Building a digital twin of indoor airflow for reducing HVAC energy consumption

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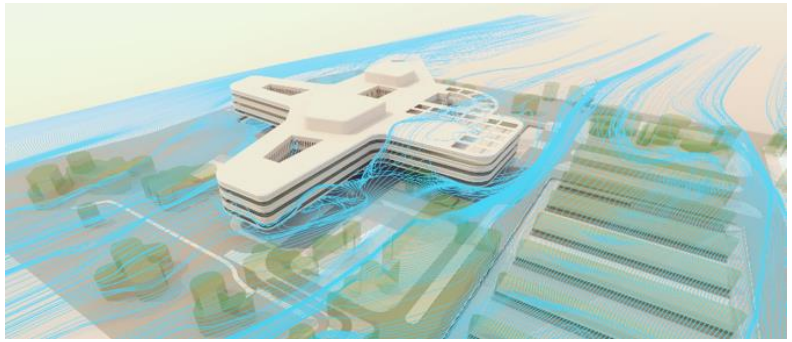
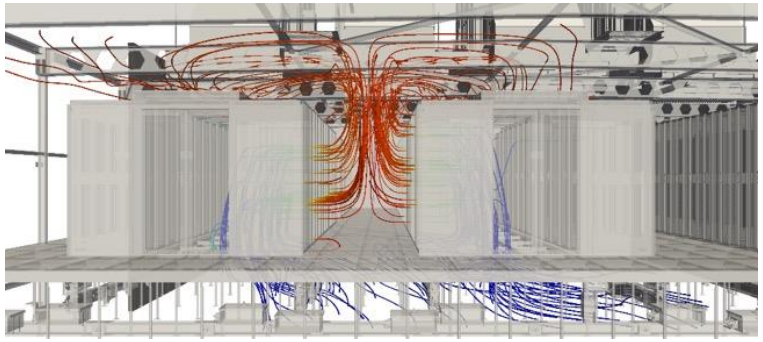
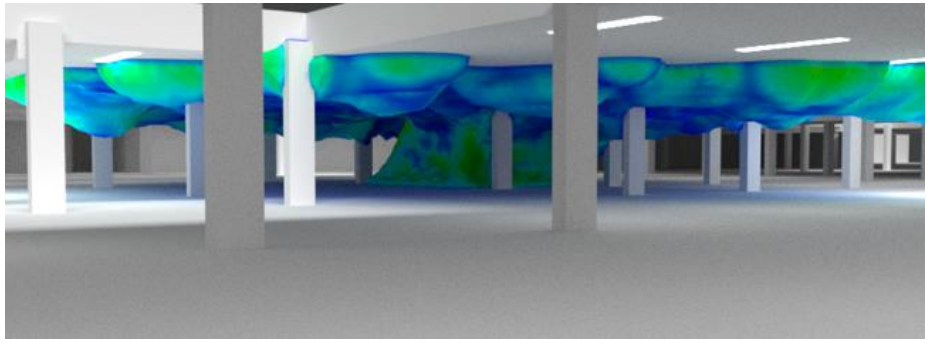
Company introduction: Actiflow - experts in fluid dynamics

- Actiflow is an engineering company specialized in fluid dynamics
- We use complex airflow simulations (CFD) to support our customers in product development, and we advice them about flow related issues in the built environment (mainly HVAC and wind)
- In the built environment:
  - Wind comfort and loading
  - Urban microclimate
  - Smoke and heat removal in case of fire
  - HVAC system analysis & design for offices, atria, classrooms, cleanrooms, datacenters, industrial facilities, etc.







Reduction of HVAC energy consumption in the built environment

- Potential to save energy consumption by using “smart” HVAC systems:
  optimizing HVAC settings according to specific use of the room, as a function of time
- Possible input for optimization:
  - Simulations: used in the design phase
  - Measurements: used during operation/use
- Hard to determine an optimization strategy
  (understand impact of HVAC system settings on indoor climate)
- A digital twin can provide the solution
  (combination of real-time measurements and simulations)
- In first instance, digital twin is developed for datacenters

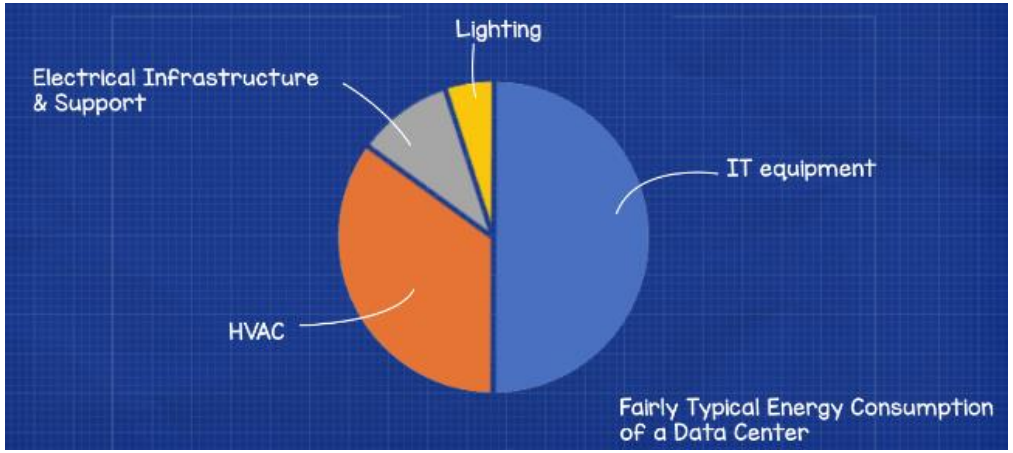
Cooling in datacenters – great potential to save energy using CFD

- Datacenters are huge energy consumers (2.7 TWh in 2019 in NL)
- Consumption is rising faster than in any other industry
- Cooling accounts for 25-40% of energy consumption
- DC operators want to save energy, but risks are high
- Uptime / SLAs are crucial
- A non-invasive technology (digital twin) is needed to monitor and optimize cooling

Tabel 1
Levering van elektriciteit via het openbaar net aan datacenters, 2017-2019

Regio	Leveringscategorie	Geleverde elektriciteit 2017	2018	2019*
		GWh	*GWh*	*GWh*
Nederland	Totaal	1.647	2.360	2.740
Nederland	< 7,5 GWh	271	289	281
Nederland	> 7,5 GWh	1.376	2.071	2.460
Gemeentes Amsterdam en Haarlemmermeer	Totaal	746	1.120	1.230
Gemeentes Amsterdam en Haarlemmermeer	< 7,5 GWh	63	87	97
Gemeentes Amsterdam en Haarlemmermeer	> 7,5 GWh	683	1.033	1.133
Overig Nederland	Totaal	901	1.240	1.510
Overig Nederland	< 7,5 GWh	208	201	184
Overig Nederland	> 7,5 GWh	693	1.038	1.327

Bron: CBS



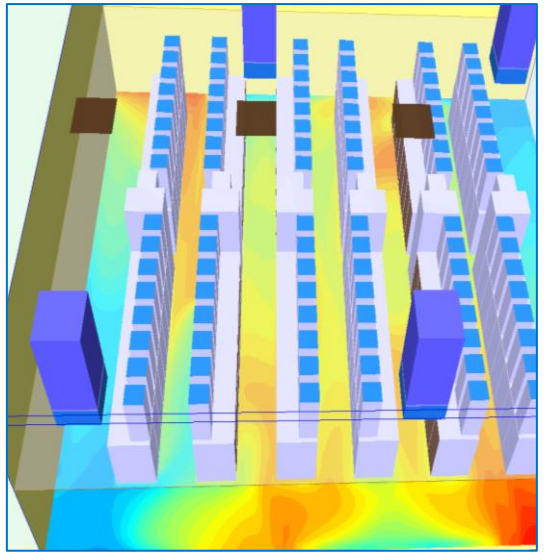
Consortium

For the development of the digital twin, a consortium of partners was set up:

- TNO: Knowledge supplier and founder
- Vortech: scientific software developers
- Perf-it: supplier of DCIM software
  (DataCenter Infrastructure Management)
- Actiflow: experts in aerodynamics
  E.g. wind and indoor climate studies

Technologies for monitoring and optimization

- **Sensors are used for real time temperature monitoring**
  - Accurate and real-time data, but only at discrete locations
- **3D flow models (CFD) are used for design & optimization**
  - Good 3D insights, but stationary and not coupled with reality (result depends on input which may differ from reality)



Digital twin combines both technologies

Combining sensors and CFD = best of both worlds

- Sensors provide local real-time data
- CFD model uses measurement data to create a reliable full 3D overview

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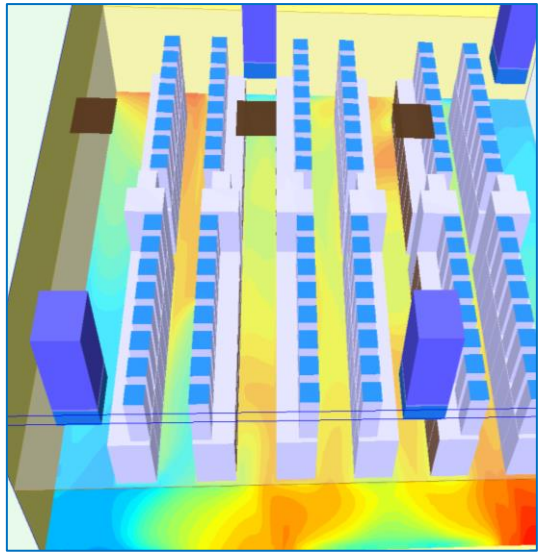


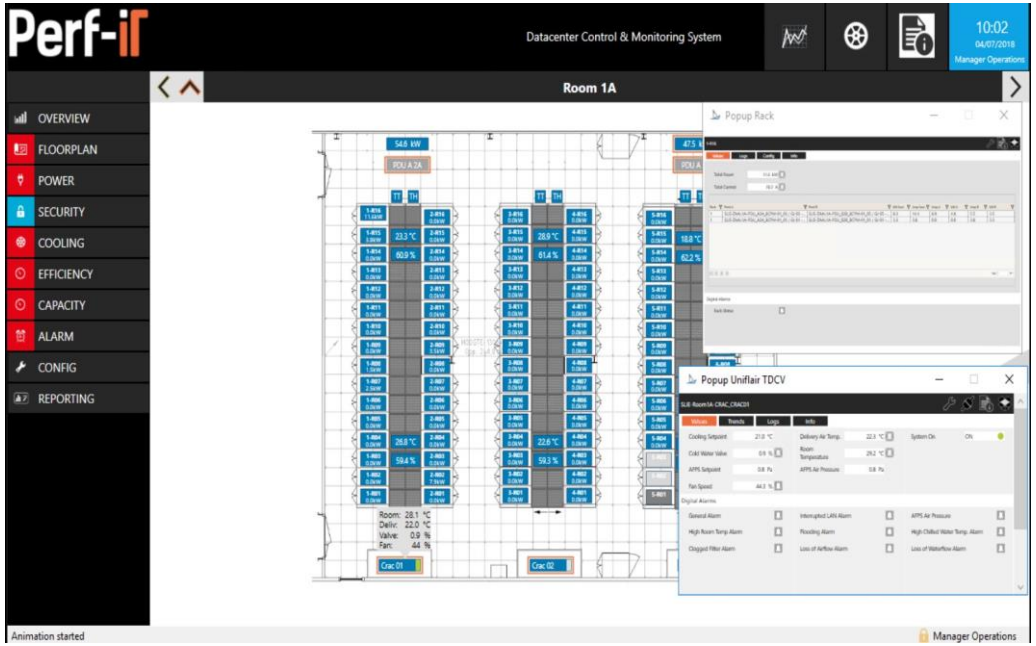
Mathematical fusion of measurement data and CFD

- Input measurement data as hard boundary conditions in CFD does NOT work
- Instead, an optimization routine is used to nudge the simulation result towards the data
- Uncertainties (e.g. exact heat load of servers) are defined in the simulation setup
- “Uncertain” parameters are modified until a result is reached that best fits the measurements
- Result is physically correct and validated
- Thanks to the use of the data, the CFD simulations can be largely accelerated (nearly real-time)
- The result is a (nearly) real time computer model of reality with predictive capabilities

Digital twin is called 4DCOOL and has 2 functionalities

- 4DCOOL shows you the real-time temperature distribution in the white space in 3D or clear 2D cross sections

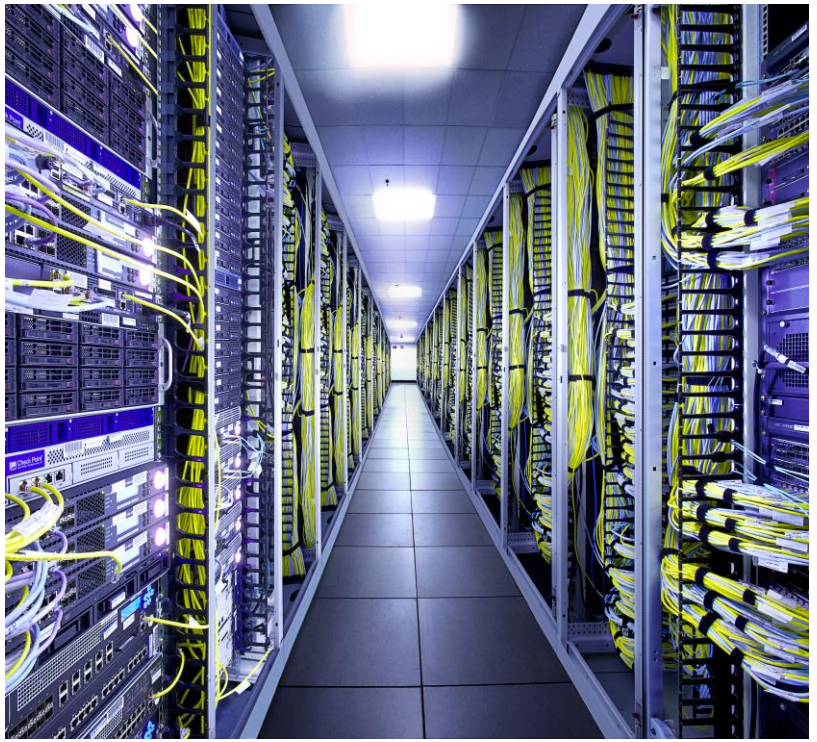
- With the “what-if” functionality, future scenarios can be analyzed:
  - What if one of my cooling units fails?
  - What if my customer installs additional servers?
  - What if I would reduce the fan speed of one of my cooling units?
  - What would happen if I open more perforated tiles?



The answer to these questions enables a safe optimization of the cooling

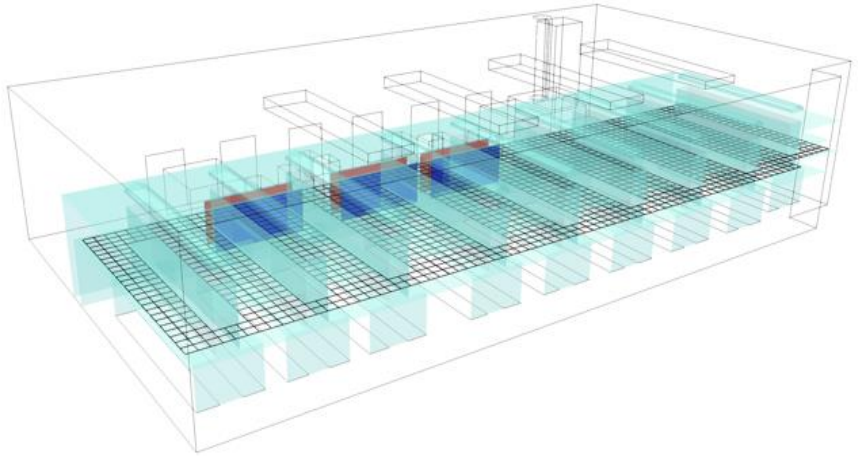
What are the advantages for the datacenter?

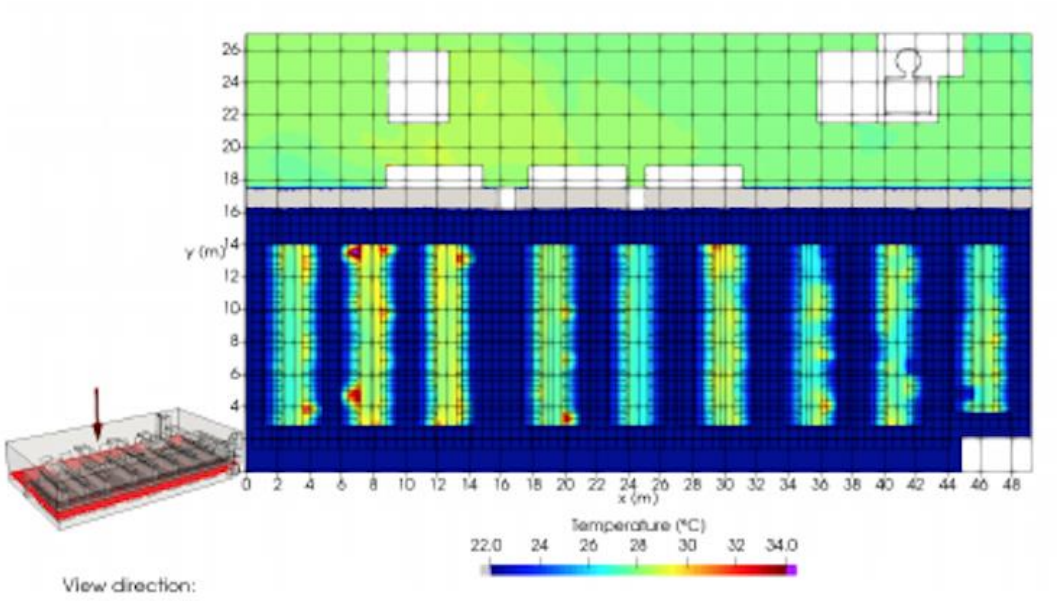
- Optimize (minimize) cooling and as such save on cooling energy without the risk of SLA breaches or outages (2 pilot projects show savings of 20-25% on air cooling)
- Be able to adapt the cooling to the growth of the datacenter
- Delay investments in new cooling capacity
- Prove to customers that you do maximum efforts to be a safe, sustainable and reliable partner



4DCOOL is tested in 2 pilot projects

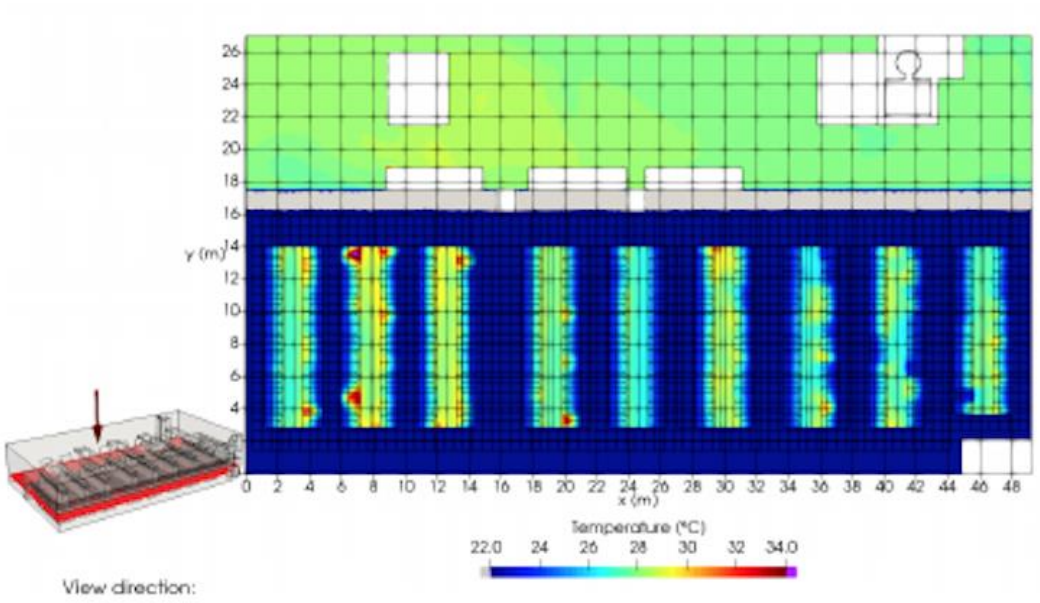
- 4DCOOL is tested in a datacenter in Mechelen (BE) and Groningen (NL)
- The CAD model and 4DCOOL output for one of these data-centers is shown below

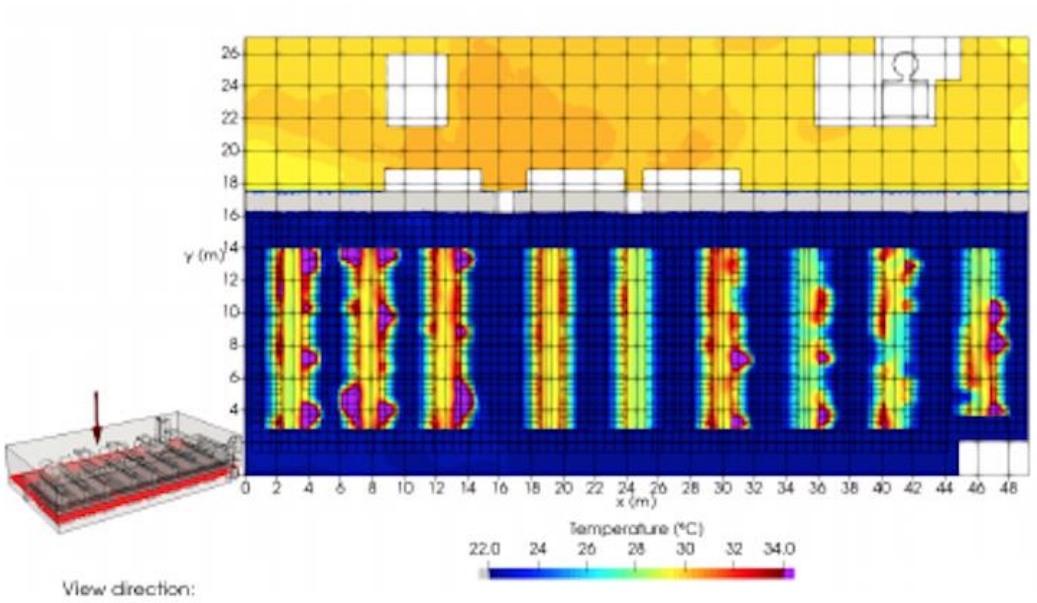




4DCOOL is used to reduce cooling energy (1)

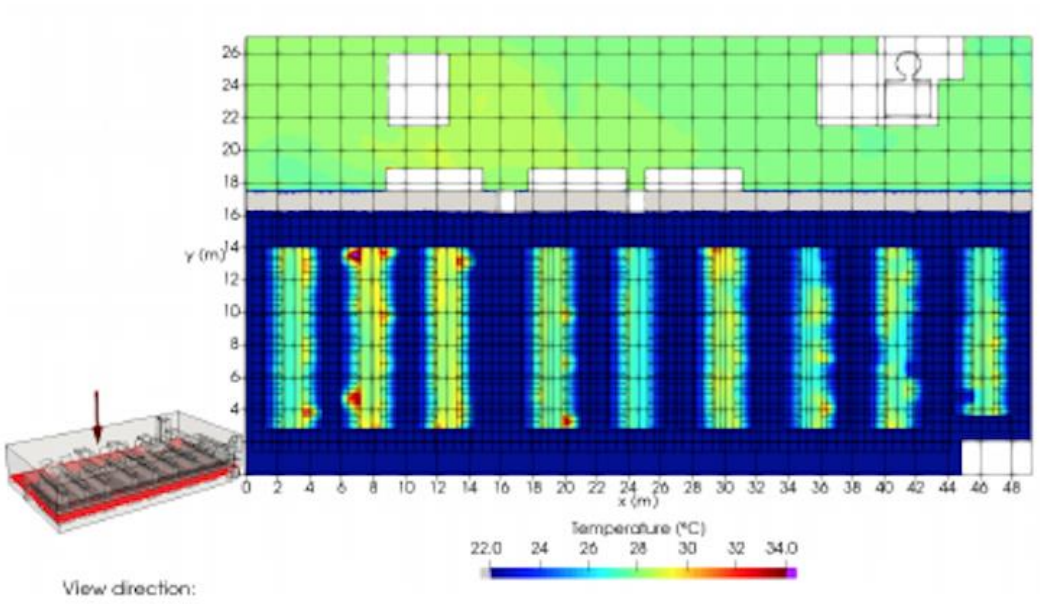
What if I simply reduce the fan speed of all cooling units by 25%?

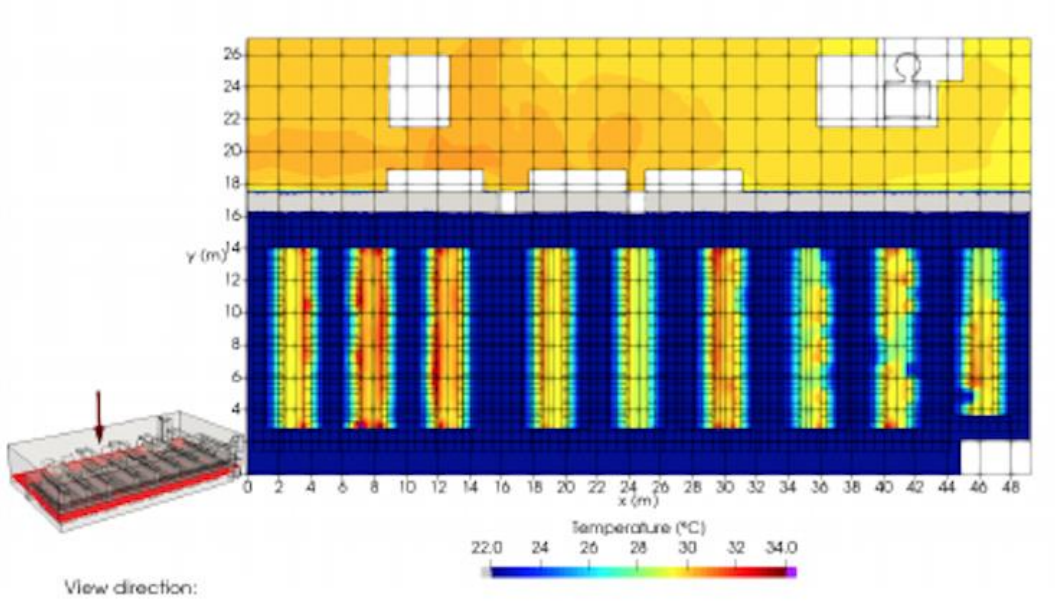




4DCOOL is used to reduce cooling energy (2)

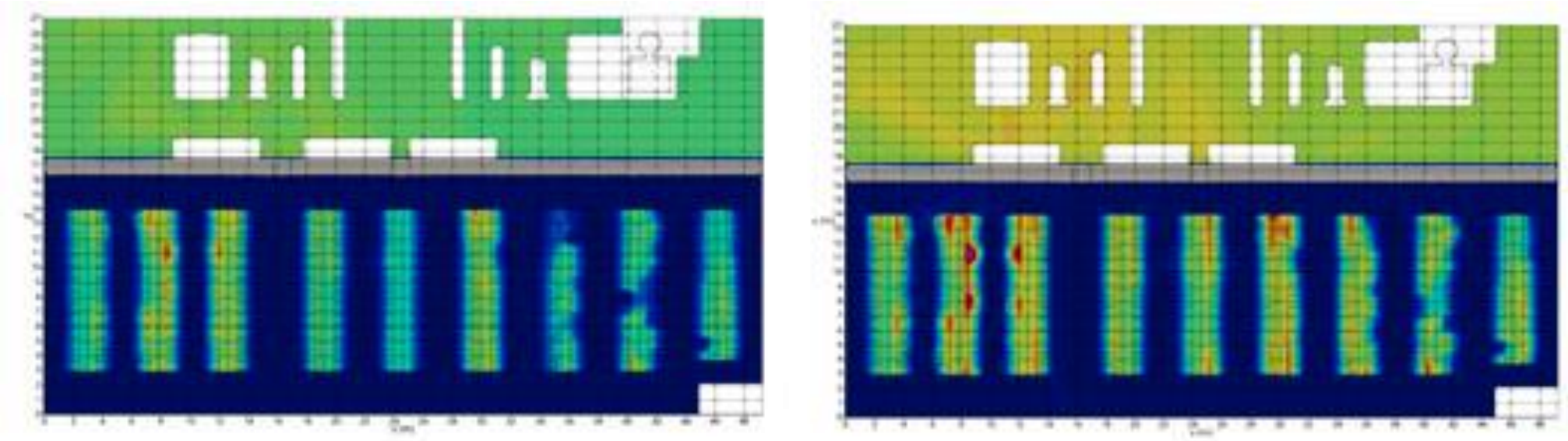
Result after optimization of the tile configuration which determines the inflow of cold air, again, reducing the fan speed of all cooling units by 25%





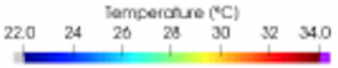
4DCOOL is used to analyze the impact of added heat load

What if I add 42kW of heat load to isle 5 and 7 without changing any cooling parameter?



Original

‘What if’ I add 42kW of load to hot isle 5 and 7



Conclusions and remarks

- About 4DCOOL:
  - A digital twin of the temperature distribution inside datacenters is successfully developed and validated
  - The tool has the additional functionality to evaluate “what-if” scenarios
  - In both pilot projects, optimization of the cooling has led to energy savings of more than 20%
  - The consortium is looking for opportunities to initiate new commercial pilot projects to understand the impact of 4DCOOL on further energy savings in the cooling water circuit

- The digital twin technology can also be used in other type of buildings:
  - Monitor the indoor climate with changing indoor or outdoor heat loads (e.g., people, equipment, outside air temperature, solar radiation, etc.)
  - Optimize the indoor climate by testing possible improvements through ”what-if” scenarios
  - Safely implement the improvements and save on energy consumption

Questions

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