EngD Program
SMART BUILDINGS & CITIES

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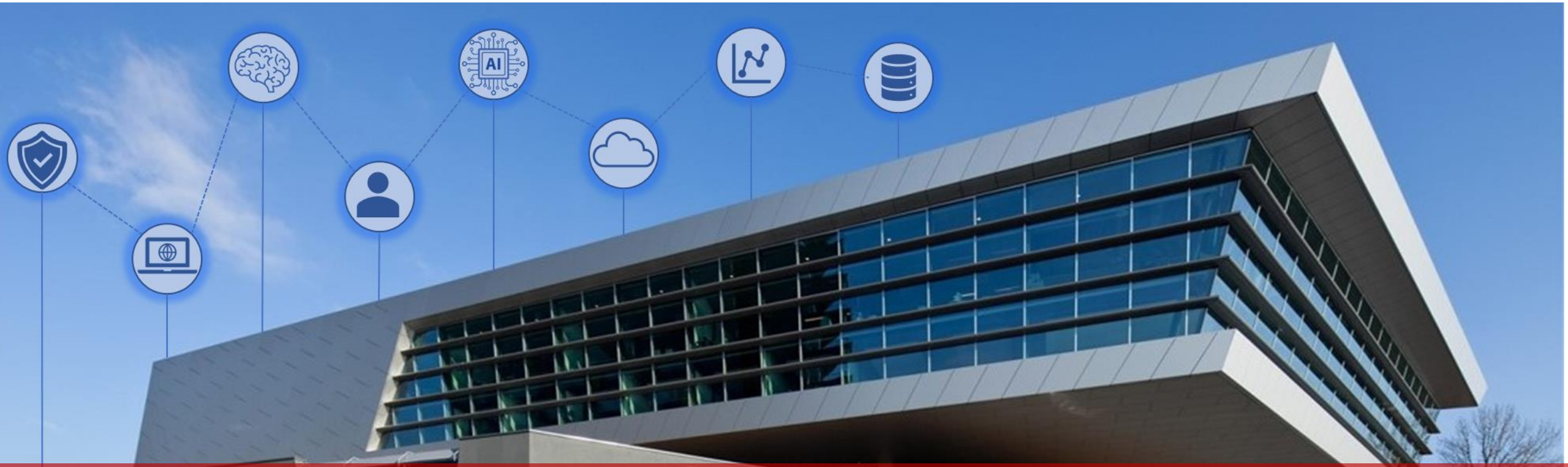
systemair



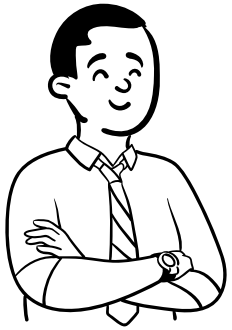
Fault detection and diagnosis of the low ΔT syndrome in cooling coils of chilled water systems

ANAND THAMBAN

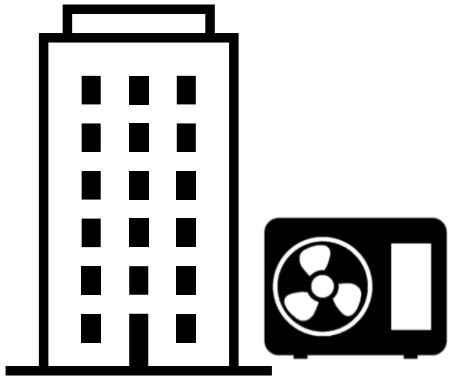
Brains4Buildings Webinar

BRAINS 4 BUILDINGS

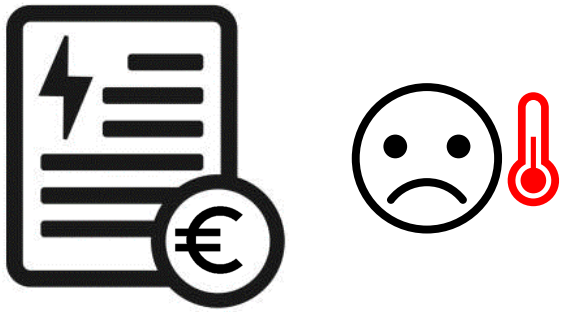
22nd September 2022



Tim
Building manager

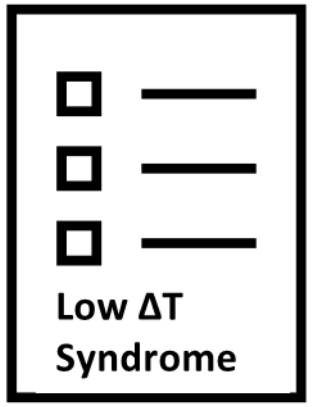


Manages HVAC system
of a large office building

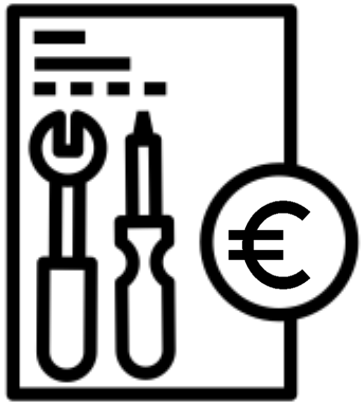


Observes 20-30% increase in energy bills
and increased comfort complaints

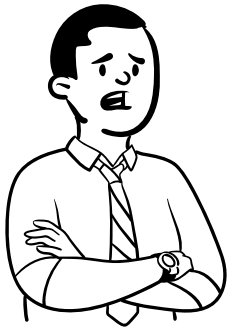
Requests help from
technician



Issue identified:
Low ΔT syndrome

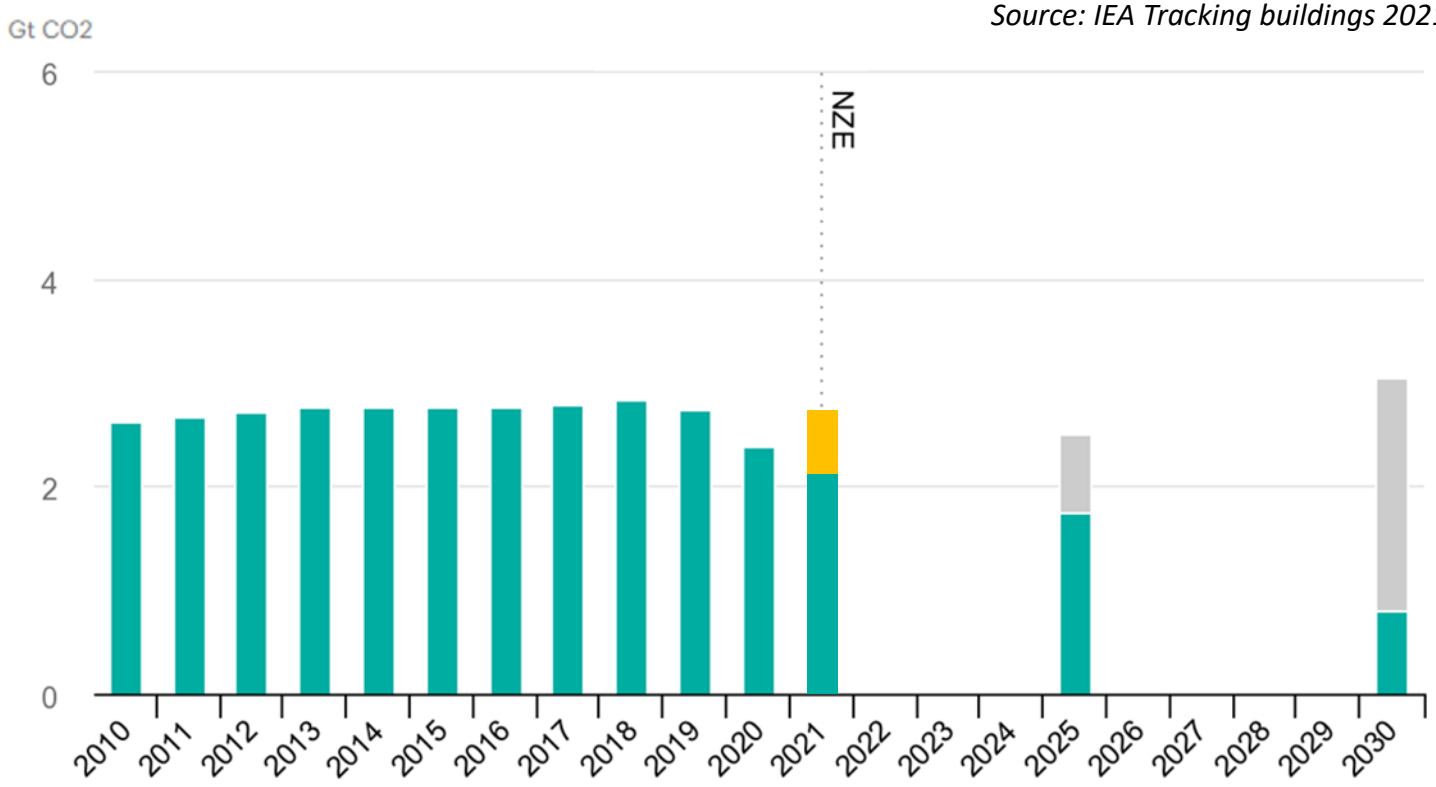


Costly inspection bill



Unsatisfied with
the costly process

Source: IEA Tracking buildings 2021



Global CO_2 emissions (indirect) from non-residential building operations (2010-2030)

Announced Pledge Scenario (APS) reductions

Extreme climate conditions

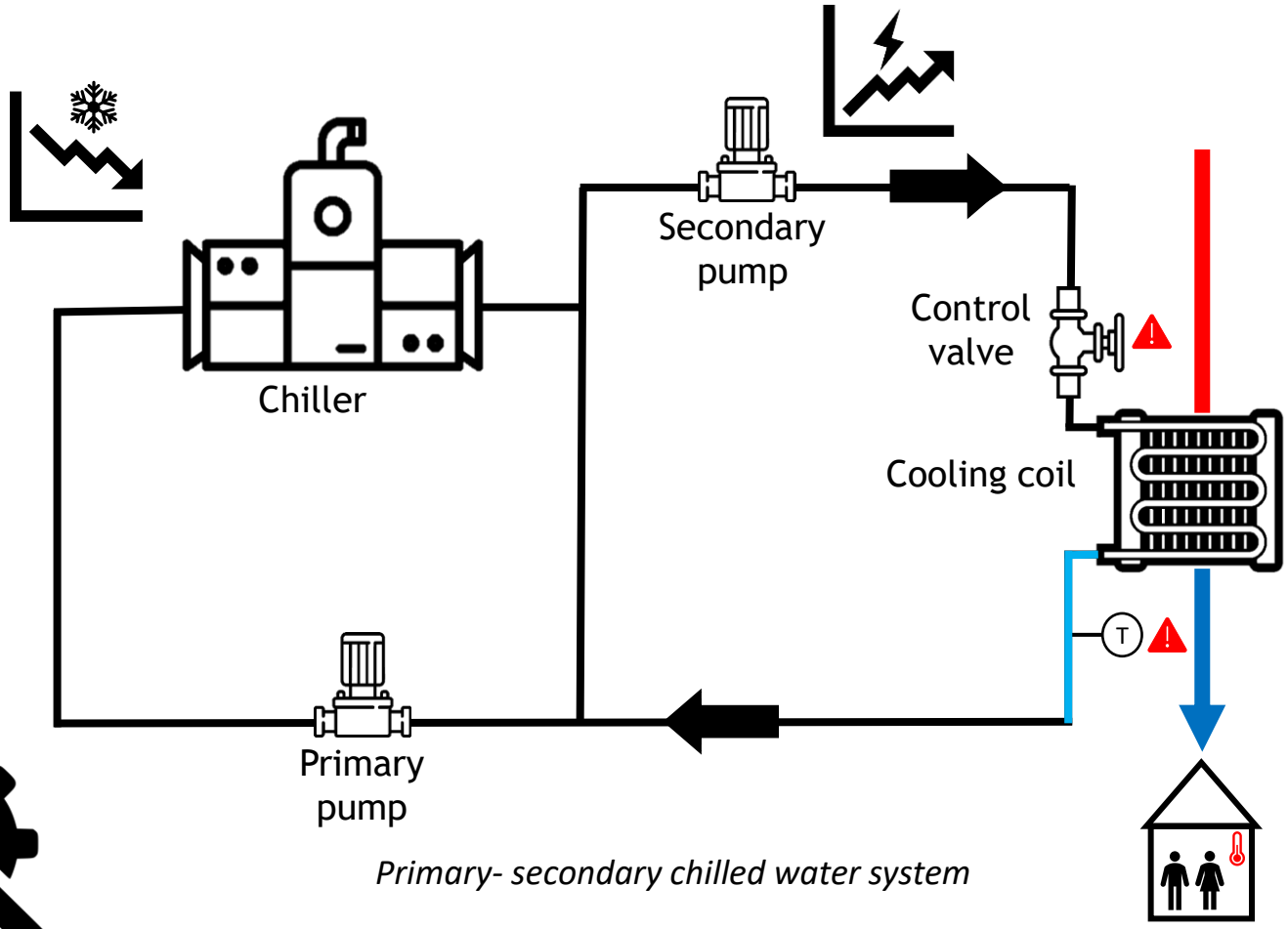
Not on track to reach 2030 emission goals

Potential to reduce around 0.5 Gt CO_2 emissions!

5 x

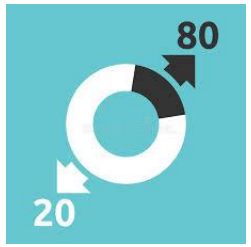
Low ΔT syndrome

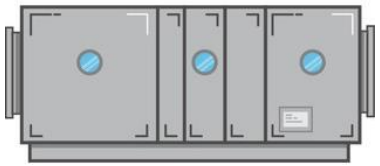
- Increased mass flow & reduced return water temperature
- Increased HVAC energy consumption by 20-30%
- Decreased chiller capacity
- Discomfort for occupants
- Important to develop FDD tools

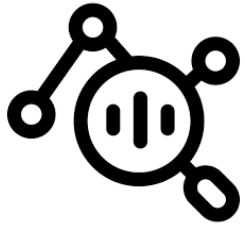


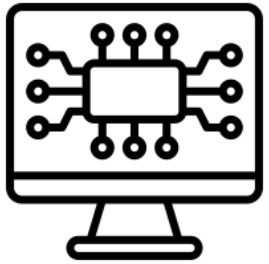
Primary- secondary chilled water system

Methodology



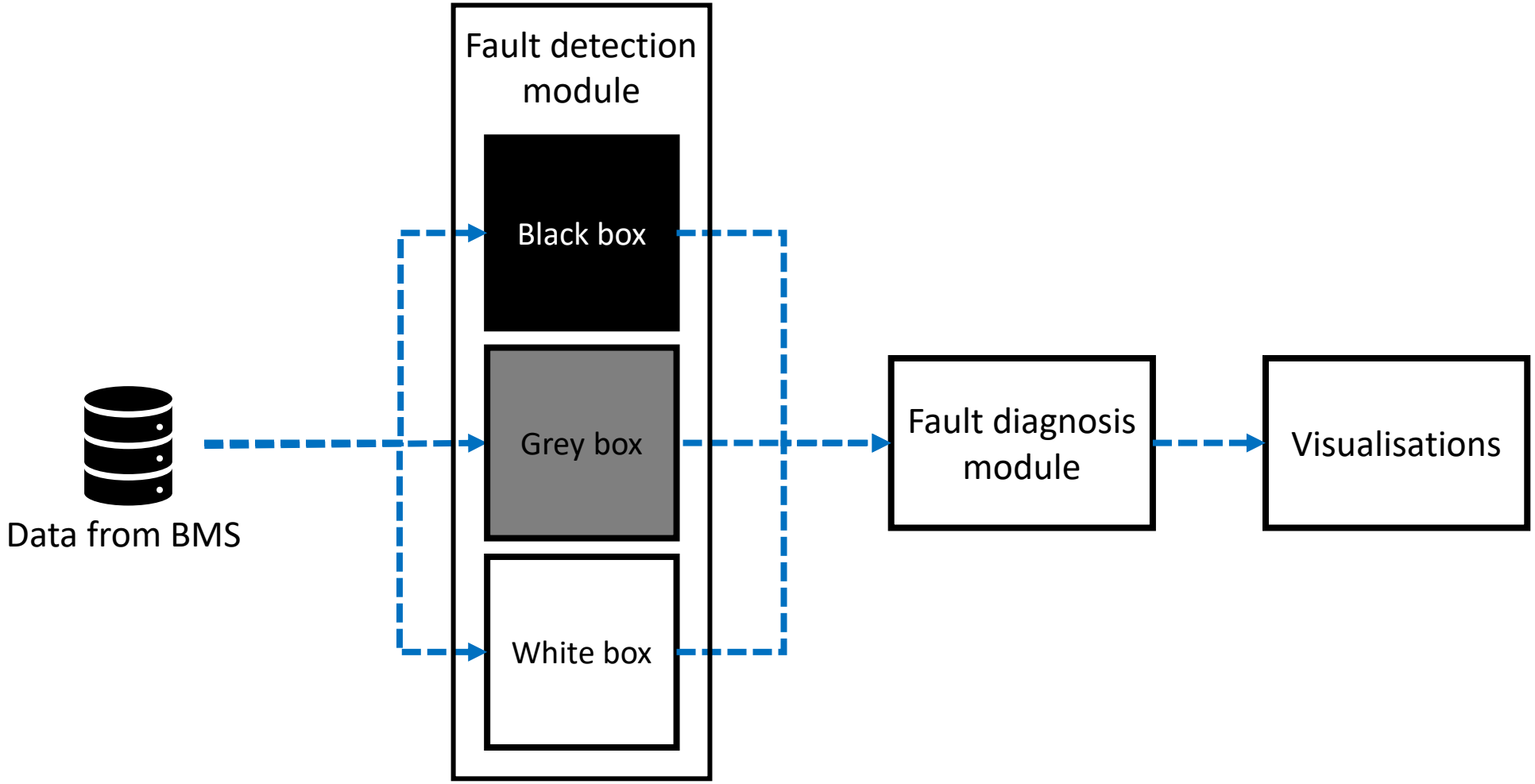




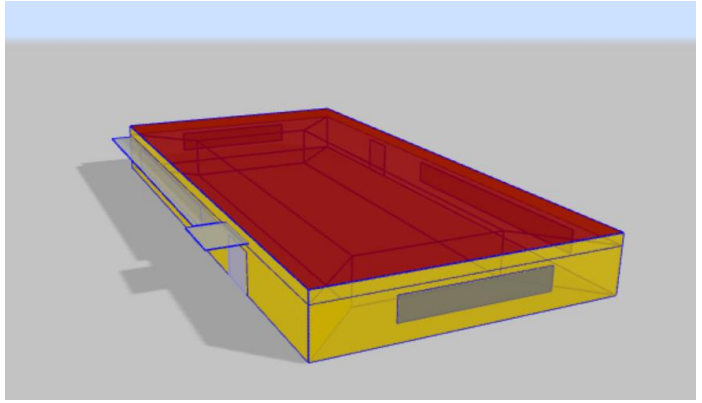


Fault impact analysis using Pareto-LEAN → Fault experiments and data collection → FDD algorithm development → Product development and integration → Product verification and validation → Conclusion and business plan

Proposed architecture



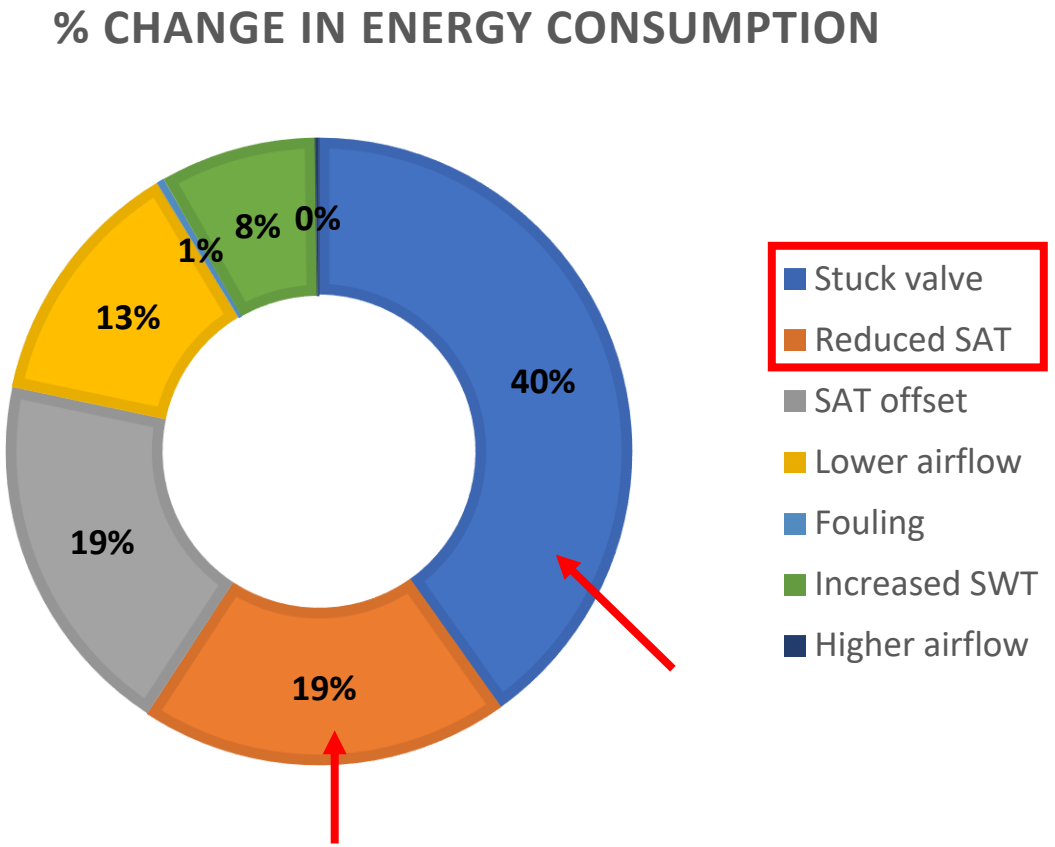
Fault impact analysis

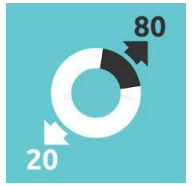


5-zone small office building

Software: EnergyPlus

Simulation period: 1 year





Pareto-LEAN

Experiments

Office building in Breda

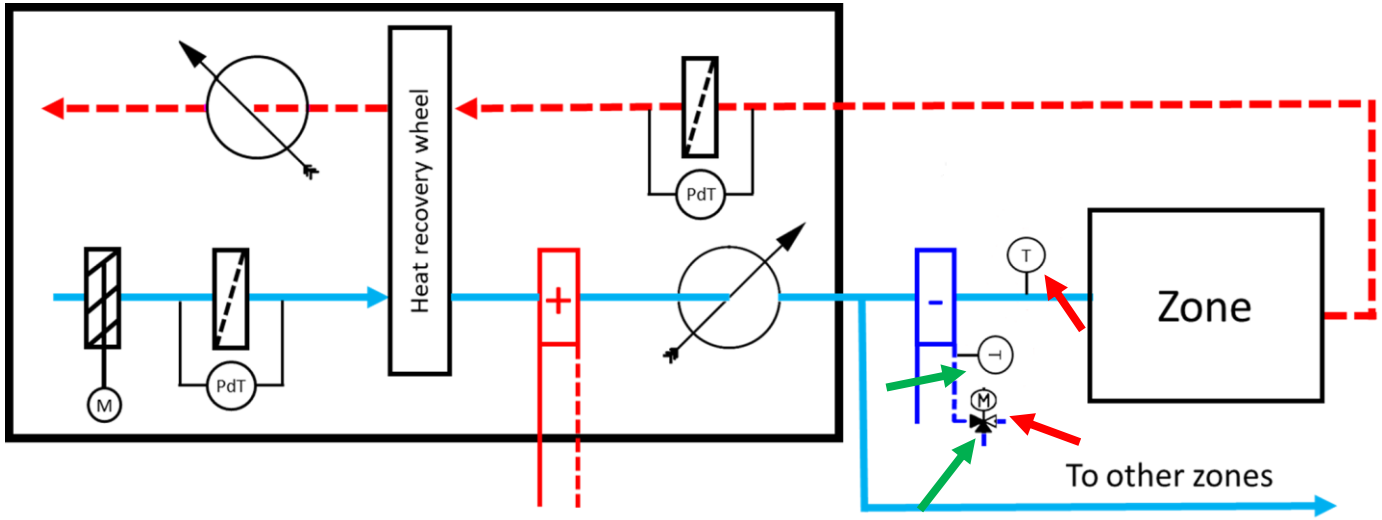
Experiment period: Jun 2021 – Aug 2021
Validation period: May 2022 – Jun 2022

- Installation of additional sensors
- Introducing faults manually into the system
- Changing setpoints and limits in the BMS

School building in Nijmegen

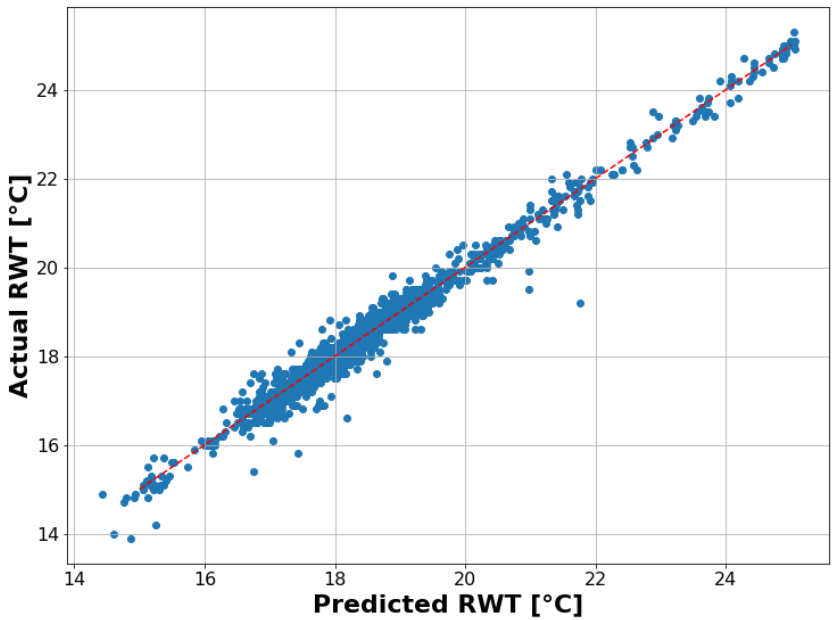
Experiment period: Jul 2020 – Aug 2020

- Cooling coil valve position
- Return water temperature

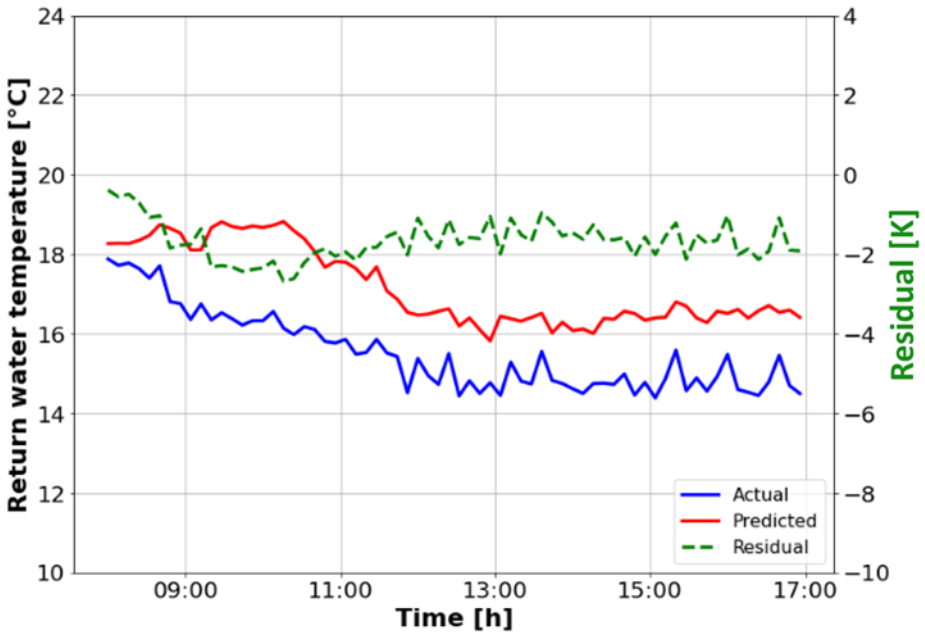


- Stuck valve fault
- Reduced supply air temperature fault

HVAC schematic of office building in Breda

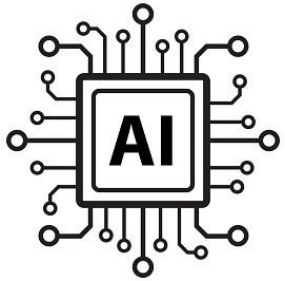


Performance evaluation of ML model (3 months fault-free data)

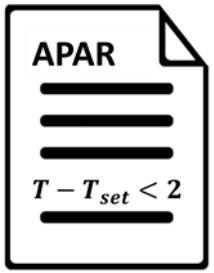


Fault-free prediction (9 hours) using ML model

FDD algorithm

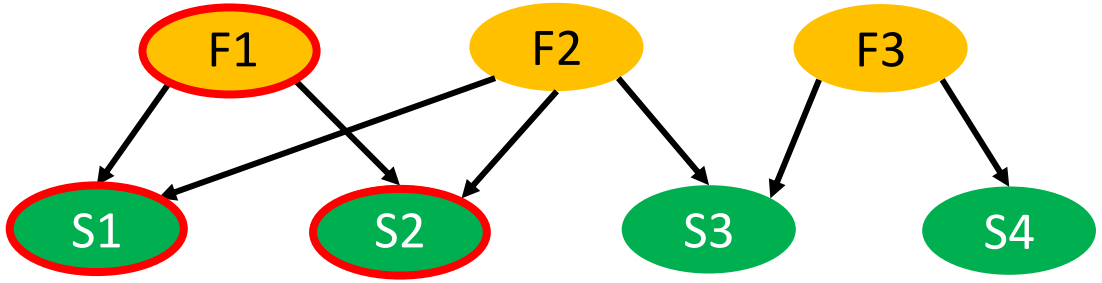


Machine learning

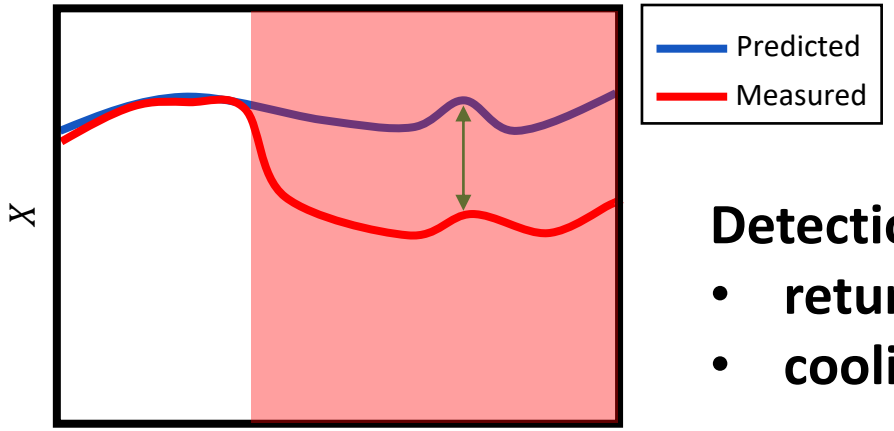


Rules-based

Statistical



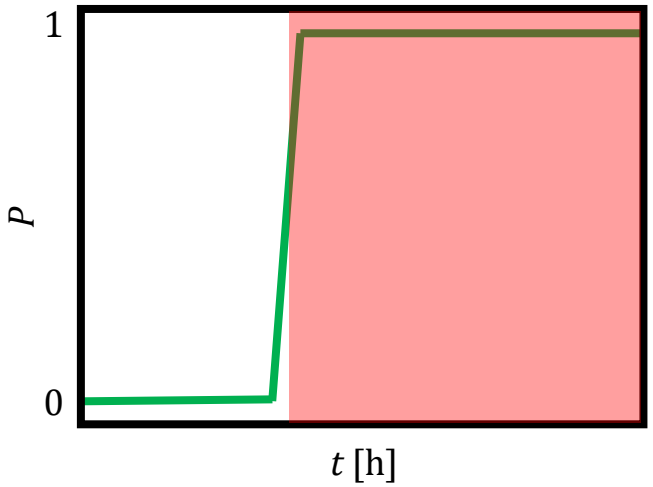
Diagnostic Bayesian Network (4S3F)



Variable prediction

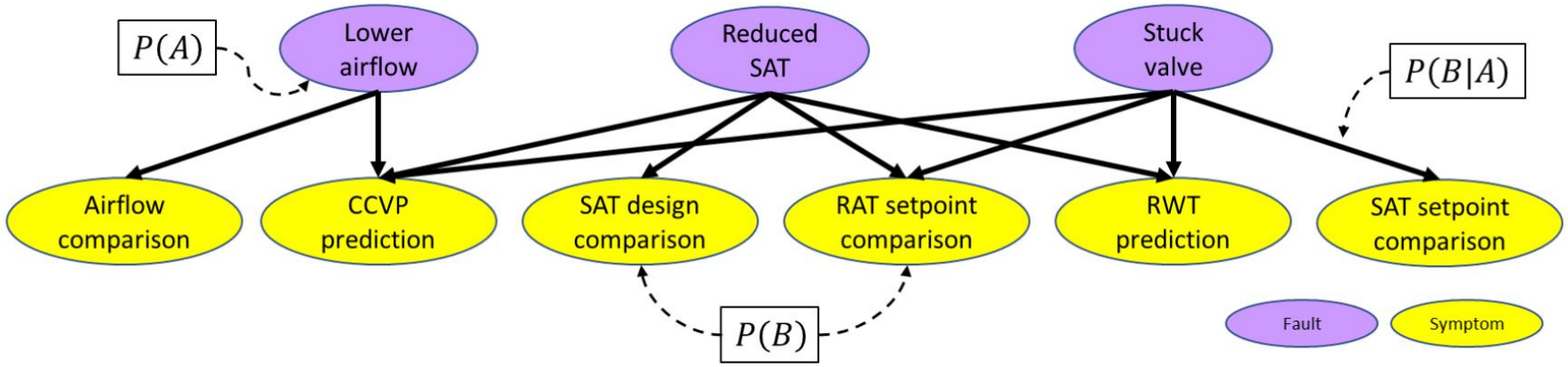
Detection of low ΔT based on:

- **return water temperature**
- **cooling coil valve position**



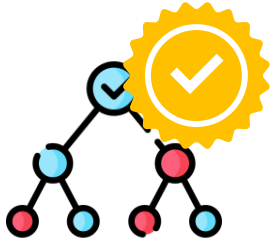
Fault posterior probability

FDD algorithm



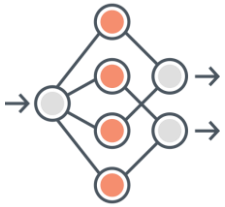
$$P(A|B) = \frac{P(B|A) \times P(A)}{P(B)}$$

ML algorithm comparison

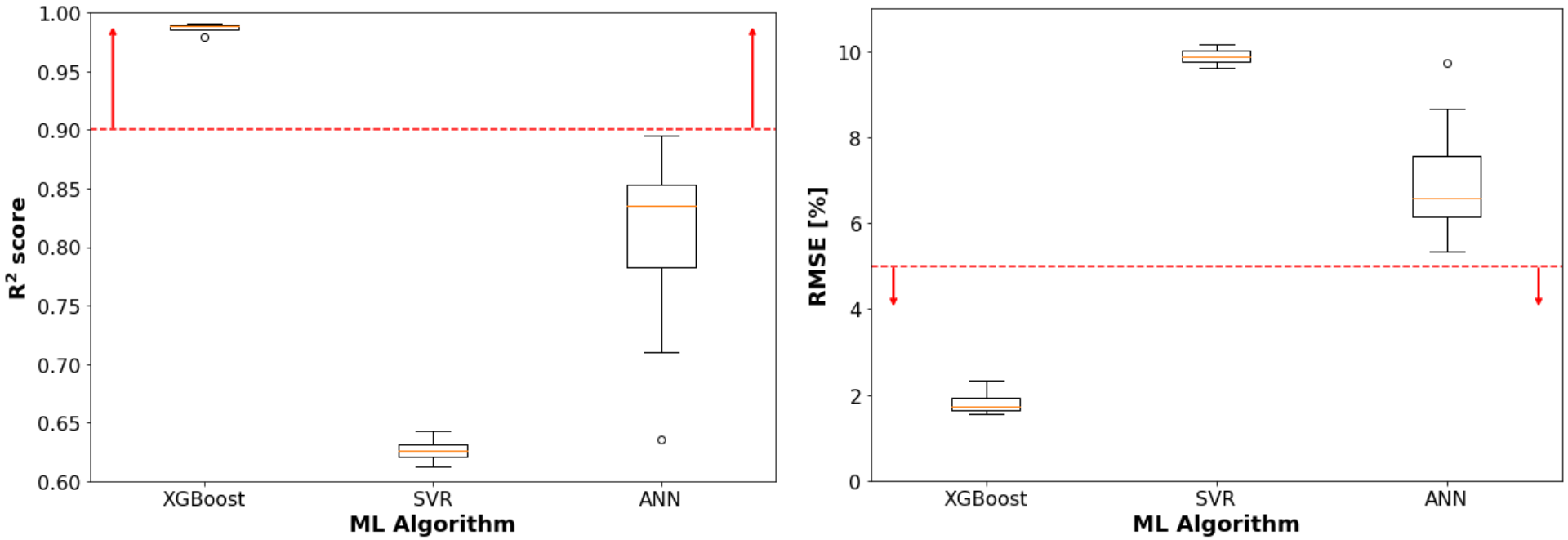


XGBoost

SVR



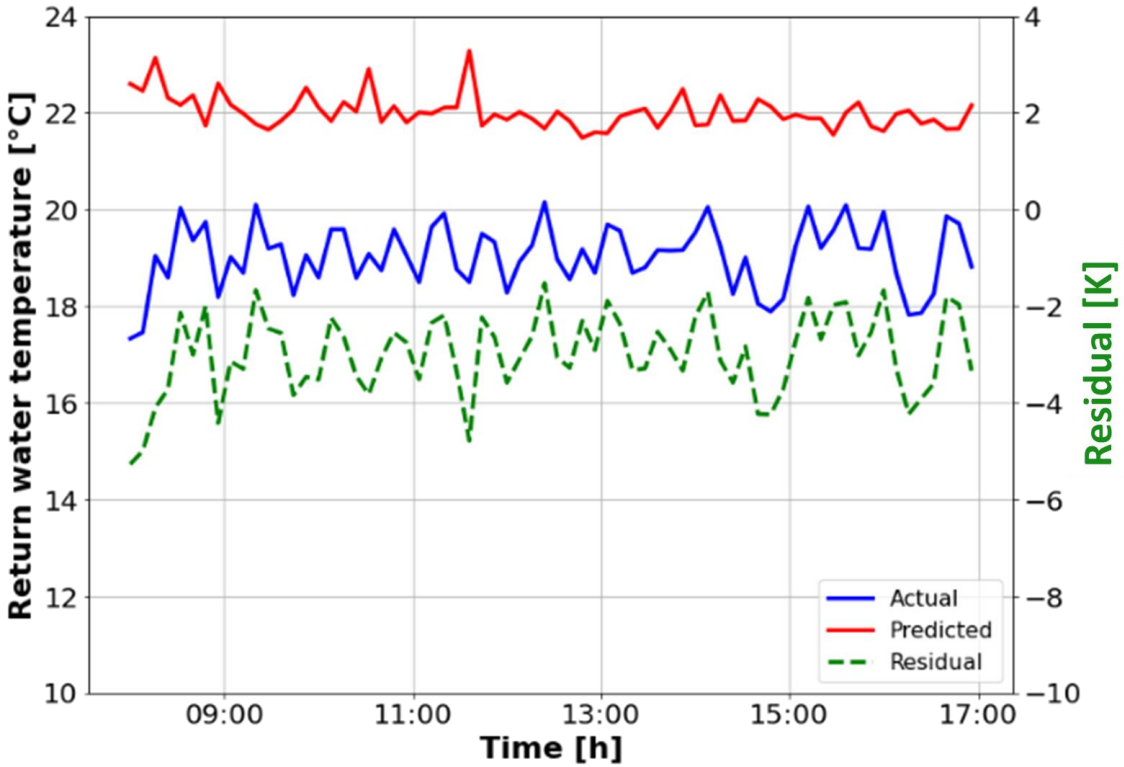
ANN



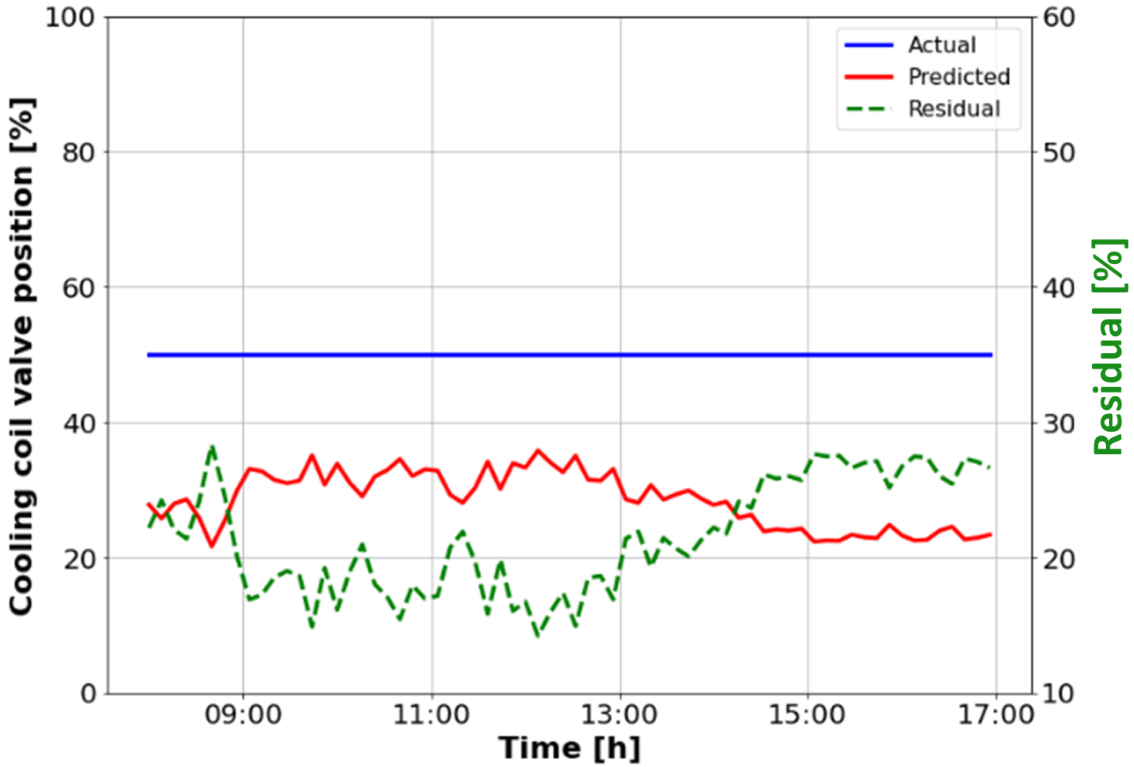
Comparison of R^2 score and RMSE for cooling coil valve position prediction

Similar results observed for return water temperature prediction!

Fault detection



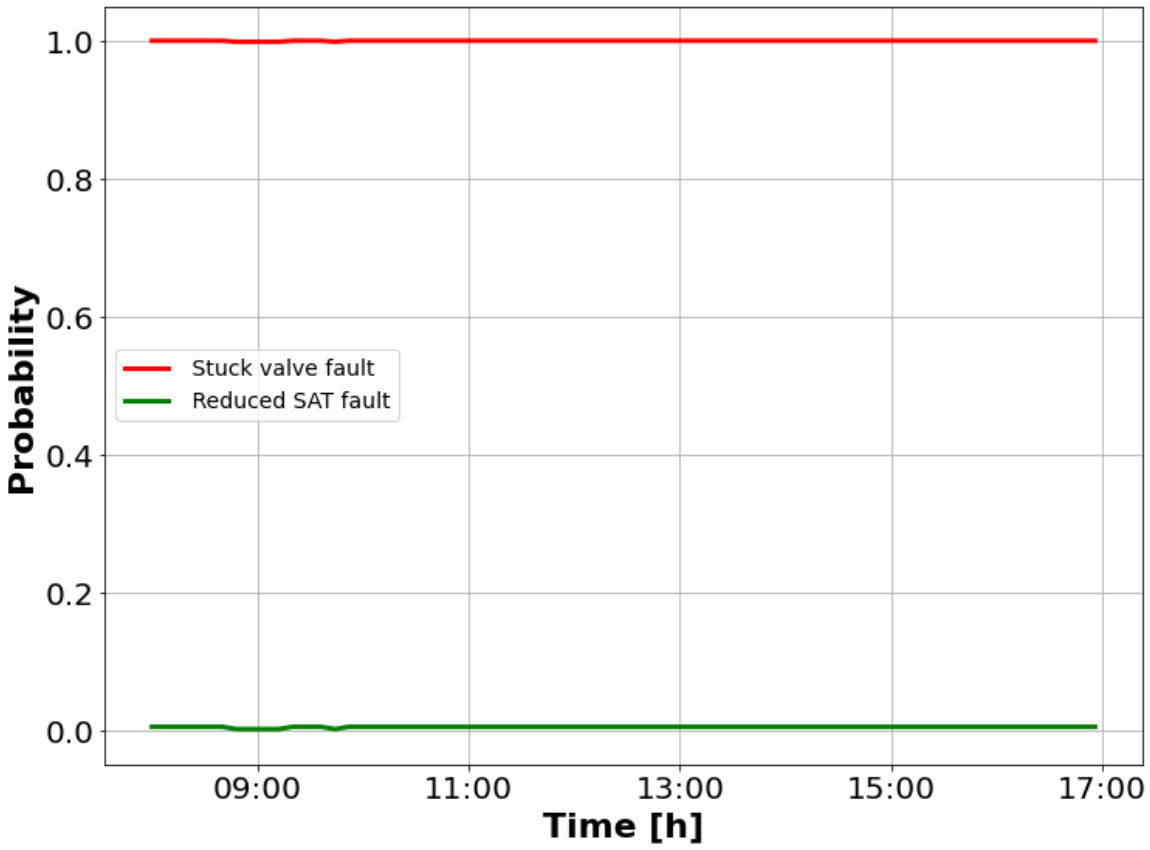
Fault–free prediction of return water temperature during 50% stuck valve fault (error threshold = -0.5K)



Fault–free prediction of valve position during 50% stuck valve fault (error threshold = 5%)

Large residuals observed for both predictions, low ΔT syndrome detected!

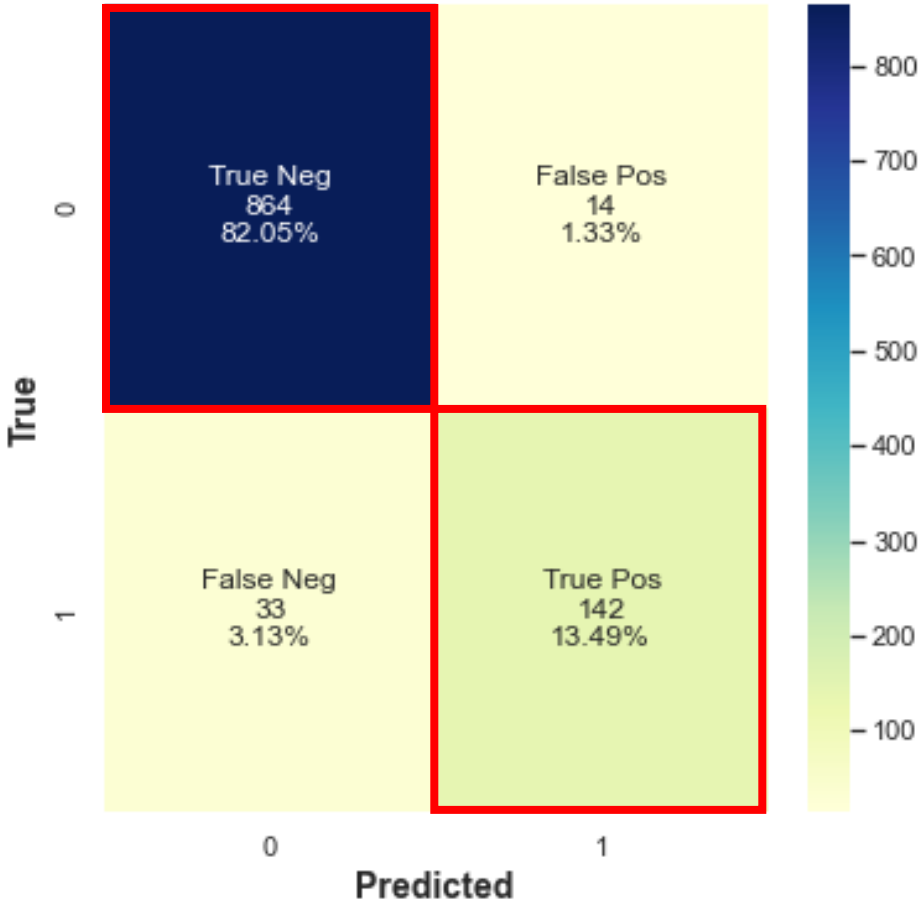
Fault diagnosis



Posterior probabilities for all faults

Stuck valve fault identified to be the cause due to high posterior probability.

Validation

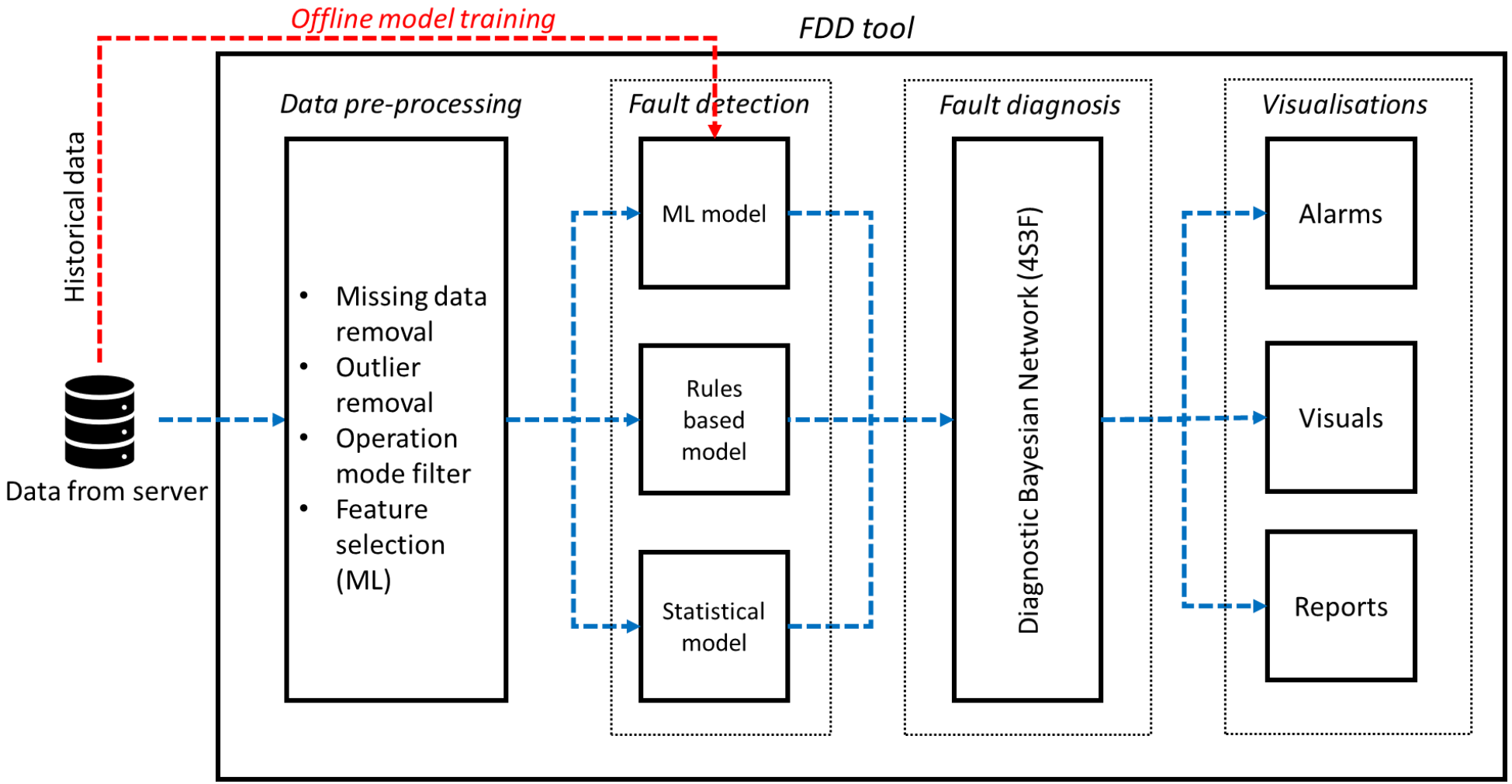


Confusion matrix for office building in Breda. Validation study in 2022.

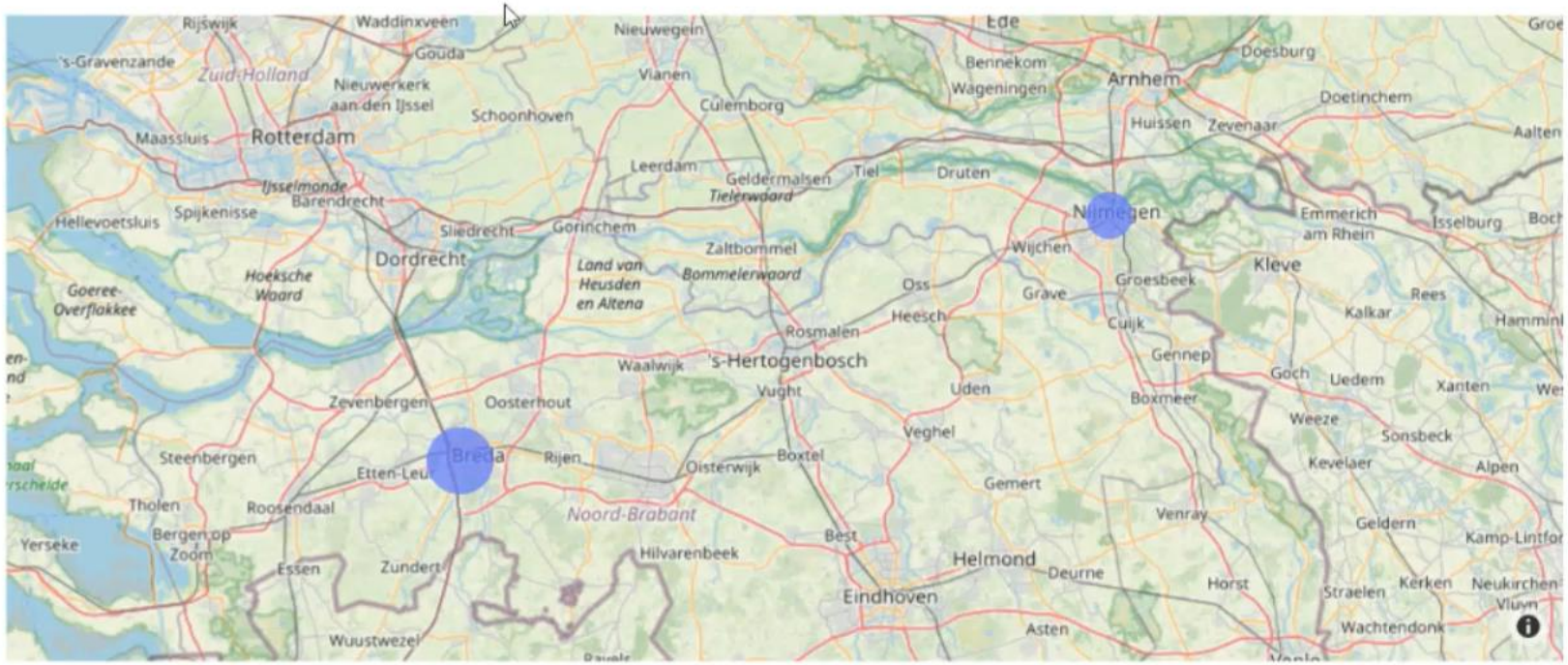
Fault detection accuracy = $\frac{TP+TN}{TP+TN+FP+FN}$ **= 95.5%**

Fault diagnosis accuracy = 93%

FDD tool architecture



SITES



PROJECT PARTNERS

Rijksdienst voor Ondernemend Nederland
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EINDHOVEN ENGINE
ROC NIJMEGEN
Radboudumc
systemair
ISSO

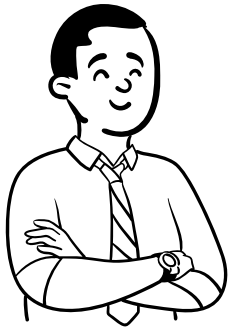
Early alarms

Reduced maintenance cost

Reduced energy cost

Better occupant comfort

Scalable product with business plan



Satisfied user

Thank you!

Questions?

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