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Increasing Data Center Energy Efficiency via Simulation and Optimization of Cooling Circuits

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A Practical Approach

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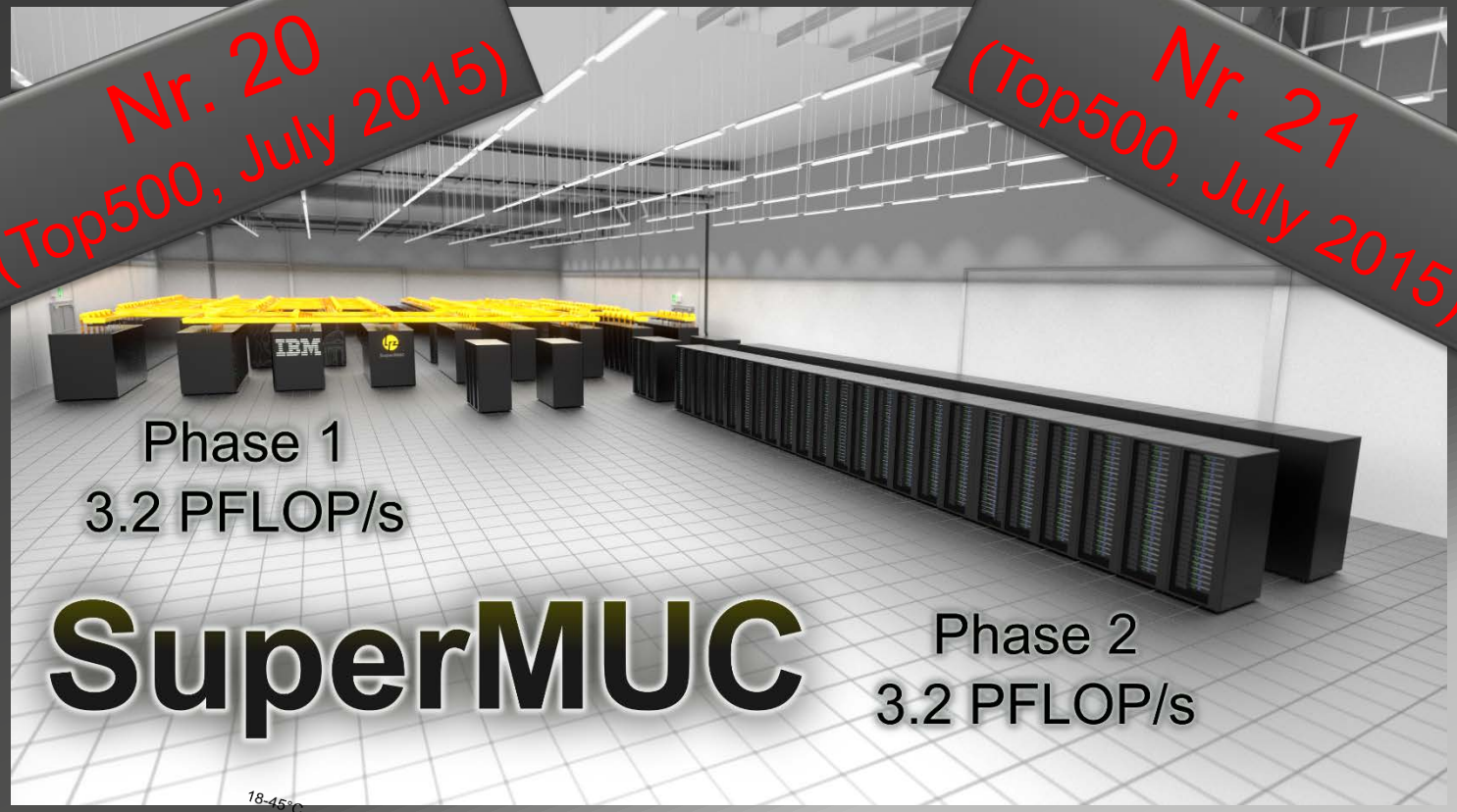
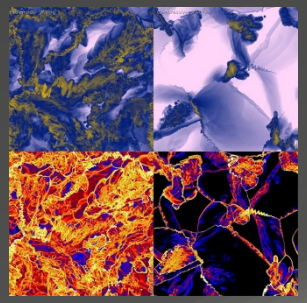
Some more Facts

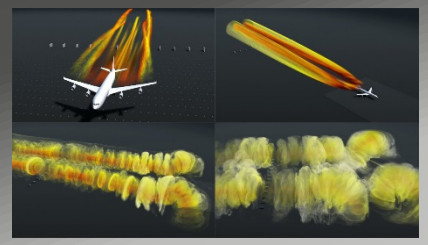
- **3160.5 m²** (34 019 ft²) IT Equipment Floor Space (6 rooms on 3 floors)
- **6393.5 m²** (68 819 ft²) Infrastructure Floor Space
- **2 x 10 MW** 20kV Power Supply
- **Powered Entirely by Renewable Energy**
- **> 5M €** (> 6M US$) Annual Power Bill

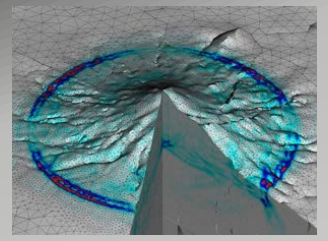
The Leibniz Supercomputing Centre

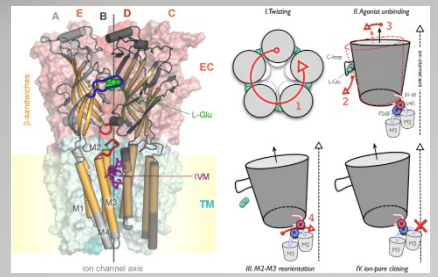
Scientific Computing at LRZ

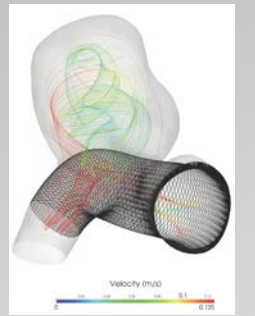


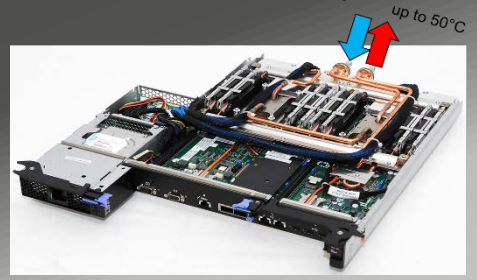


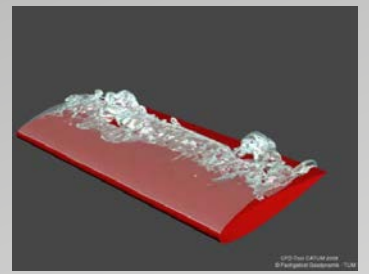


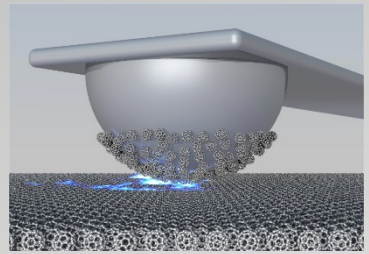


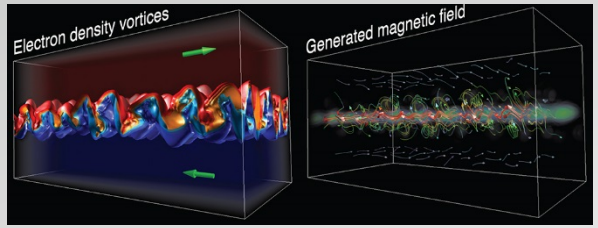










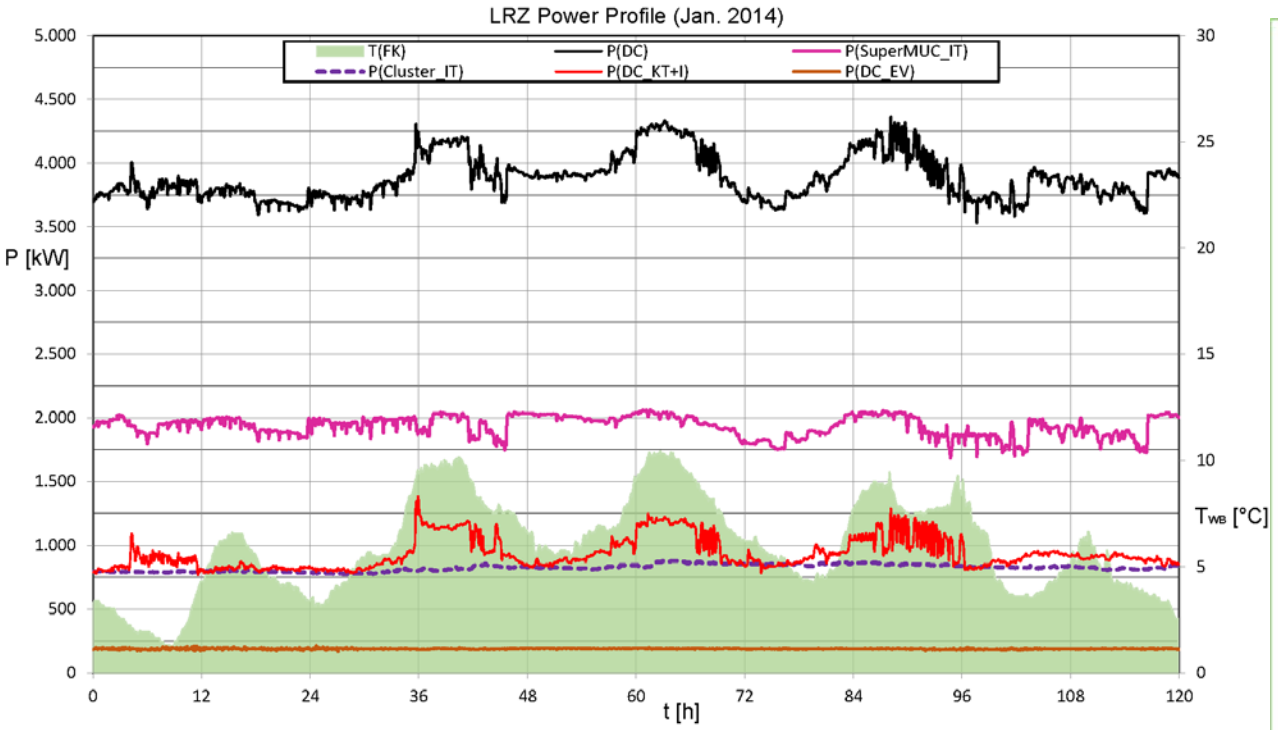


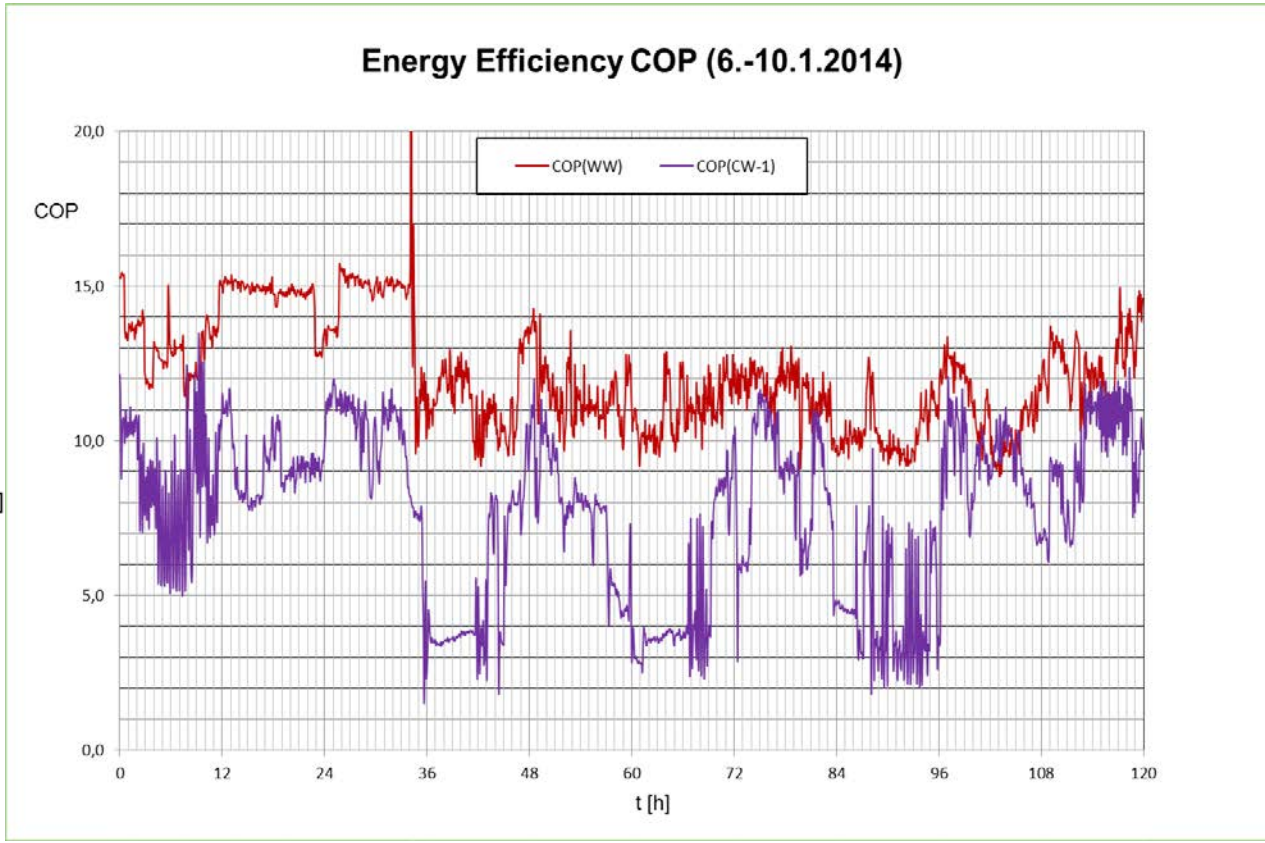
http://www.lrz.de/services/compute/supermuc/magazinesbooks/2014_SuperMUC-Results-Reports.pdf

http://www.gauss-centre.eu/gauss-centre/EN/Projects/projects_node.html

Challenges

Outside Conditions and LRZ Cooling Efficiency

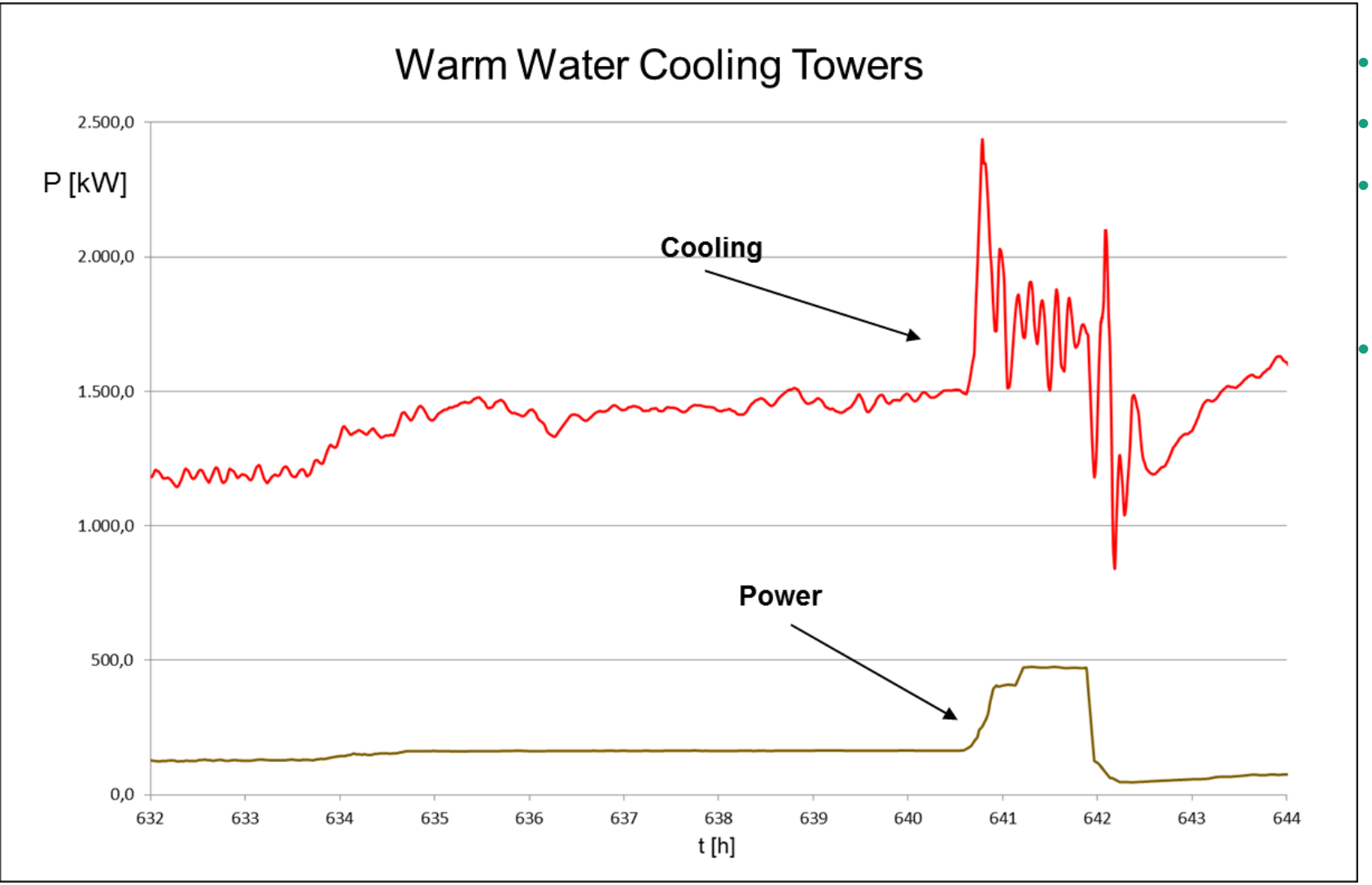




- IT power constant but cooling consumption increased by nearly 100%
- Outside temperature change
- Need instrumentation to figure out **WHERE**
- Much harder to figure out **WHY**

$$COP = \frac{Q}{P}$$

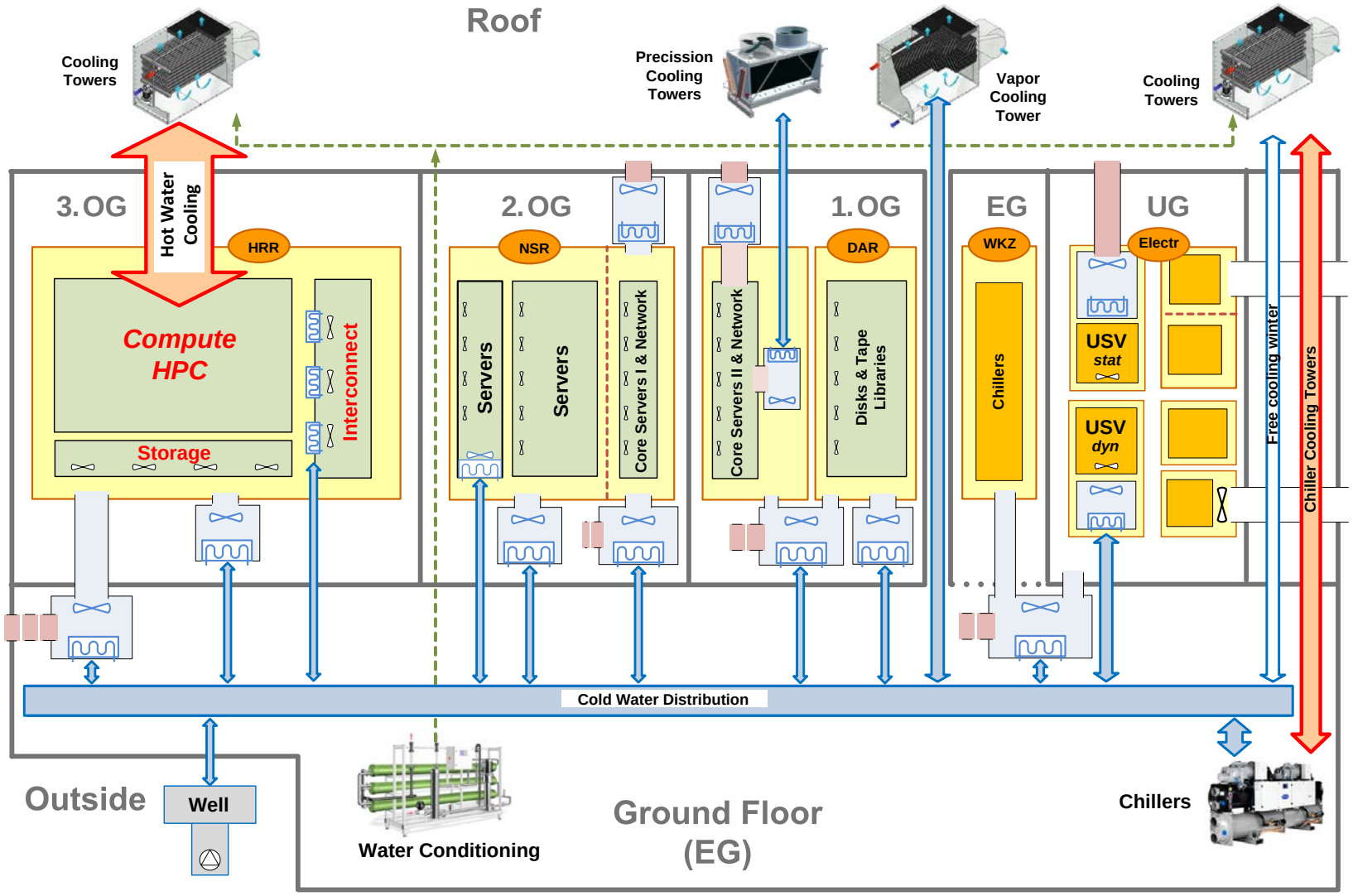
Operations Control: Test of ΔT_{inlet}(NSR) = -20 K
Response of Warm Water (Chiller-less) Cooling Infrastructure



- Chiller less cooling (4 towers 2MW each)
- No additional cooling needed
- IT power consumption did not change but not part of command and control loop
- 4 separate optimized cooling circuits -> need one control for all 4, need to integrate IT

Setting target temperature for NSR from 40°C (104°F) to 20°C (68°F) doubles the cooling system power consumption (Outside < 10°C (50°F))

New Generation of HPC Data Centers Use a Mix of Different Cooling Technologies



Cooling capacity LRZ (new construction):

- Vapor cooling: 2MW
- Well water: 600kW
- Chillers: 3.2MW
- Evaporative cooling towers: 8MW

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SIMOPEK - Extending Current Control Systems

- Add analytic and predictive capabilities to infrastructure control system
  - Use model and simulations to investigate infrastructure behavior
  - Use model and simulations to find optimal operating point for current workload and outside conditions

- Connect workload management systems with infrastructure management systems

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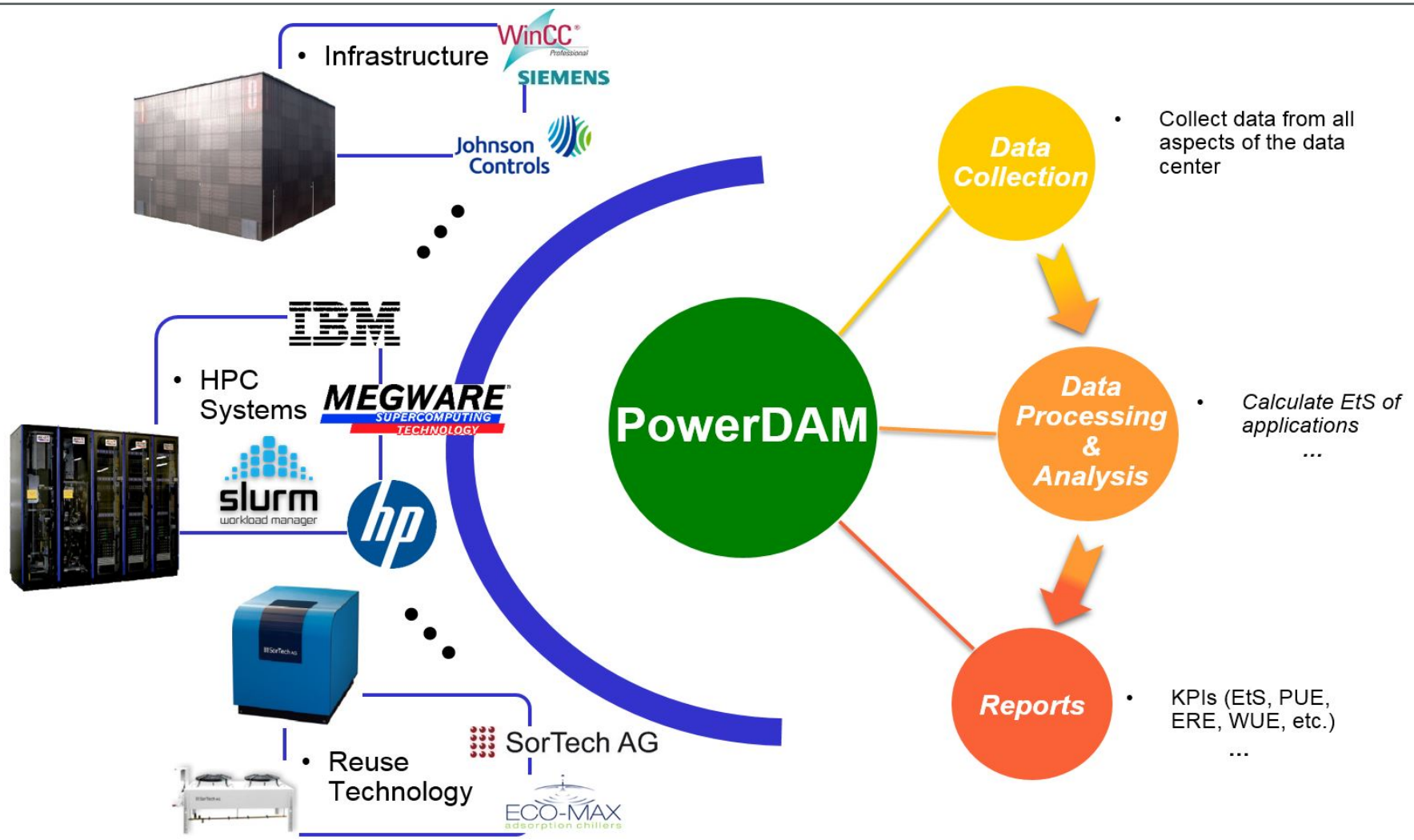
Processing requires Standards



Hayk Shoukourian, Torsten Wilde, Axel Auweter, Arndt Bode: "Monitoring Power Data: A first step towards a unified energy efficiency evaluation toolset for HPC data centers" published in Environmental Modelling & Software (Thematic issue on Modelling and evaluating the sustainability of smart solutions), Volume 56, June 2014, Pages 13–26; DOI: http://dx.doi.org/10.1016/j.envsoft.2013.11.011

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Fun With Sensor Names

Leibniz Rechenzentrum
Garching

Musterbezeichnungen

Festlegung Datenpunkt Adresse (Adress-Beispiel 1):
Bei Lüftungs / Heizung / Kälte Anlage:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
R	E	G	R	L	T	0	1	F	_	Z	U	T	_	M	W	0	1	REGRLT01F_ZUT_MW01
R	E	G	R	L	T	0	1	F	_	A	B	T	_	M	W	0	1	REGRLT01F_ABT_MW01
R	E	G	R	L	T	0	1	F	_	Z	U	F	_	M	W	0	1	REGRLT01F_ZUF_MW01
R	E	G	R	L	T	0	1	F	_	A	U	T	_	M	W	0	1	REGRLT01F_AUT_MW01
R	E	G	H	Z	G	0	1	F	_	V	L	T	_	M	W	0	1	REGHZG01F_VLT_MW01
R	E	G	H	Z	G	0	1	F	_	V	L	D	_	M	W	0	1	REGHZG01F_VLD_MW01
R	E	G	R	L	T	0	1	V	E	Z	U	F	U	S	B	0	1	REGRLT01VEZUFUSB01
R	E	G	R	L	T	0	1	V	E	Z	U	F	U	B	M	0	1	REGRLT01VEZUFUBM01
R	E	G	R	L	T	0	1	V	E	Z	U	F	U	S	M	0	1	REGRLT01VEZUFUSM01
R	E	G	R	L	T	0	1	V	E	Z	U	R	P	W	M	0	1	REGRLT01VEZURPWM01
R	E	G	R	L	T	0	1	V	E	Z	U	L	W	S	M	0	1	REGRLT01VEZULWSM01
R	E	G	H	Z	G	0	1	K	M	V	L	D	M	S	M	0	1	REGHZG01KMVLDMSM01
R	E	G	H	Z	G	0	1	K	M	V	L	D	X	S	M	0	1	REGHZG01KMVLDXSM01
R	E	G	H	Z	G	0	1	V	_	_	_	D	D	M	W	0	1	REGHZG01V__DDMW01
R	E	G	R	L	T	0	2	K	L	A	U	_	_	S	T	0	1	REGRLT02KLAU__ST01
R	E	G	R	L	T	0	2	K	L	A	U	_	_	R	M	0	1	REGRLT02KLAU__RM01
R	E	G	R	L	T	0	2	K	L	F	O	_	_	R	M	0	1	REGRLT02KLFO__RM01
R	E	G	R	L	T	0	2	K	L	M	I	_	_	R	M	0	1	REGRLT02KLMI__RM01

Stelle 1:	Gebäude (R/I/H)
Stelle 2+3:	Geschoß
Stelle 4+5+6:	Anlagenart
Stelle 7+8:	Anlagennummer 2-stellig
Stelle 9+10:	Gerät
Stelle 11+12:	Gerätestandort
Stelle 13+14:	Funktionsart (Fühlertyp)
Stelle 15+16:	Datenpunktart
Stelle 17+18:	Zähler

PowerDAM API:

$$RootResource(.Resource) * _SensorType = Value; Timestamp$$

jci.IUGSS41.EZ04_MW__PE_power

- IUGSS_41EZ__PEMW04
- @JCSQL:NAE054-01:NAE054-01/N2 Trunk1. NAE054-MIG136.IUGSS_41EZ__PEMW04.Present Value

WinCC

- Names relate to individual circuit names without any regard to possible structure
- Use of German Umlaute

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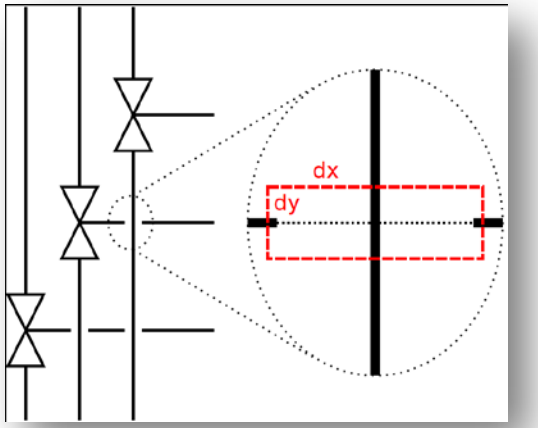
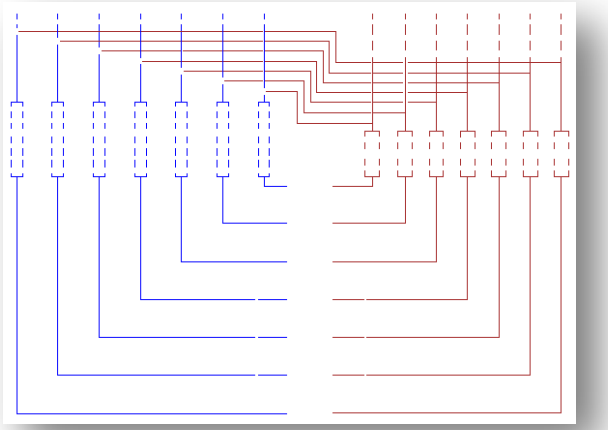
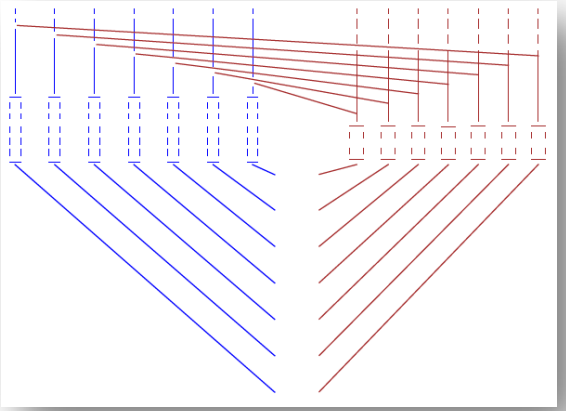
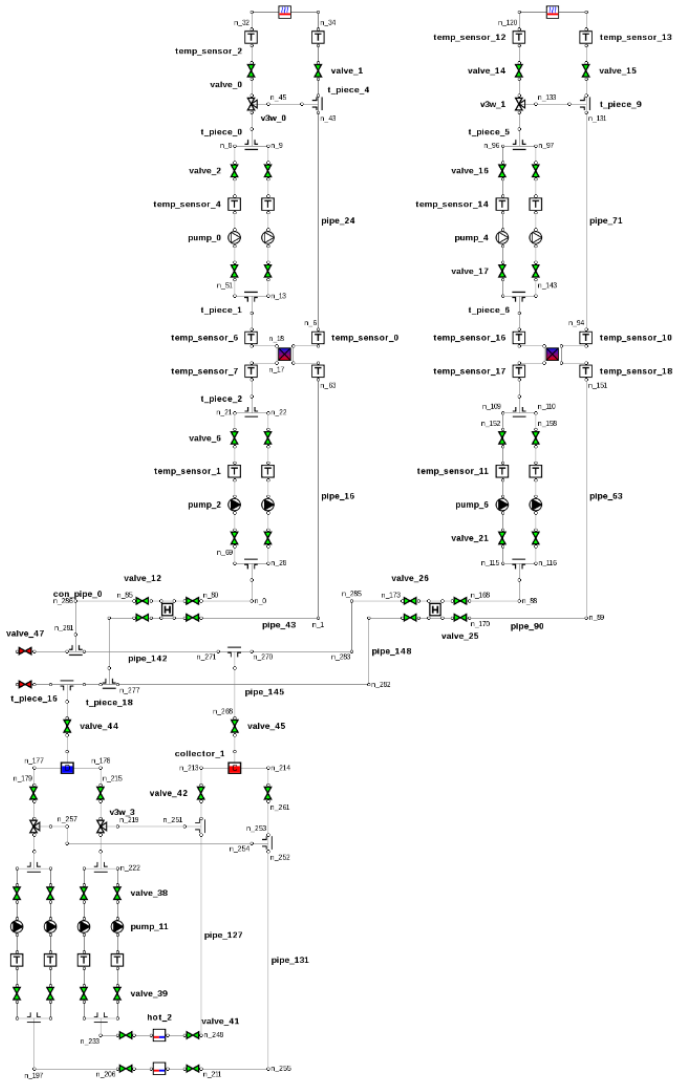
(Semi-) automatic Generation of Cooling Network

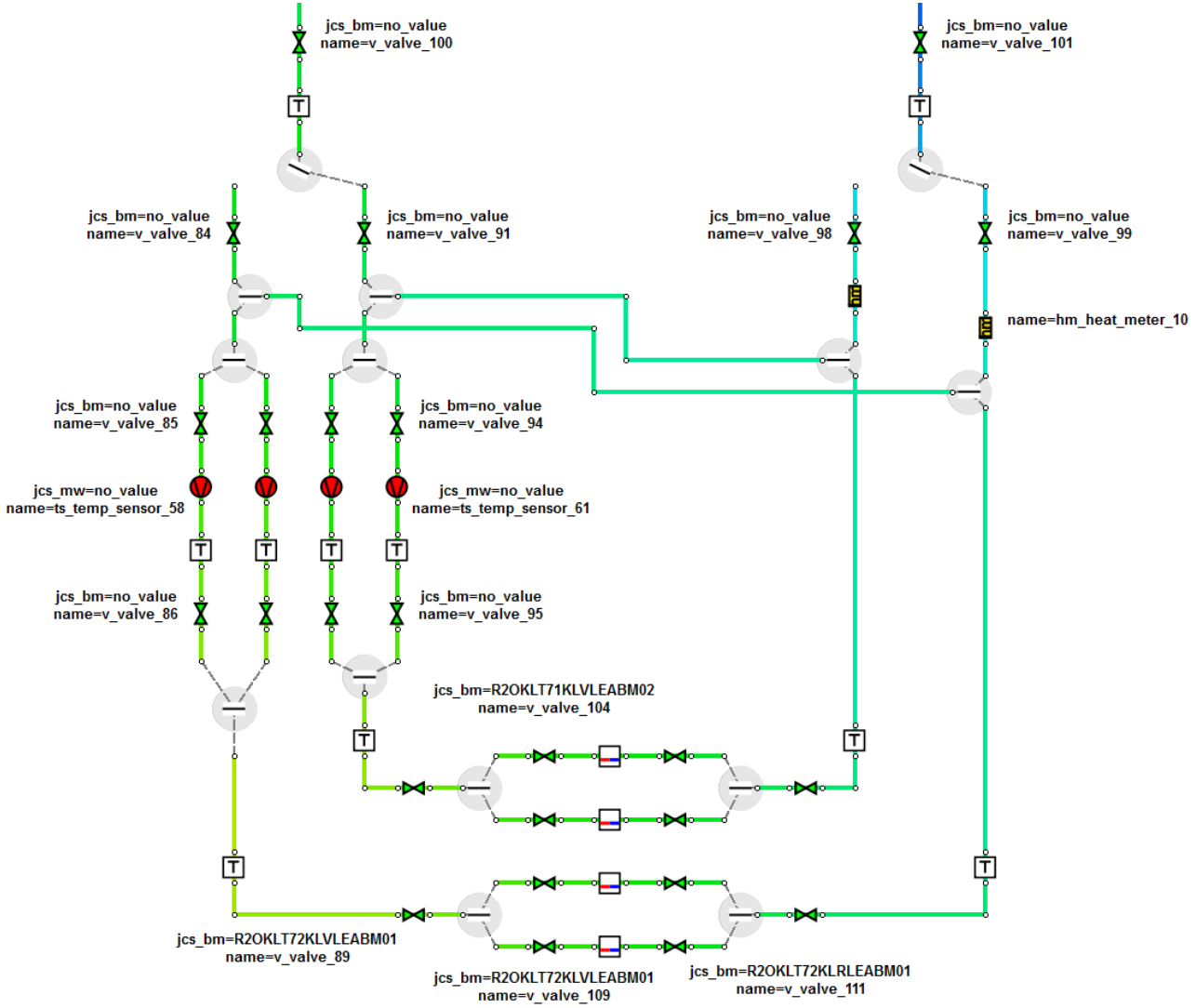








(Semi-) automatic Generation of Cooling Network



- Requires manual mapping from auto-generated devices to monitoring system device names
- Technical descriptions / characteristic curves for each installed device
  - Regulated and unregulated pumps
  - Heat exchangers
  - Cooling towers
  - 1- and 3-way valves
  - Resistors, regulators, and pipes
  - Special devices (adsorption chiller, SorTechAG)
- Control logic

Lessons Learned 1/2

- Need parsable topology maps (network topology description and technical details on its elements) of the data center infrastructure
  - Helps to check whether components are really installed according to specifications in the infrastructure plan.
- Need electronic versions of element descriptions (characteristic curves and diagrams)
  - Reduces manual labor substantially
- Need to be involved in defining the sensor naming schemas for all monitoring systems
  - Allows for easy automatically processing of data by other data center tools
  - Allows for name coherence checking tools.

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Lessons Learned 2/2

- Stick to the English alphabet everywhere in your data center software
  - Less worries when processing the data later on
  - Otherwise be aware of possible UTF-8 related issues.

- Avoid data center monitoring and automation tools that require proprietary access tools.
  - If not possible, include any extra tools and installations needed to access the data in the procurement .

- Treat collected sensor data with an appropriate amount of skepticism.
  - In most cases, invalid sensor data is the cause of strange data center infrastructure behavior.

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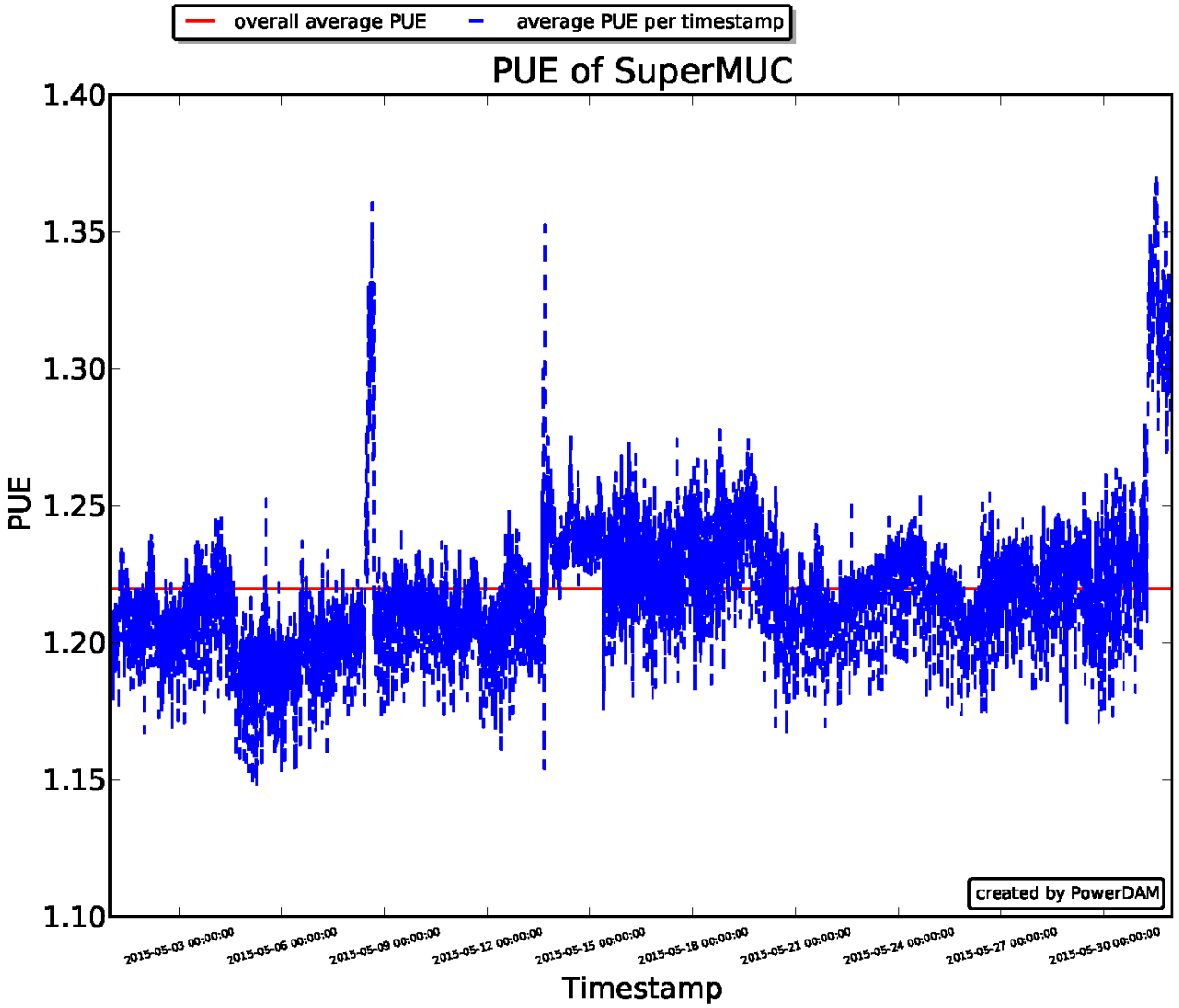
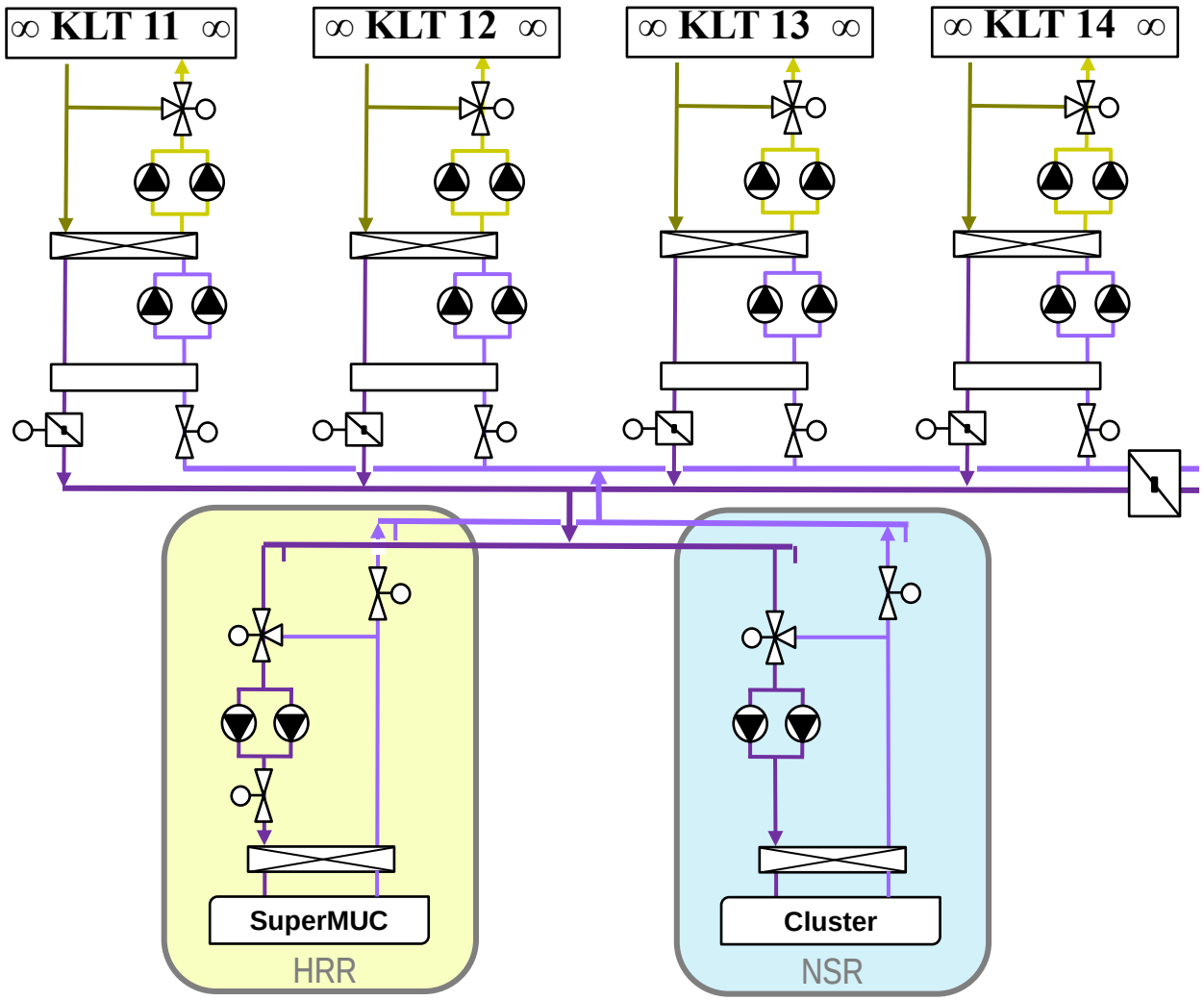
Current Status and Future Work

System Specific PUE



LRZ Chiller-free Cooling Circuit Overview Schematic



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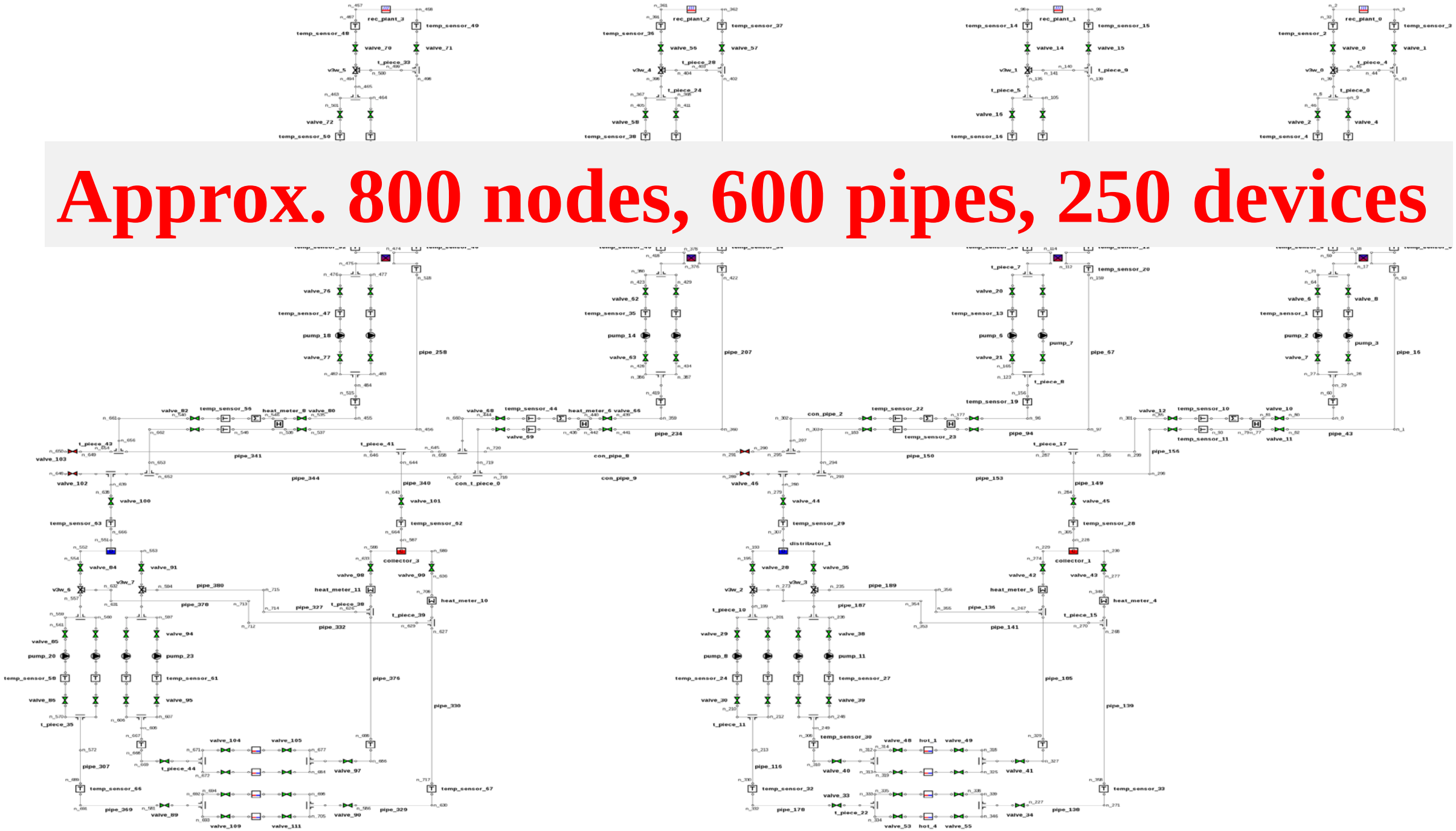
Approx. 800 nodes, 600 pipes, 250 devices



Future Work

- Extend NSR cooling infrastructure model with CooLMUC internal cooling circuit.
  - Simulation of the model and its use to find an optimal adsorption chiller design.

- Model and simulate one complete cooling circuit (HRR+NSR and KLT11)
  - Hopefully, the simulation can provide information about possible optimization potential.
    - Do we need the hydraulic gates in the chiller-less cooling circuits?

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