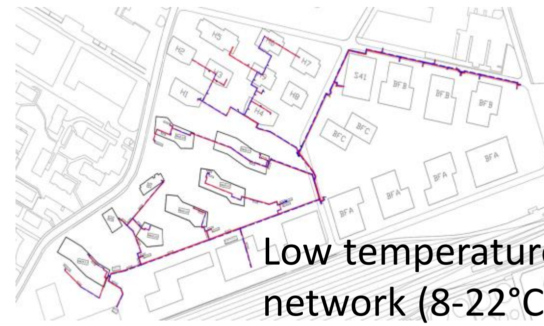
20 buildings, which include 1 kindergarten, 1 community center and 3 mixed use buildings.

Hybrid photovoltaic panels (PVT)

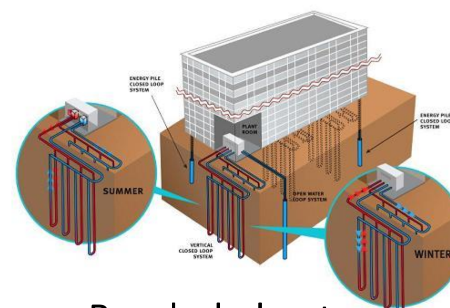
Photovoltaic panels (PV)

Image source: http://www.sccer-feebd.ch/de/multi-energy-grid-the-potential-of-thermal-networks/

All buildings have decentralised heat pumps connected to a low temperature network



Low temperature network (8-22°C)



Borehole heat exchangers

‘Anergienetz’ – experience

- Monitoring (15 min)
- Original design – heating loads should roughly balance cooling loads and heat input from hybrid photovoltaic panels.
- Performance gap
- Network heat balance
- Network pumps electricity consumption

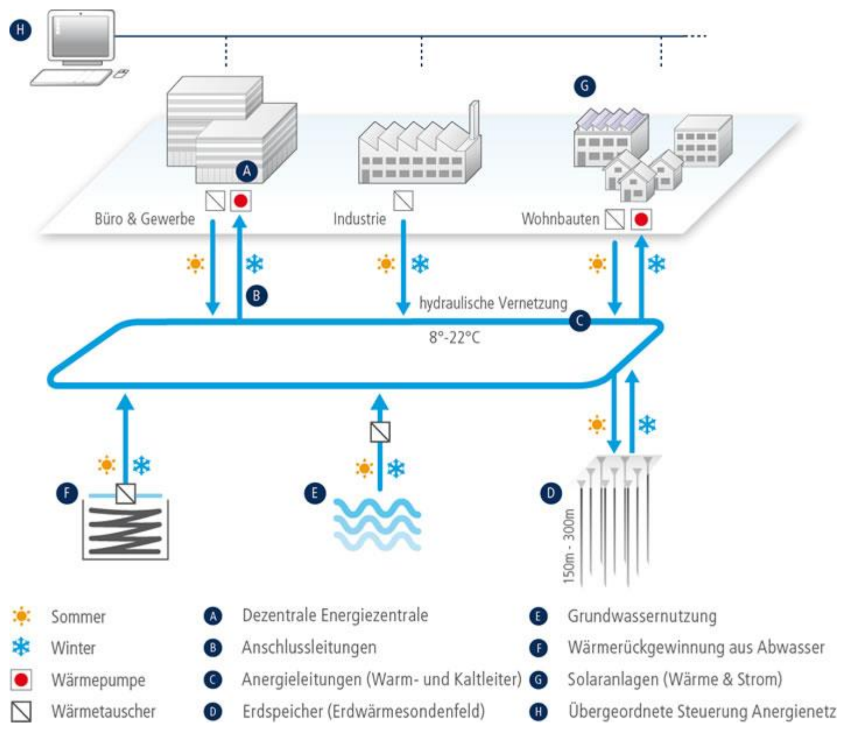
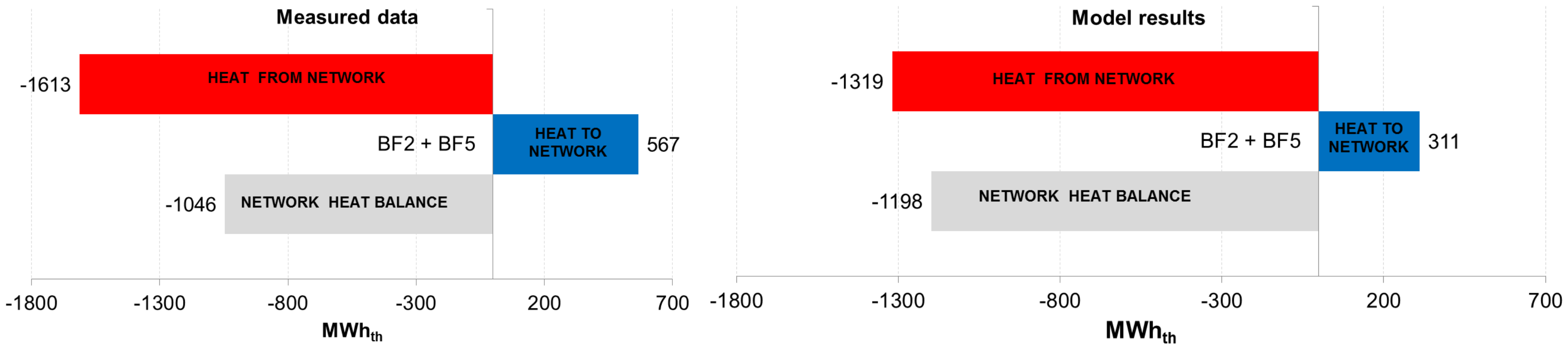


Image source: http://www.energienetz-gsg.ch/waermeversorgung

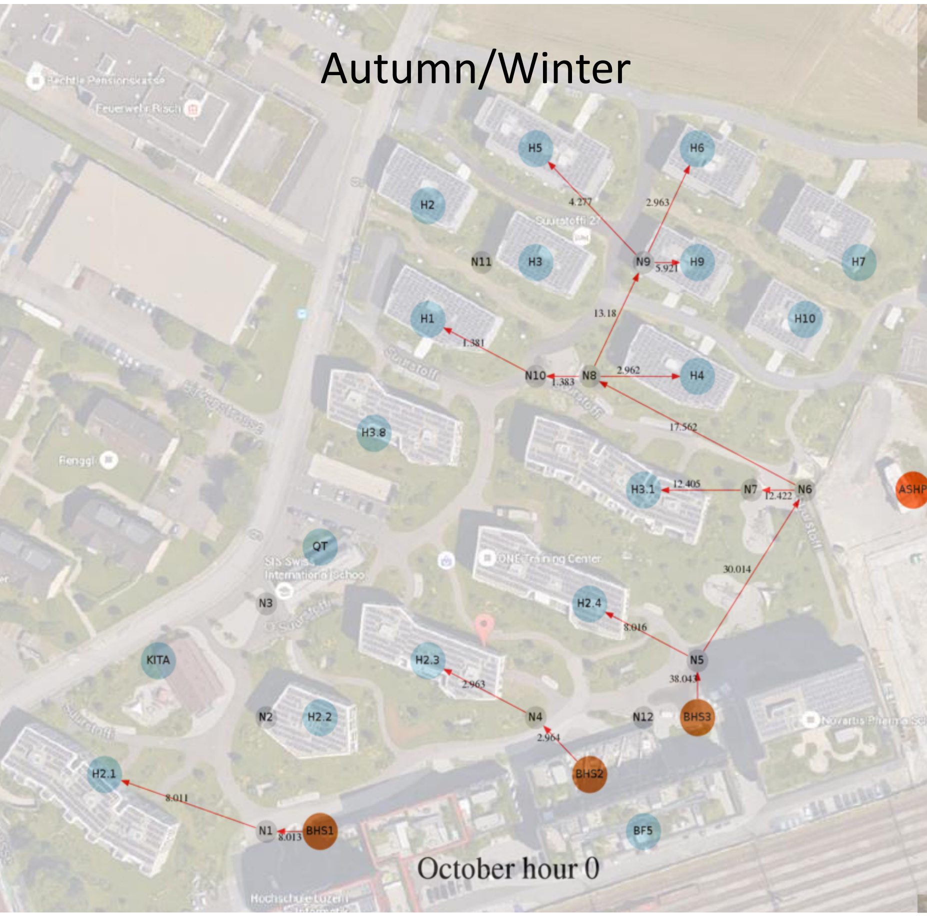
Optimisation – Heat balance

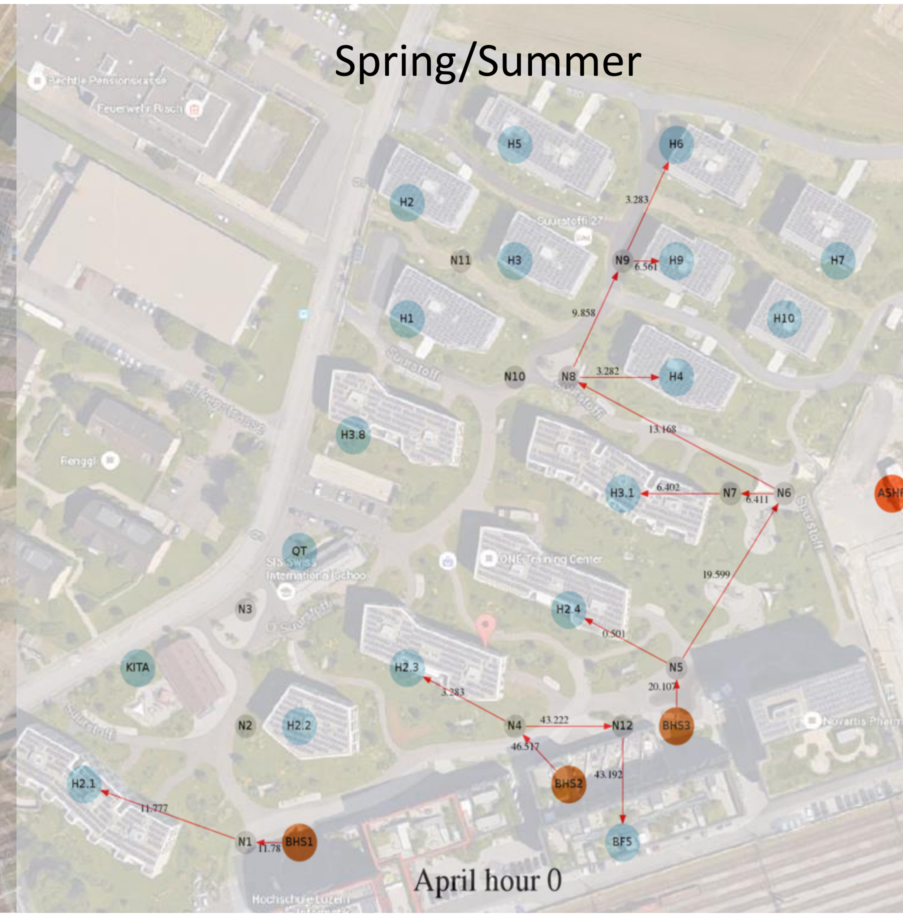


- The total network deficit calculated by the model is close to measured value
- Difference in the amount of heat injected into the network and drawn from the network
- Reason for lower electricity requirement for pumping calculated by the model

Optimisation – Heat balance

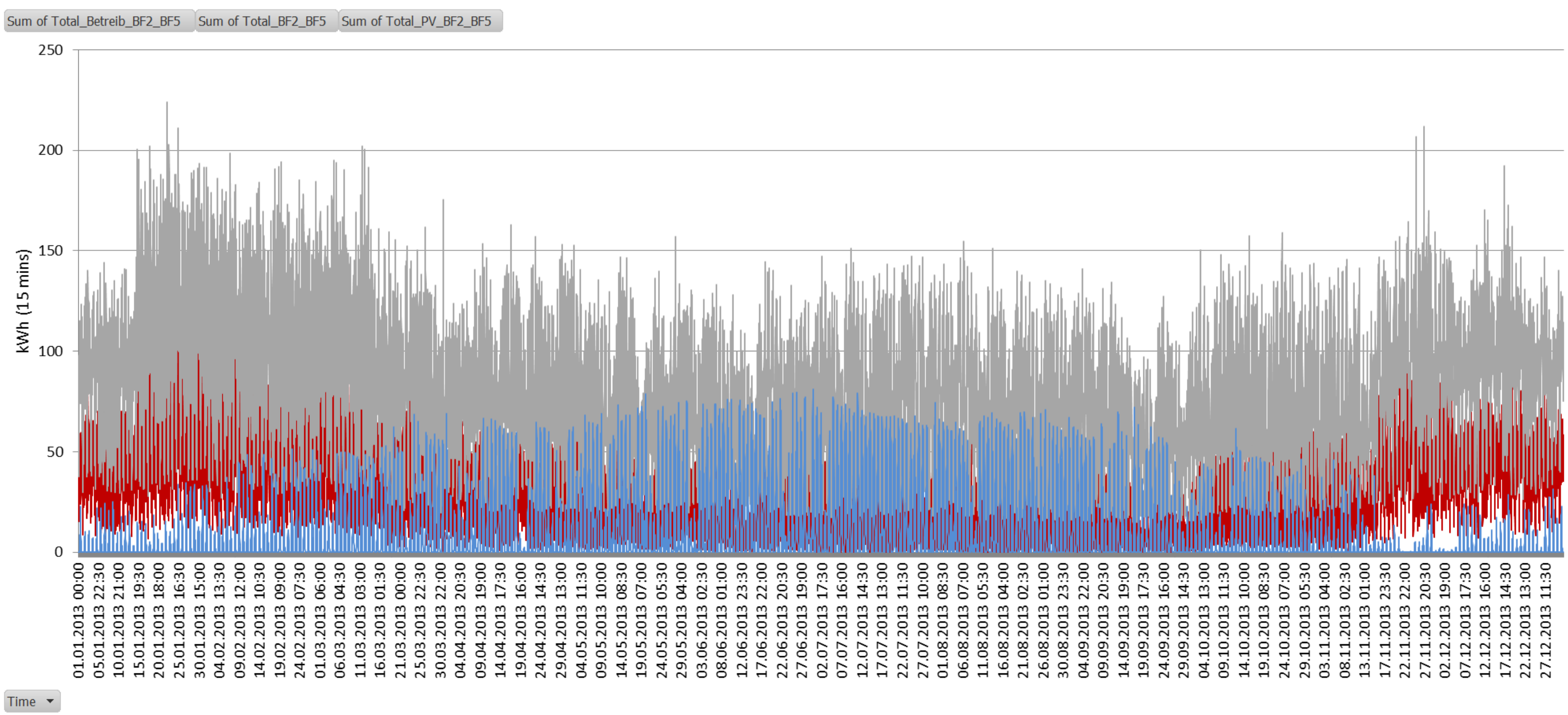
Heat fluxes (hourly values) (kWh / h)





Analysis – benefits of multi energy system

	Total Demand (MWh/year)	PV Production (MWh/year)	Load cover factor (year)	Supply cover factor (year)
BF2 (residential)	1068	274	0.257	1
BF5 (offices)	1584	65	0.041	1
BF2+BF5	2652	346	0.130	1

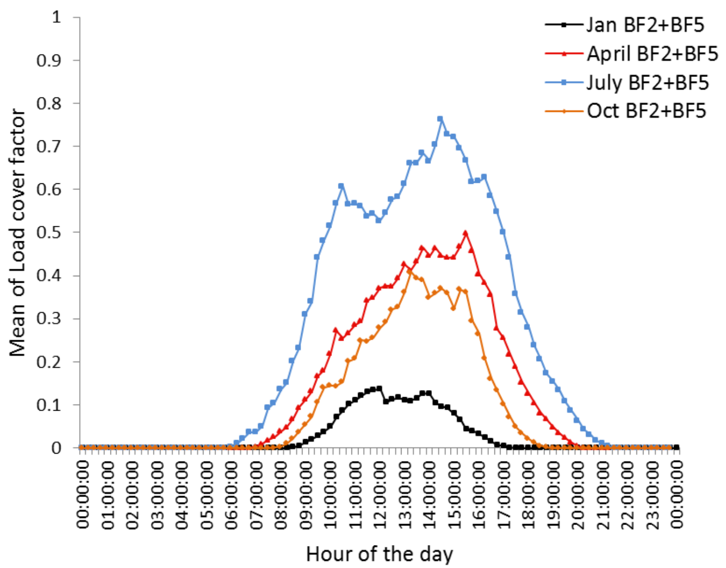


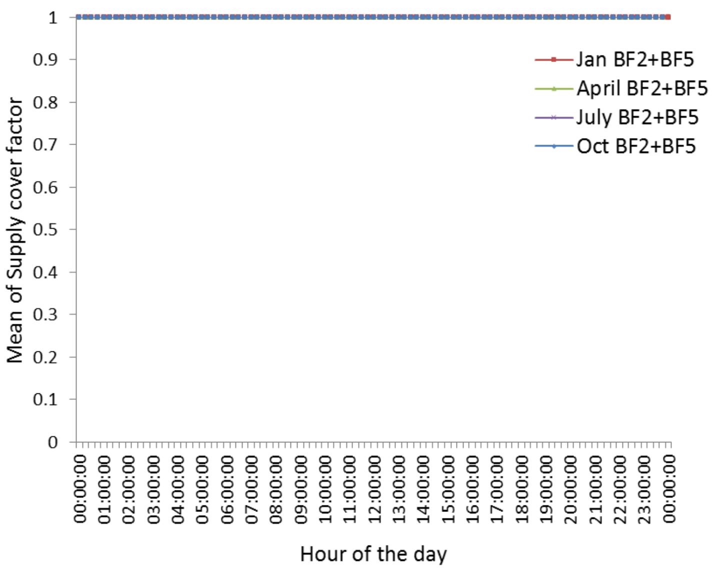
of **the**
eating
on-site

of the
sed by

Analysis – benefits of multi energy system

	Load cover factor (15 mins)	Supply cover factor (15 mins)
BF2 (residential)	0.220	0.959
BF5 (offices)	0.041	1
BF2+BF5	0.130	0.997

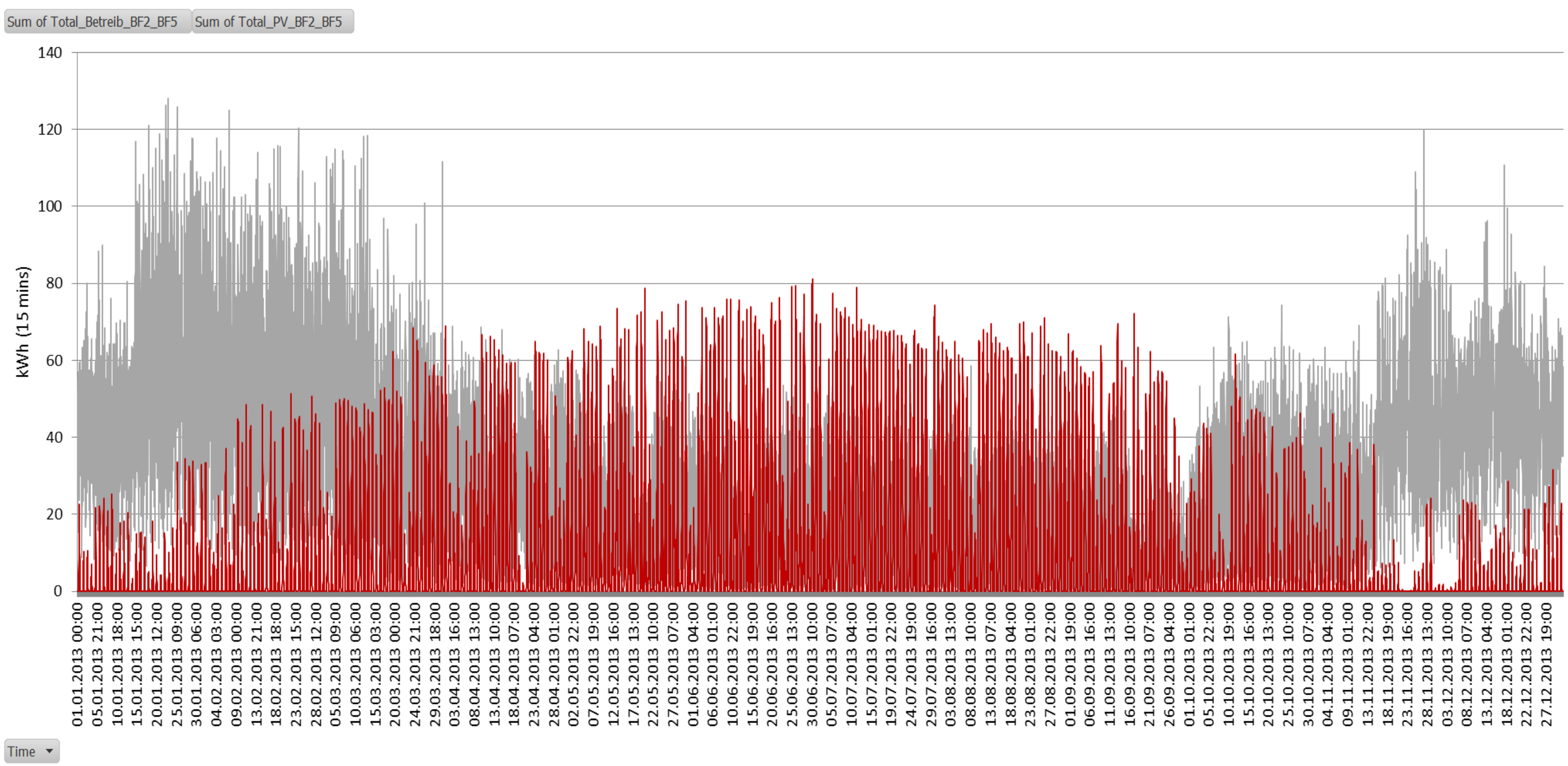




Analysis – benefits of multi energy system

4DH
4th Generation District Heating Technologies and Systems

	Electricity for Heating (MWh/year)	PV Production (MWh/year)	Load cover factor (year)	Supply cover factor (year)
BF2	365	274	0.752	1
BF5	581	65	0.111	1
BF2+BF5	946	346	0.365	1

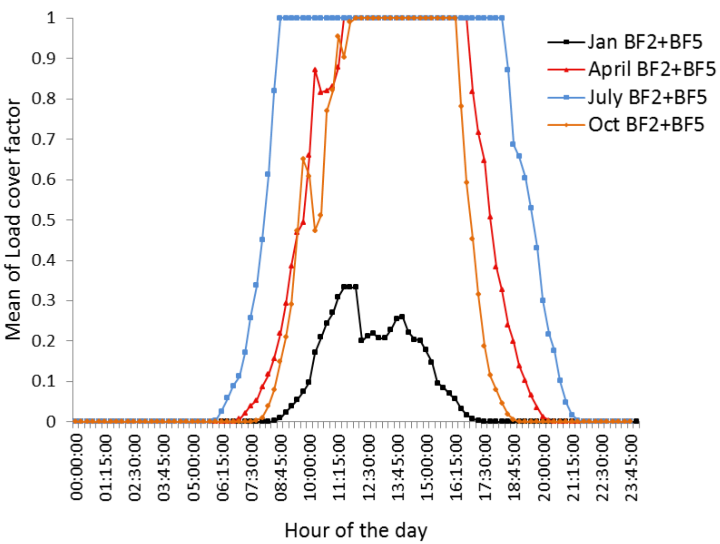


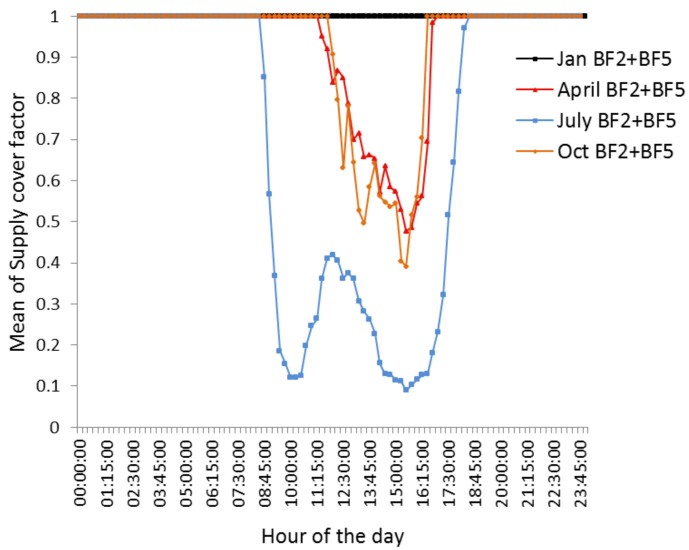
e of the
ting
ectricity

e of the
used by

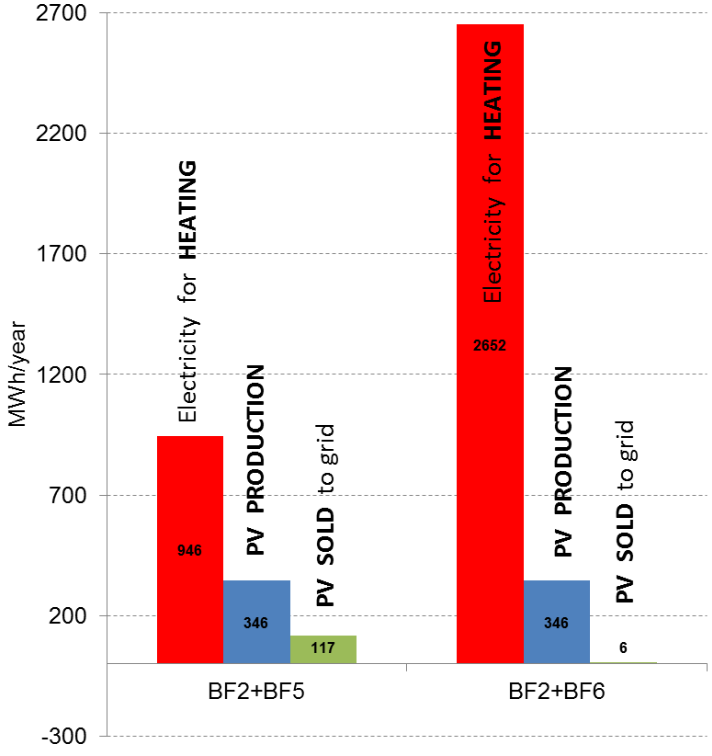
Analysis – benefits of multi energy system

	Load cover factor (15 mins)	Supply cover factor (15 mins)
BF2	0.328	0.817
BF5	0.10	0.889
BF2+BF5	0.274	0.879

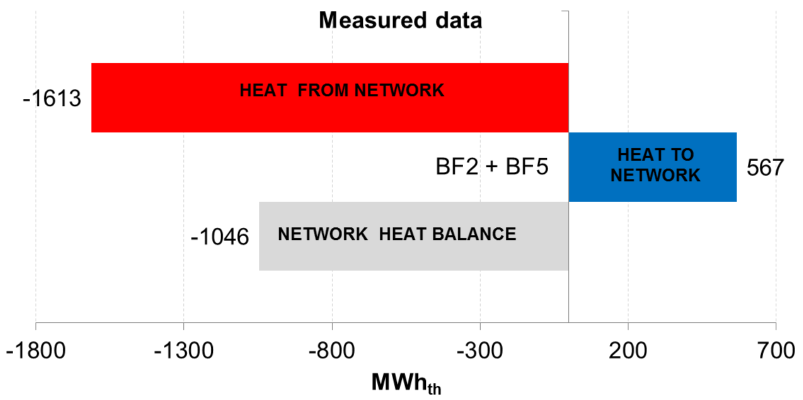




Analysis – benefits of multi energy system



Network deficit = - 1046 MWh_{th}/year



Improving supply cover factor to 1:

- Instead of PV sold to the grid, HP are run in the summer and heat produced is sent to network/storage

~117 MWh/year or 117 x COP (8) = 936 MWh_{th}/year

Conclusions

Benefits of multi energy system:

- Improve energy balance in low energy districts
- Improvement of supply cover factor
- Possibility to optimise operation of heat pumps

Current optimisation model:

- Calibrated and verified with monitoring data
- Identified possible optimisation of system energy balance, given existing knowledge of system

Further steps:

- Detailed simulation of network to derive further constraints for network optimisation
- Development of further concepts/scenarios for new districts

References:

Salom J.,Marszal A.J.,Candanedo J., Widen J., Lindberg K.B., Sartori I., Analysis Of Load Match and Grid Interaction Indicators in NZEB with High-Resolution Data, IEA Task 40 / Annex 52 , October 2013.

Vetterli N., Brücker S., Monitoring Suurstoffi – Monitoring einer thermischen Arealvernetzung in Kombination mit einem Erdsondenfeld, Jahresbericht 2014, Bundesamt für Energie BFE, Bern, 2015

ZugEstates, Nachhaltigsbericht 2015, retrieved from http://www.zugestates.ch/documents/

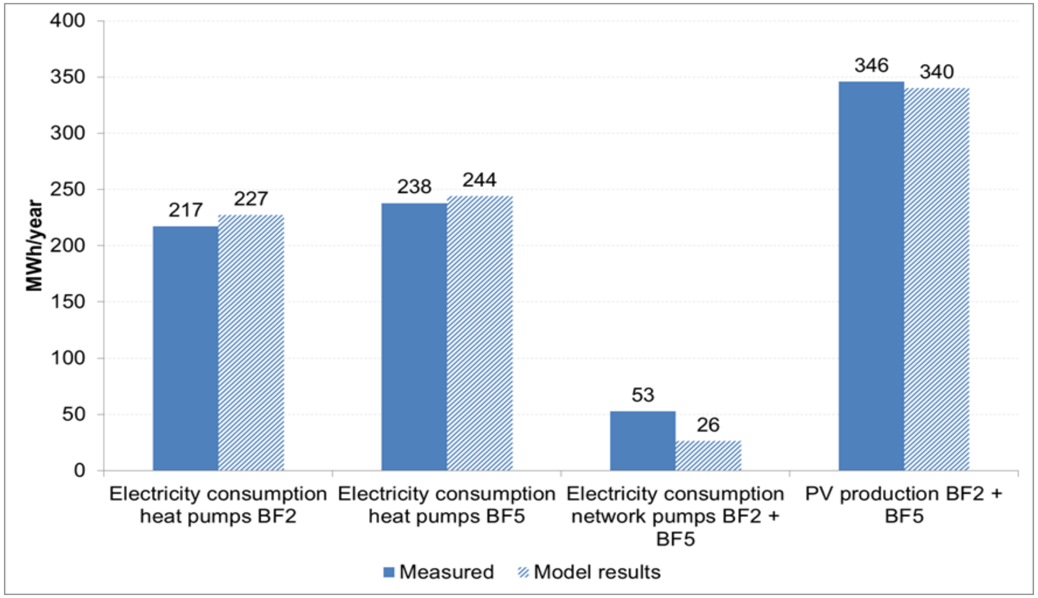
Thank you for you time

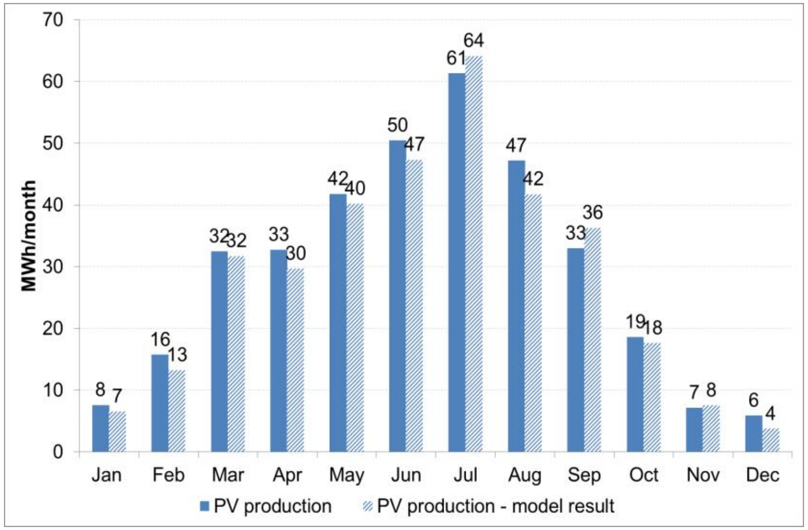
Contact: ashreeta.prasanna@empa.ch

EXTRA slides

Heat demand and supply – BF2 and BF5

Measured data compared with model results

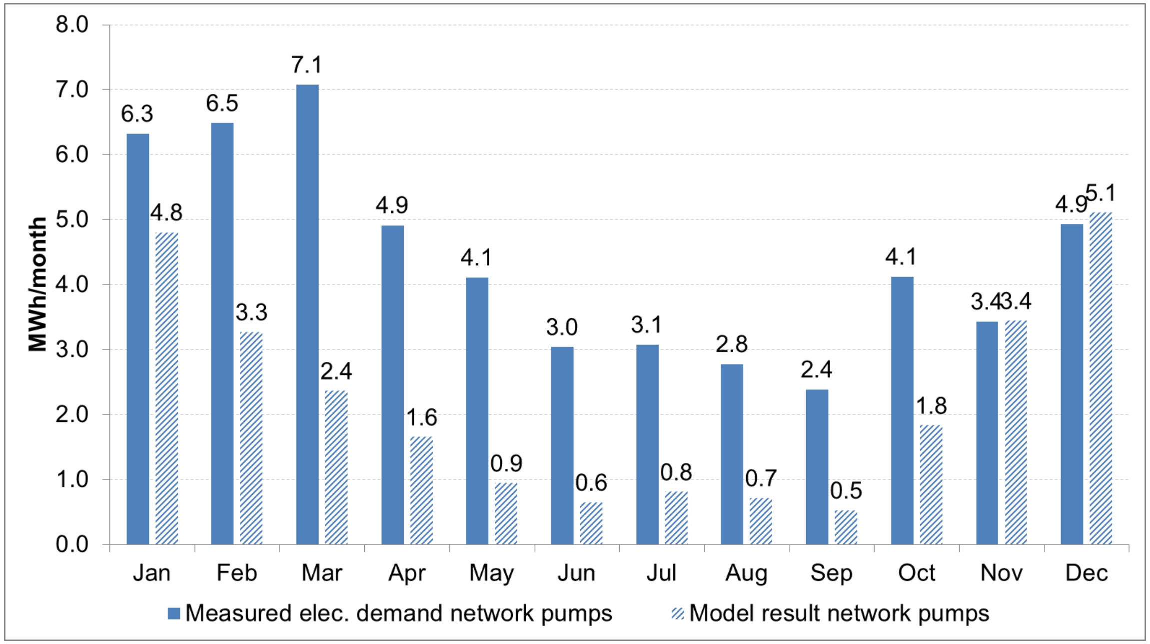




- Freecooling higher due to data reduction – high variability of cooling required during summer months
- Differences due to data reduction – high variability of solar radiation during summer months

Network pumps consumption– BF2 and BF5

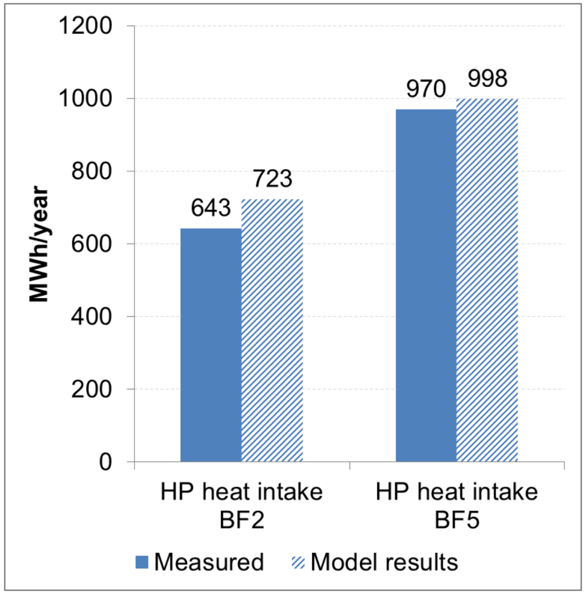
Measured data compared with model results

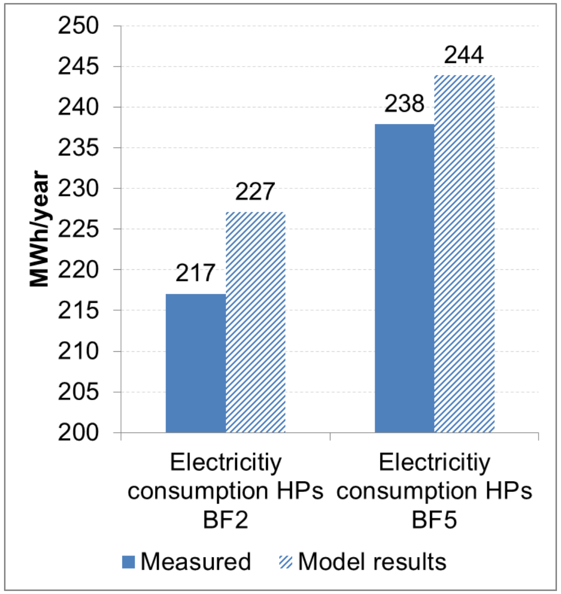


- Model result is 26 MWh/year while the measured value is 53 MWh/year
- Heat energy recovered from freecooling is stored within the buildings and used to preheat domestic hot water

Heat pumps heat intake and consumption

Measured data compared with model results





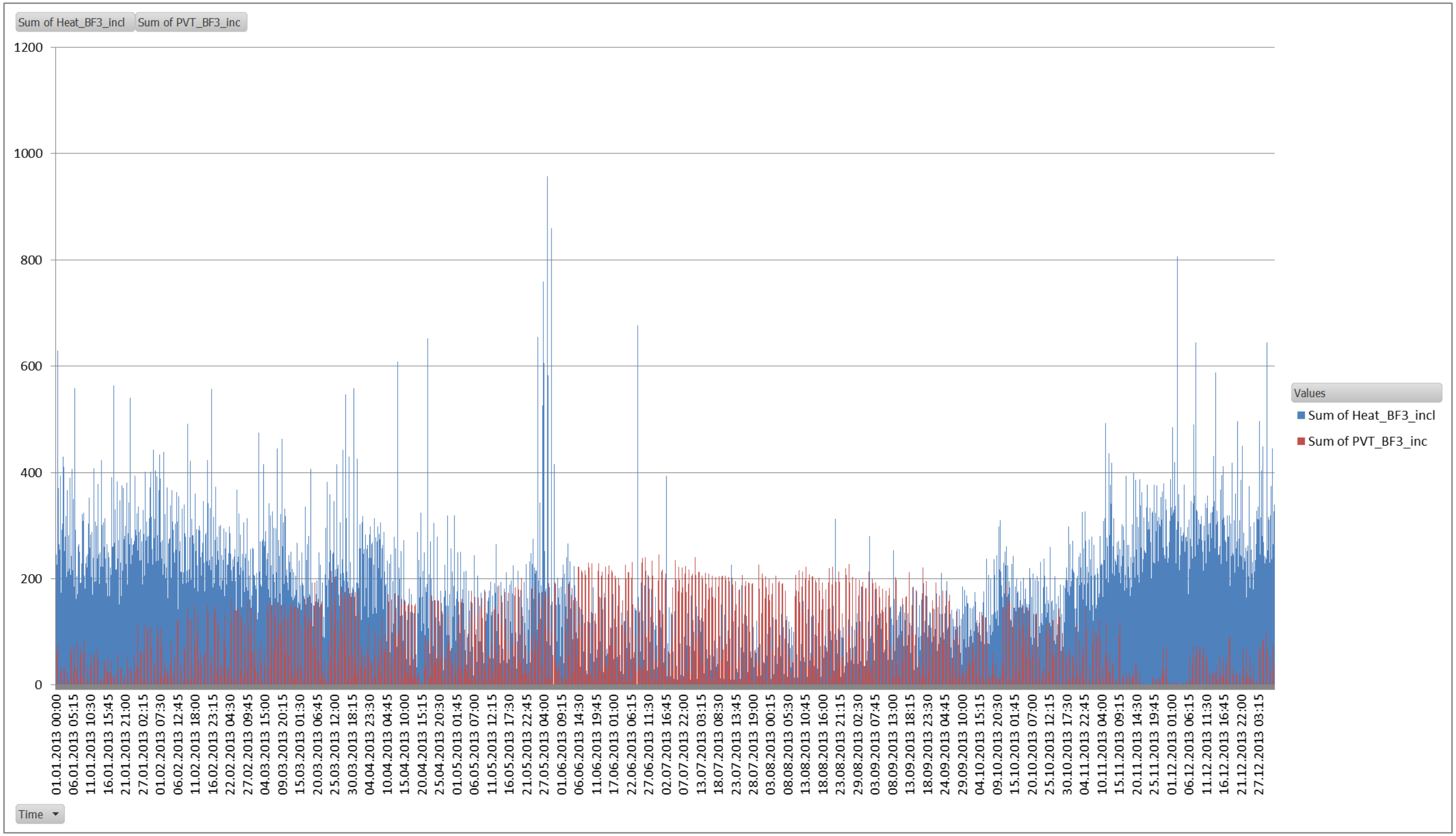
- During certain months the HPs for the production of DHW in BF2 and BF5 were shut down and substituted by electric heating to prevent undercooling of the borehole field.
- Change in operation could have impacted the coefficient of performance (increase of COP).
- Measured heat intake and electricity consumption of the heat pumps is thus lower.

Konfiguration	BF	Erdsonden	Bedarf		
			Wärme MWh/a	WW MWh/a	Freecooling MWh/a
Vergleichsfall (Messung: Okt/2013 – Sep/2014)	BF2	Feld West 215x150 m	603	315	45
	BF5		856	322	533
Basisfall	BF2	Feld West 215x150 m	616	304	73
	BF5		848	329	678
	BF3		549	375	71

RH & WW Total: 2'096 MWh/a (E+P: 2'009 MWh/a)

FC Total: 578 MWh/a (E+P: 574 MWh/a)

Heat demand and production – BF3 included



Heat demand and production –
IF all buildings had PVT thermal production