

Soft Sensors for Perceived Human Comfort in Office Rooms Based on a Combination of Building Simulations and Data-Driven Modelling



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e-Nova 2020

Consortium



Associate Partner

Funding



FH Salzburg



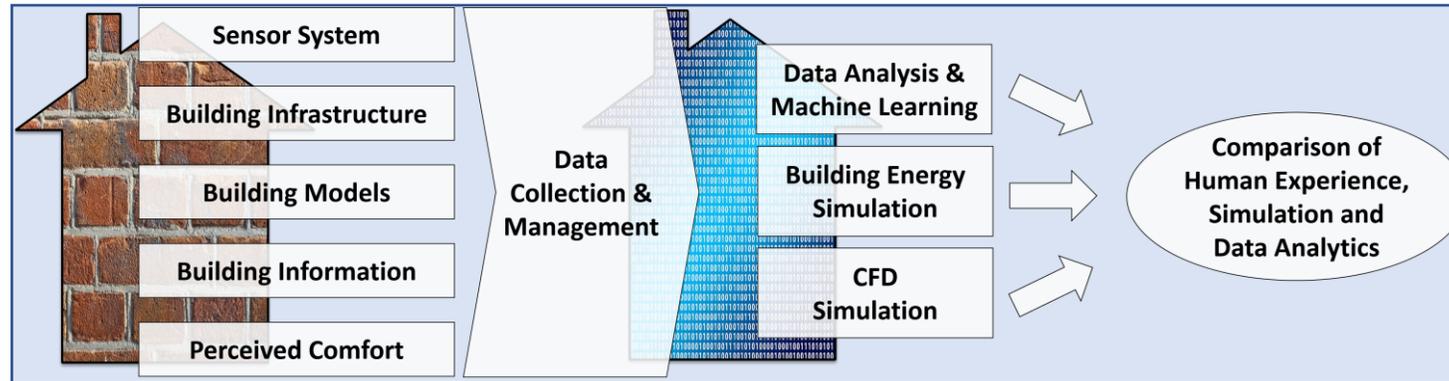
Agenda



- Project scope
- Soft sensors
- Data collection and management
- Coupling of simulation and data-driven analysis
- Solar Radiation Modelling
- Simulation Results
- Outlook



Project „COMFORT“ – Facts

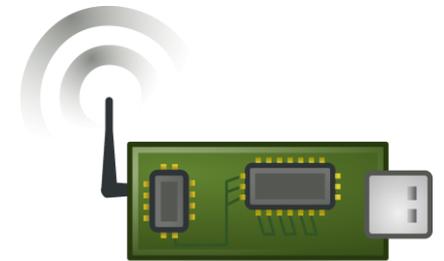


- COMFORT - Comfort Orientated and Management Focused Operation of Room condiTions
- Understand, predict and simulate perceived human comfort with operational constraints
 - Develop a wireless measurement system
 - Apply coupled data analysis and building simulation approaches
- 8 partners, run time 10/2018 – 09/2021, budget approx. €1mio.

Soft Sensors

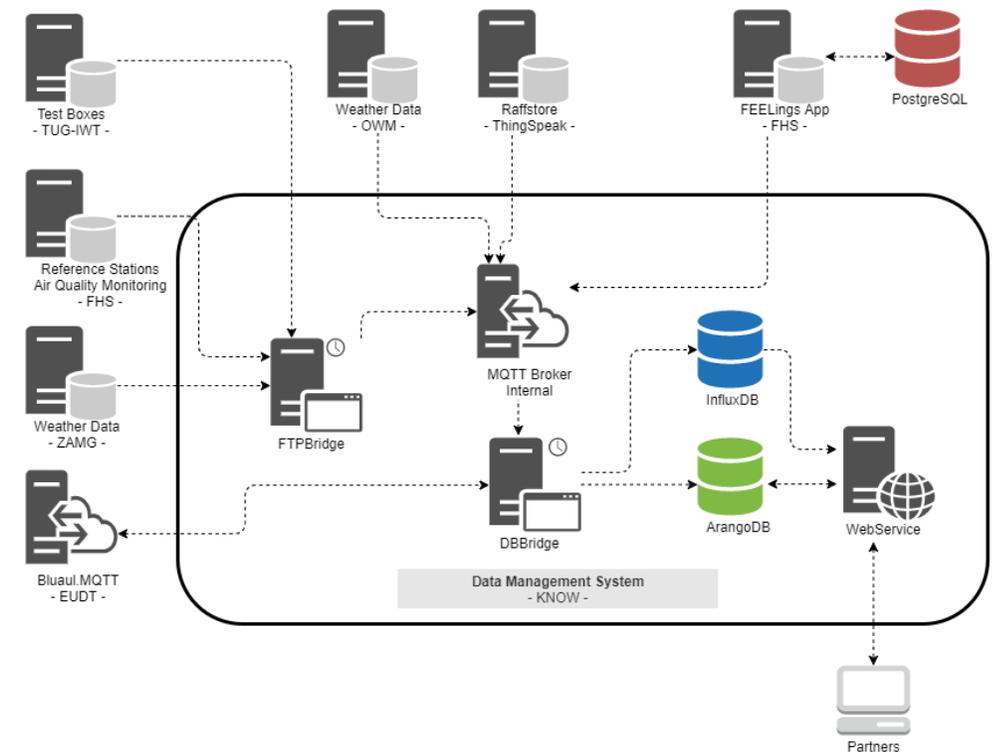


- Soft or virtual sensors:
 - Quantities not directly measurable due to costs, availability of energy supply, utility or practicability
 - Implemented as software programs
 - Based on other, measurable quantities
 - Delivers physical quantity or characteristic values like index figures
- Usage in COMFORT:
 - Augment sensor data with perceived human comfort
 - Focus on office rooms



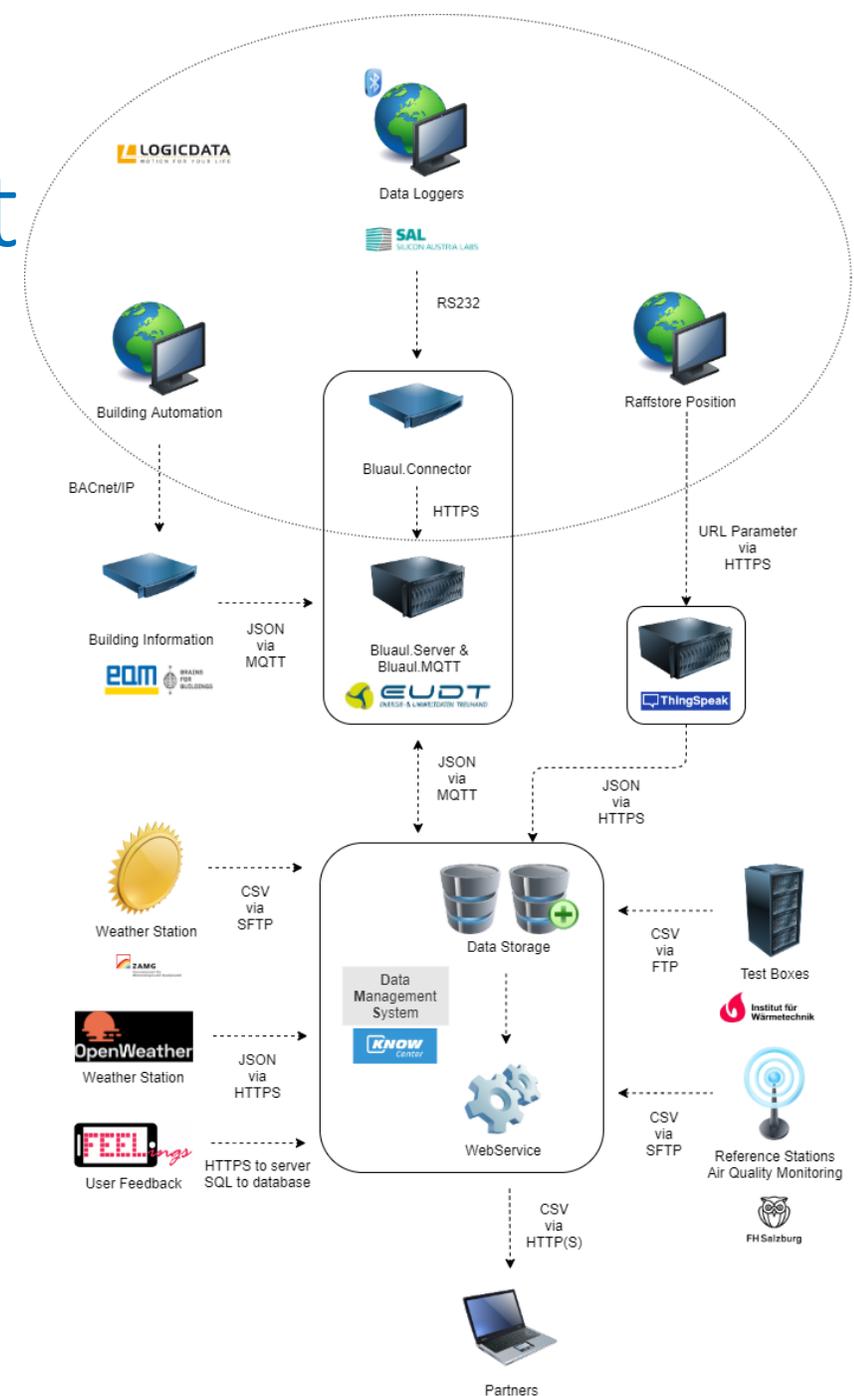
Implementation of Soft Sensors

- Simulation-driven soft sensors
 - Computational Fluid Dynamic (CFD) Simulation
 - Building Energy Simulation (BES)
- Data-driven soft sensors
- Data Management System (DMS)
 - Basis for all soft sensors
 - Simulation
 - Verification
 - Boundary conditions
 - Data-driven analysis
 - Model training



Data Collection & Management

- Main challenges
 - Sensor vs. meta data
 - Heterogeneous data sources (protocols, formats)
 - Reliability of connections
- Webservice for all partners
 - Download „pre-processed“ data sets
 - Common database for all partners



Data Logger
[Source: Know-Center / SAL]



Building Automation
[Source: EAM Systems]



Reference Station
[Source: FH Salzburg]

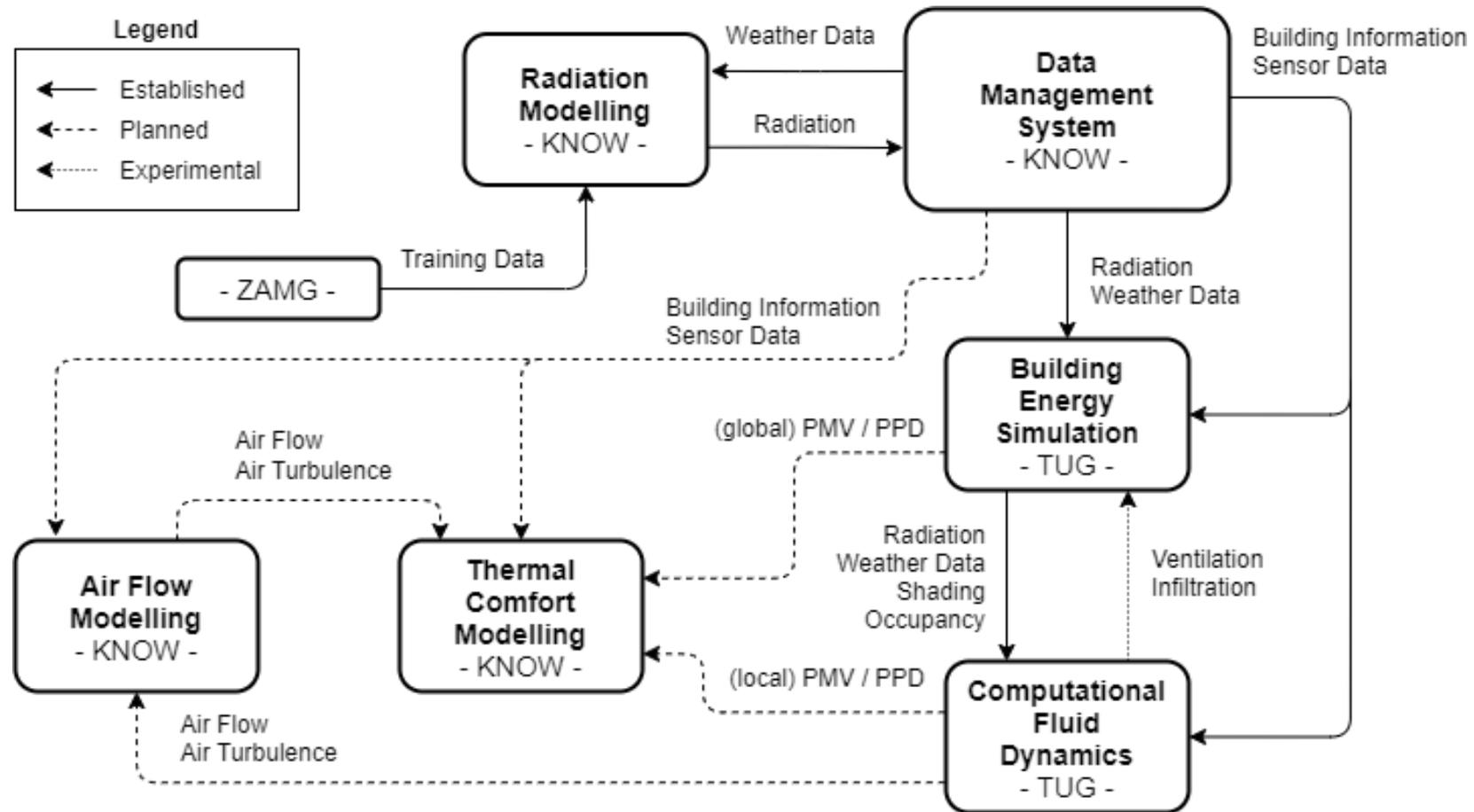


Test Box
[Source: TUG-IWT]



Weather Station
[Source: ZAMG]

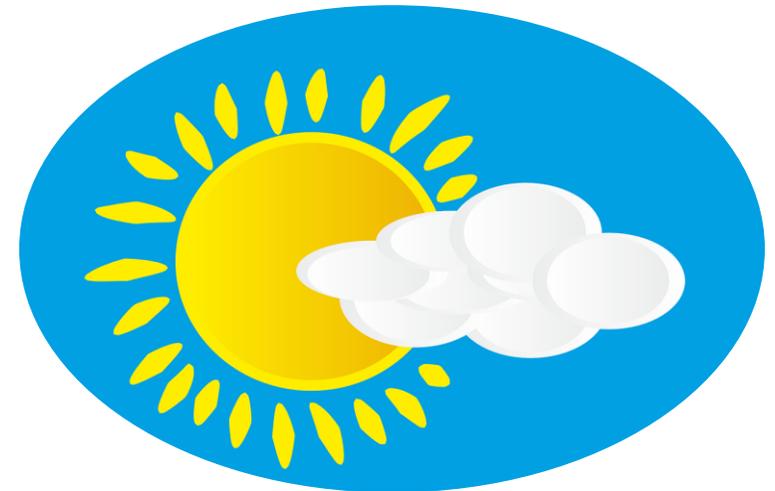
Simulation & Data-Driven Analysis



Solar Radiation



- Significant influence on thermal comfort
- Problem
 - Only global radiation available for Deutschlandsberg (@LogicData)
 - Measuring direct/diffuse radiation is costly (special instruments, i.e. Graz)
- Create soft sensors for direct and diffuse radiation
 - Regression Modelling in Python
 - Direct fraction as target value $f_{dir} = \frac{R_{glob}}{R_{diff}}$
 - Training data from Klagenfurt and Graz
 - Model applied to Deutschlandsberg



Solar Radiation Models



- Linear objective function with polynomial features up to order of 5
 - With and without Tikhonov Regularization
- Linear objective function with Principal Component Analysis
- Logistic objective function
- Mixed Logistic-linear objective function, version 1
 - inspired by Equation (8) in Ridley, Boland & Lauret, 2010
 - Various permutations of Logistic and linear features
- Mixed logistic-linear objective function, version 2
 - Physical features as logistic input
 - Mixed terms as linear inputs



Modelling Evaluation

- Error functions
 - RMSE, rRMSE, MBE, rMBE, MedAE, $AE_{0.75}$, $AE_{0.95}$, MaxAE,

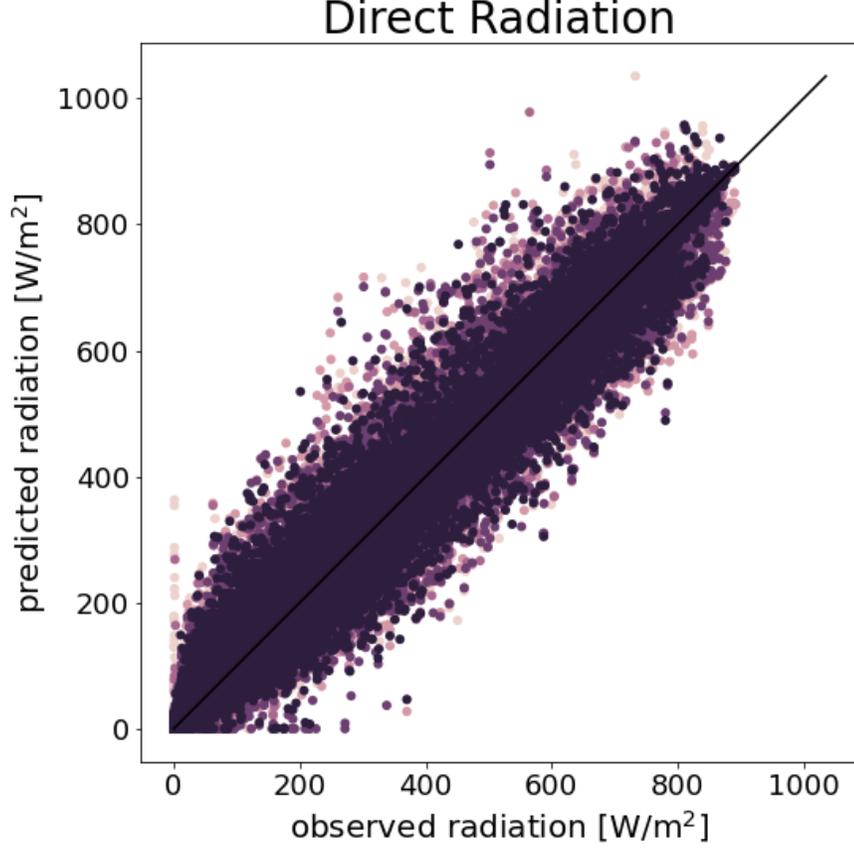
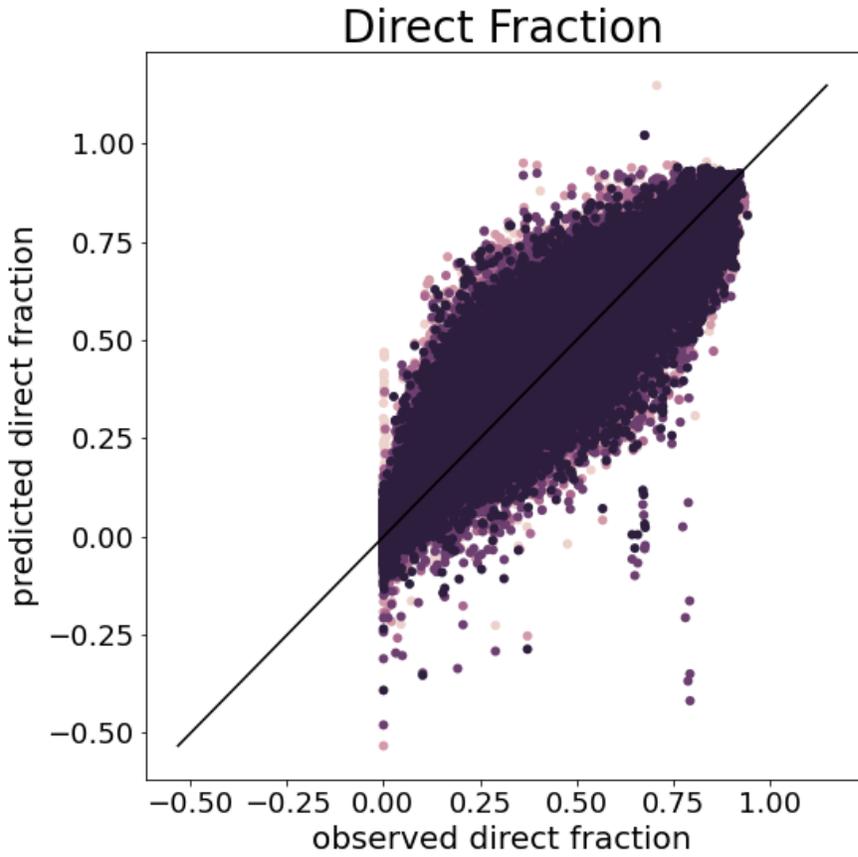
- Seasonality

- Evaluation over complete year
- Seasonal splits

| Period | From | To | Event |
|---------|--------------------------|--------------------------|------------------|
| SOL_W | 6 th November | 5 th February | Winter solstice |
| EQU_S | 6 th February | 5 th May | Spring equinox |
| SOL_S | 6 th May | 5 th August | Summer solstice |
| EQU_A | 6 th August | 5 th November | Autumnal equinox |

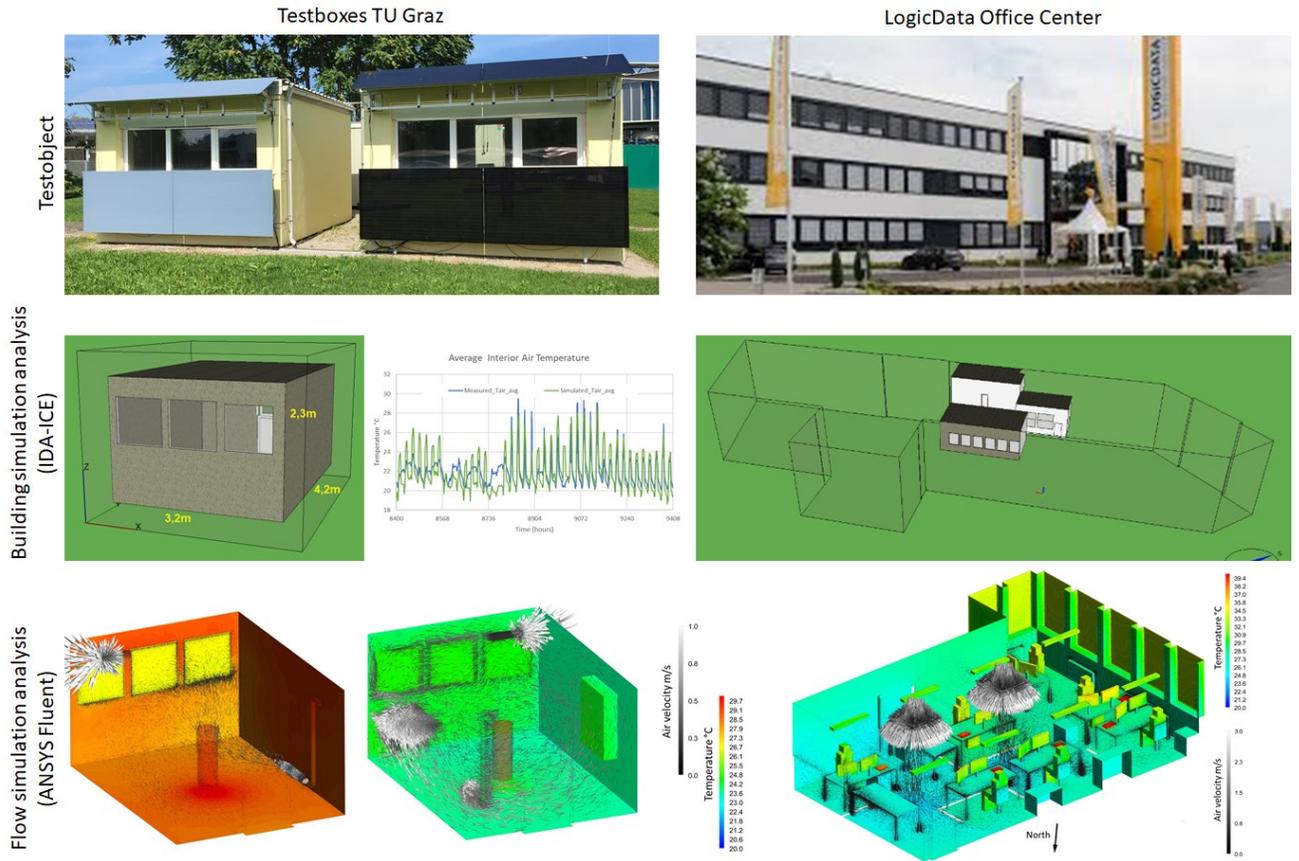
- Linear objective function with polynomial features up to order of three and Tikhonov Regularization
 - Best compromise
 - Model complexity
 - Low Overfitting

Direct Fraction & Radiation

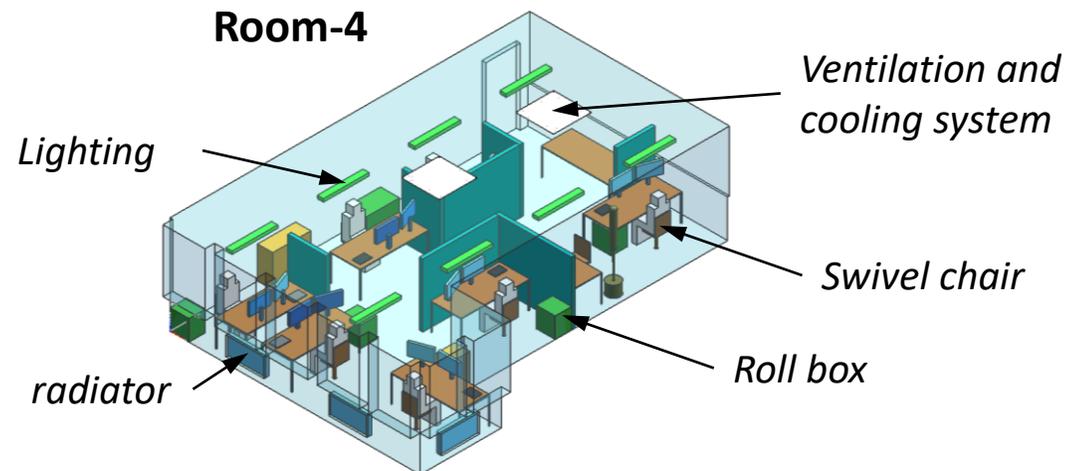
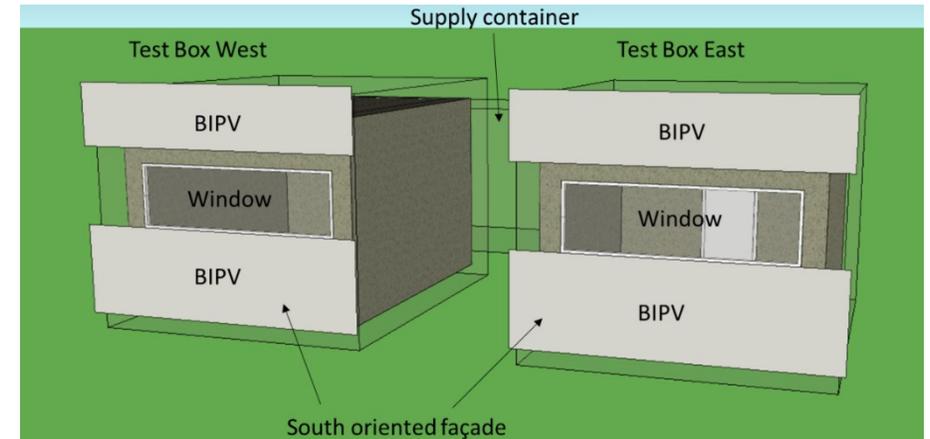
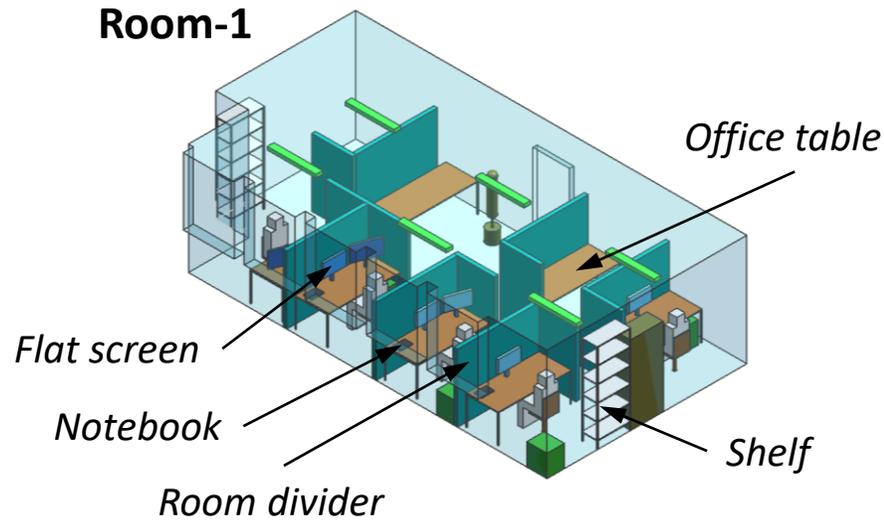


Building Simulation Models

- BES
 - Average thermal comfort in zones (i.e., offices)
 - Fast and time-efficient
 - IDA ICE
- CFD simulation
 - Detection of local discomfort (i.e., hot/cold spots)
 - Simulations in real time
 - Calibration via *Test Boxes*
 - Ansys



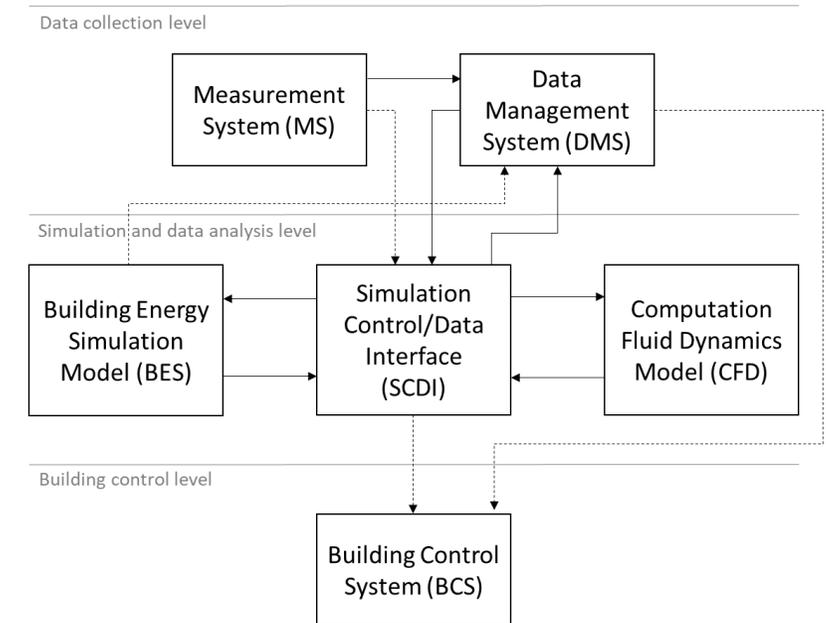
CFD & BES Models



CFD & BES

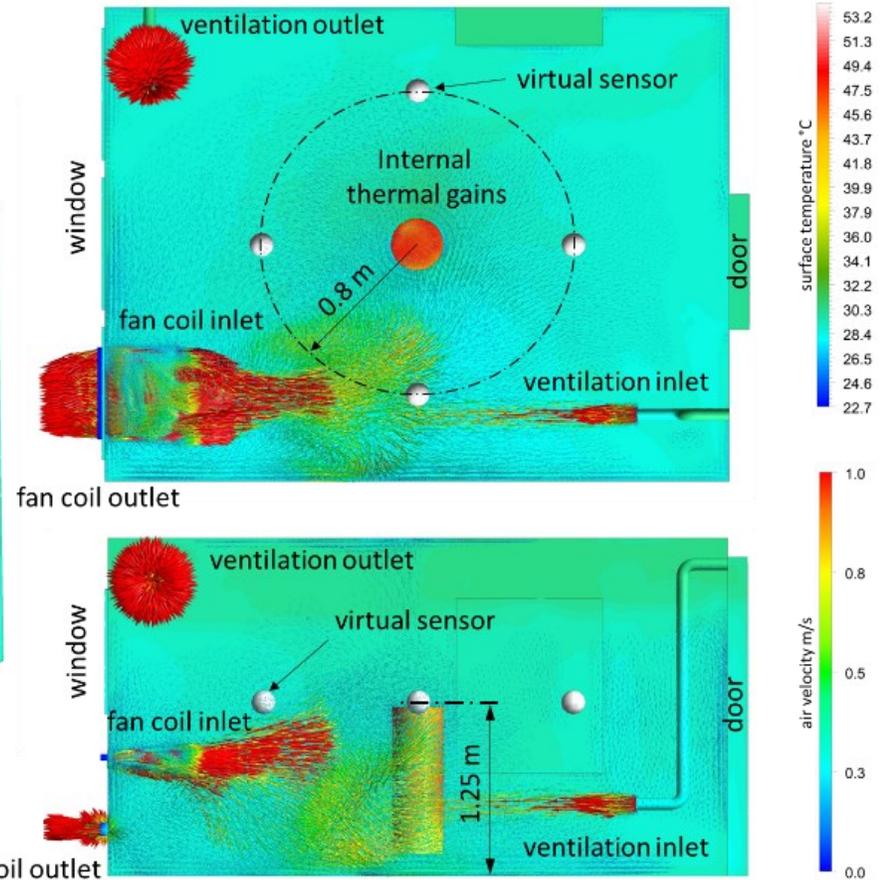
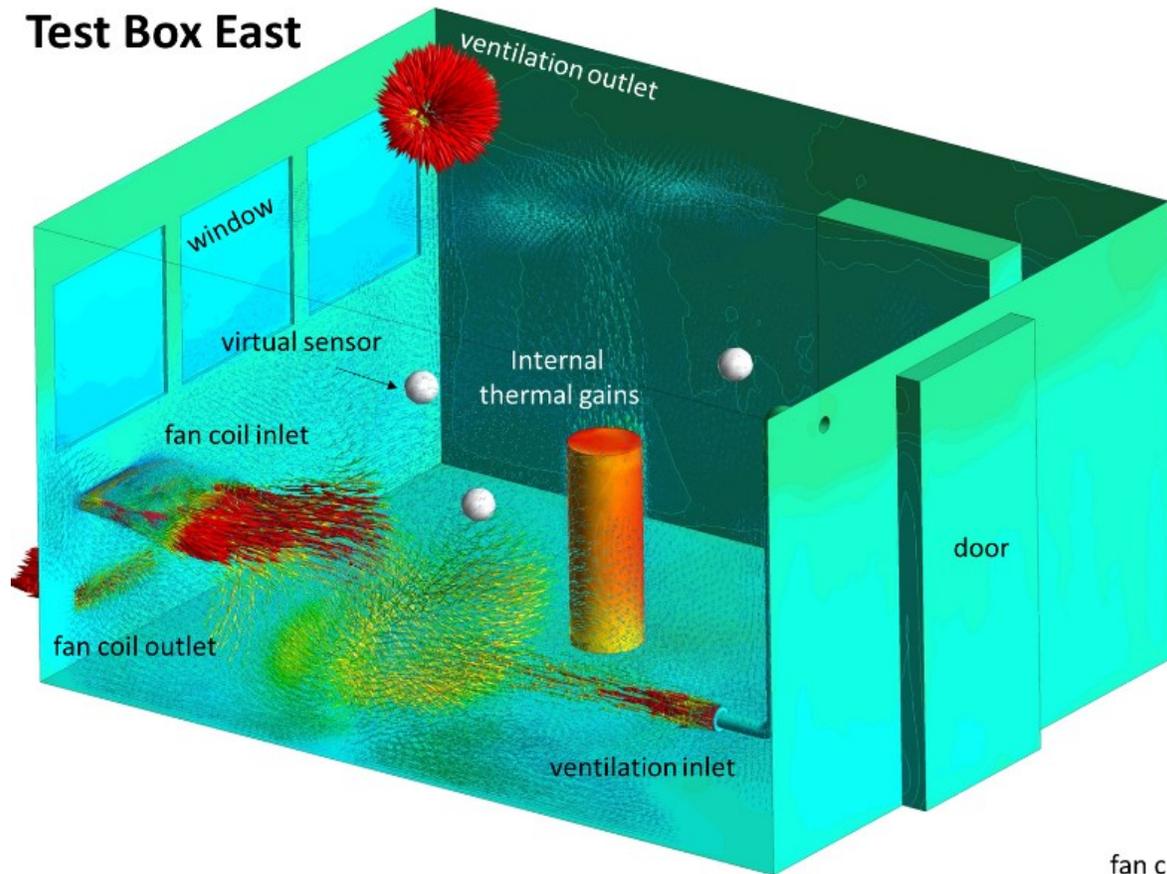


- Simulation Control/Data Interface in Matlab
- BES:
 - Boundary conditions for CFD
 - Global soft sensors:
 - Predicted Mean Vote (PMV)
 - Predicted Percentage of Dissatisfied (PPD)
- CFD:
 - Local soft sensors:
 - PMV, PPD and Operative Temperature (OT)
 - Air speed and air turbulence
 - Air temperature, humidity, min. and max air temperature, average surface temperature

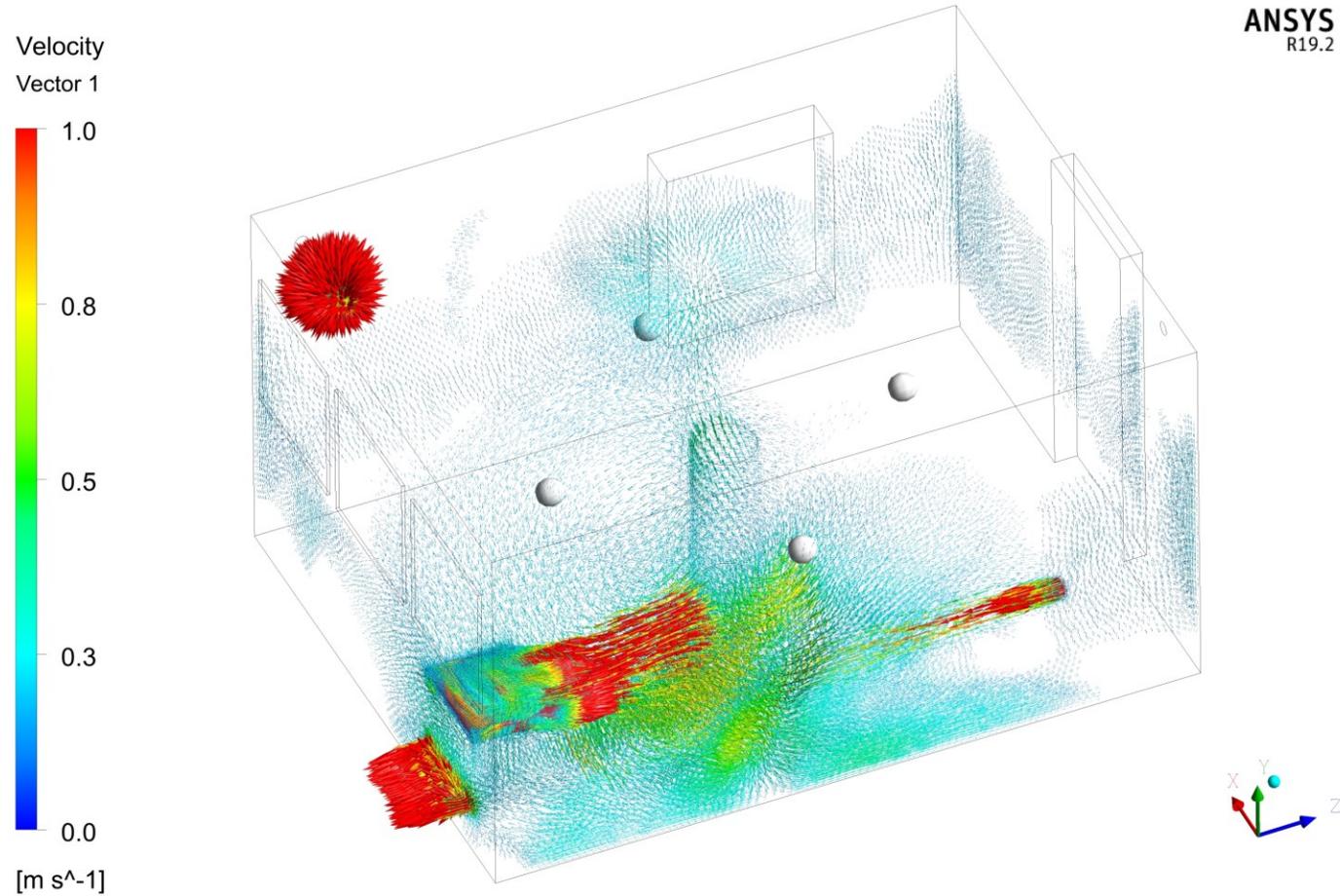


Soft Sensor Setup

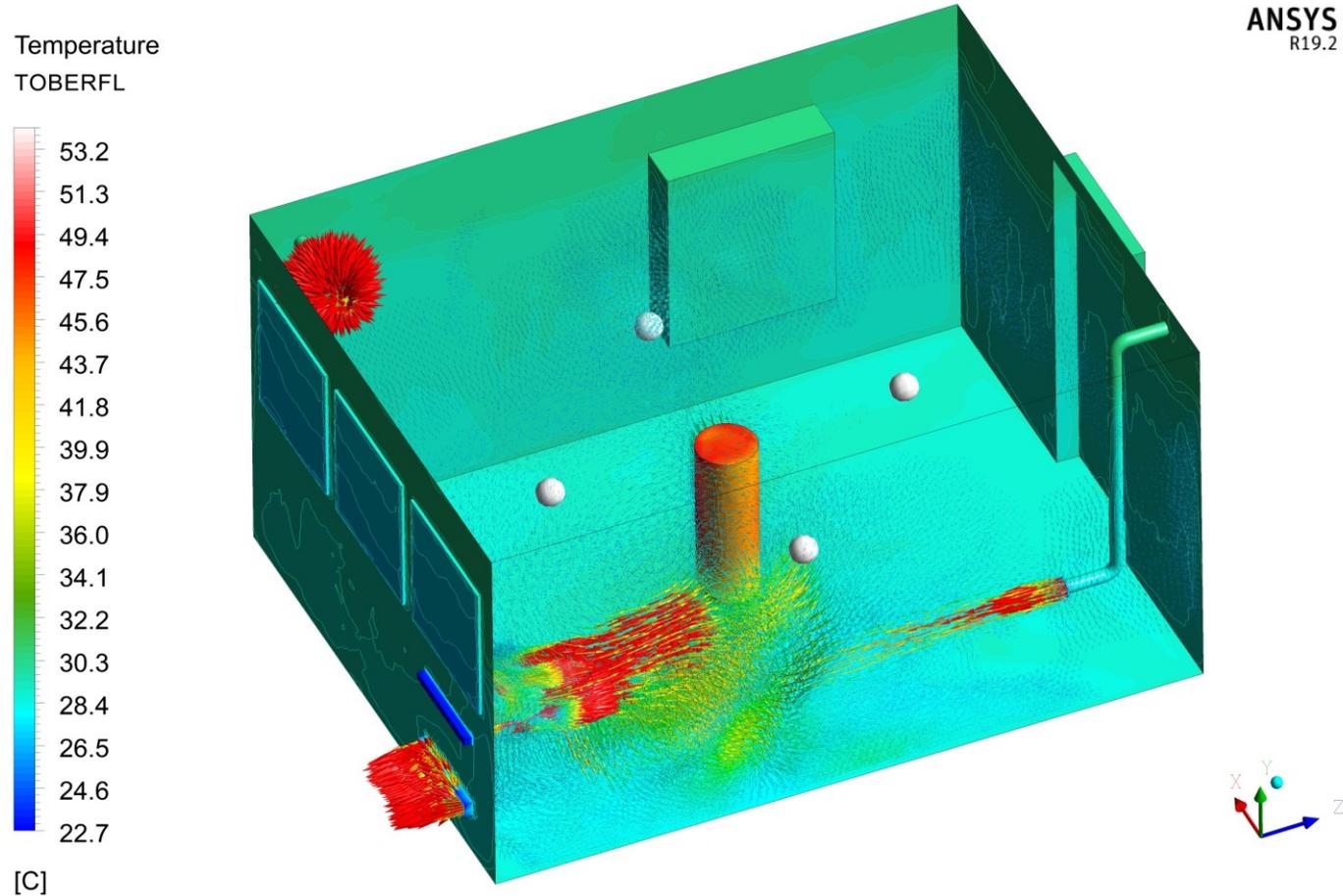
Test Box East



CFD Air Speed Results

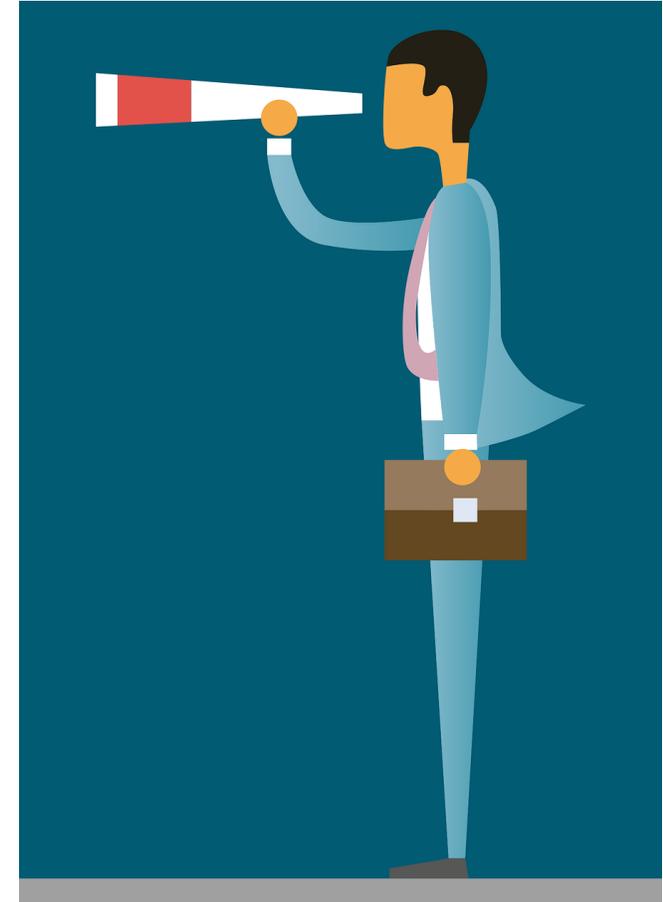


CFD Surface Temperatures



Outlook

- Validate the soft sensors on the office of LogicData in Deutschlandsberg
- Data-driven air-flow modelling
- Data-driven PMV & PPD modelling
- Collect our BIM experiances



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