Machine learning in smart building operation

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Content

- Scope of the presentation
- Machine learning (ML) based control applications
- ML in fault detection and diagnostics (FDD)
- Current themes from research and practical perspectives

What is a smart building?

- Healthy indoor environment
- Energy efficient and flexible
- Ease of everyday life
- Learns based on data and feedback
- Future-proof
- Smart readiness indicator (SRI) one methods to measure smartness

(Source: European Commission)

Building operation and maintenance

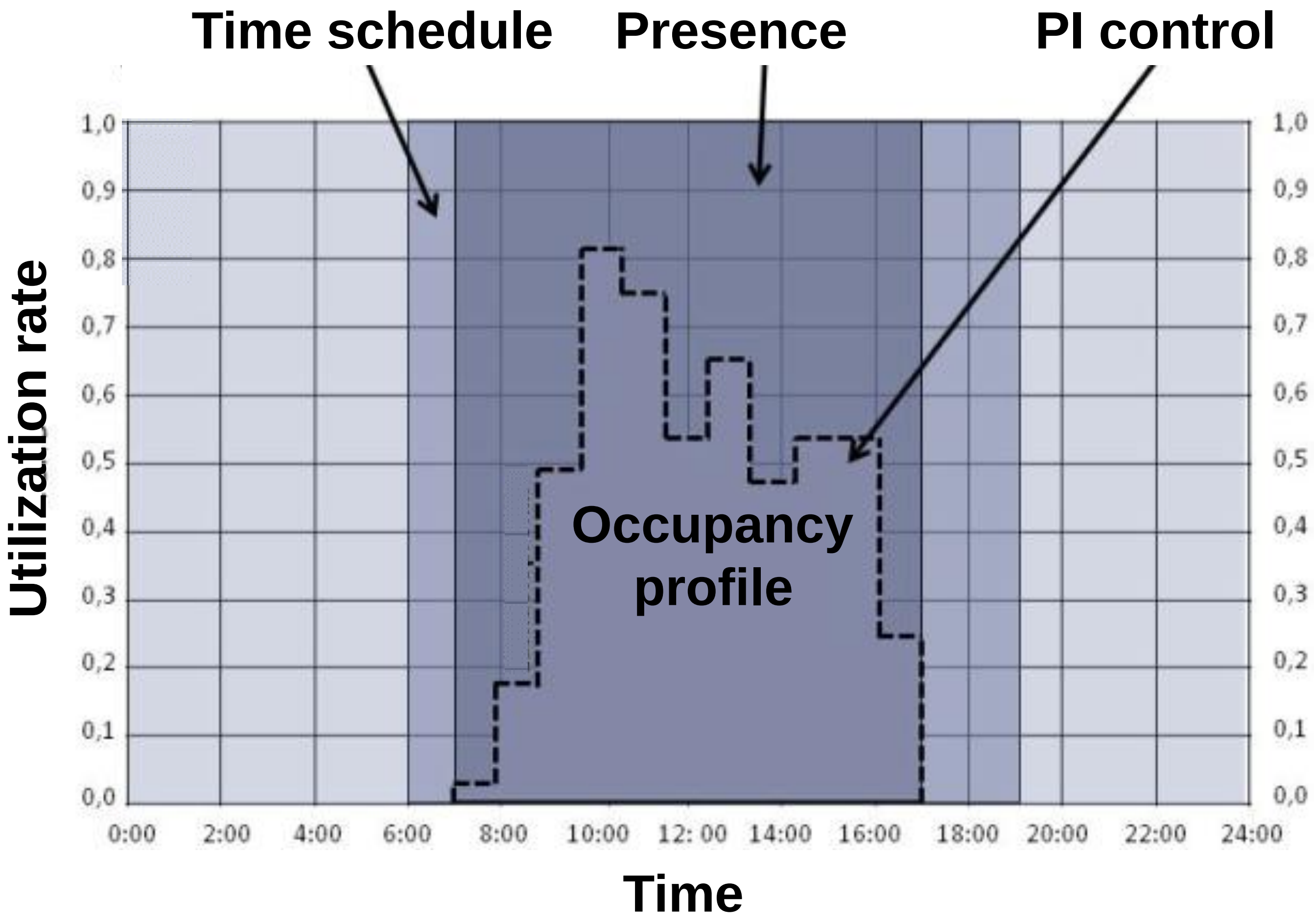
Buildings

- Largest asset class in the world, ~$380 trillion
- 40% of energy consumption
- People spend 90% of time indoors

Operation and maintenance

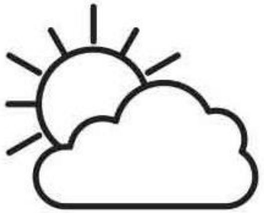
- "Cinderella" of the building industry
- Little glamour, unproductive and under budget cuts
- Operation = efficient use of systems → ML used in control and FDD
- Maintenance = inspections, cleaning and repair

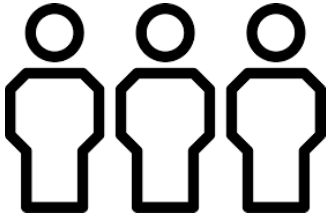
Traditional control methods

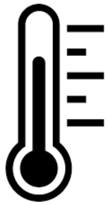


ML application areas at sensor level

- ML used in estimates and predictions
- Weather
- Occupancy
  - Wifi and bluetooth
  - Camera
  - Indoor enviroment sensors
  - Data fusion
- Indoor environment
- Building and appliance energy consumption







Meeting room occupancy estimation using multiple sensors

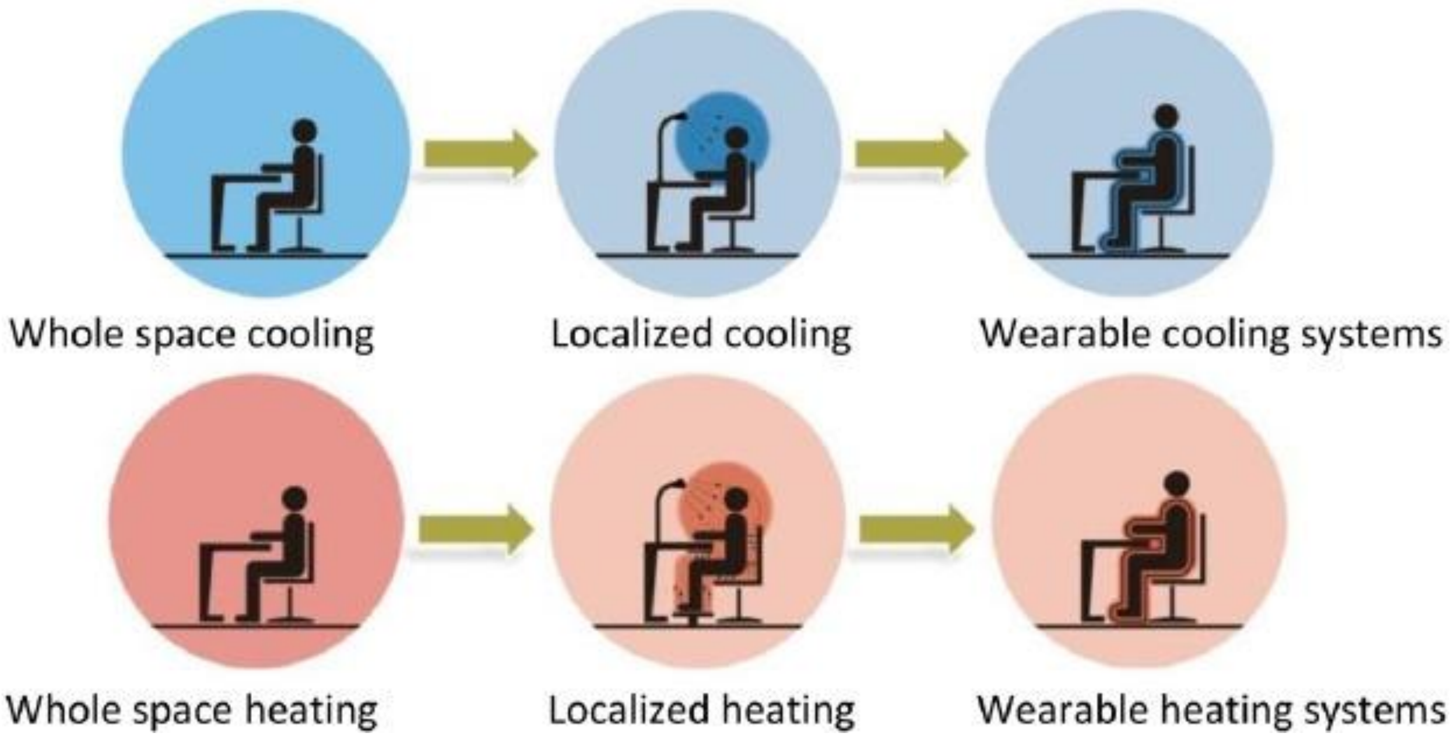
- Sensors
  - People counting camera
  - Passive infrared sensor
  - CO2
  - Temperature
  - Humidity
  - Volatile organic compound
  - Supply and extract airflow

Model	features	Accuracy	RMSE
KNN C	All no camera	0.7928	1.0179
KNN C	All	0.7838	0.8220
KNN C	Reduced	0.7838	0.8275
KNN R	All	0.7748	0.8275
KNN R	All no camera	0.7658	0.9910
KNN R	Reduced	0.7297	0.7711
RF C	All no camera	0.7207	1.0527
DT C	CO2 no camera	0.7207	0.6507
DT C	CO2	0.7207	0.6712
RF C	Reduced	0.7207	0.8436

(Source: Mikala 2023)

- Presence accuracy 95%, amount of people accuracy 79%
- RMSE = Root Mean Square Error ~ error deviation

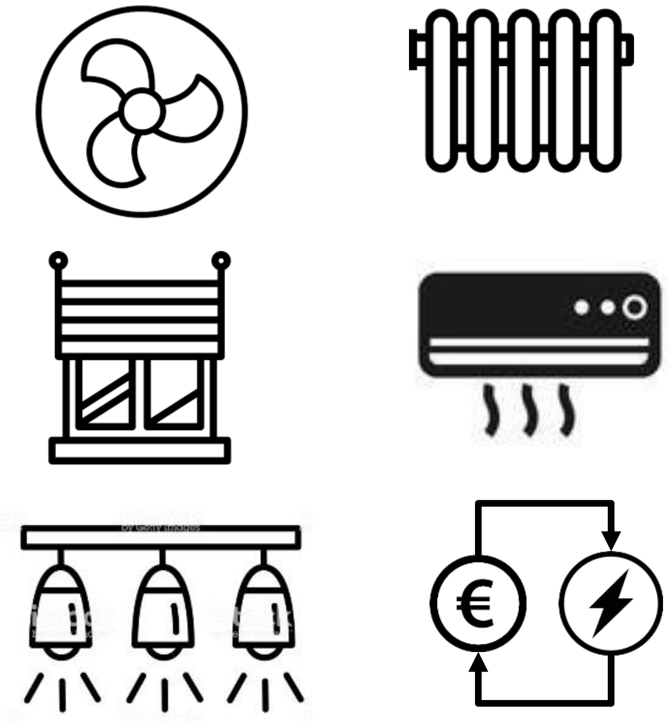
Human as a sensor



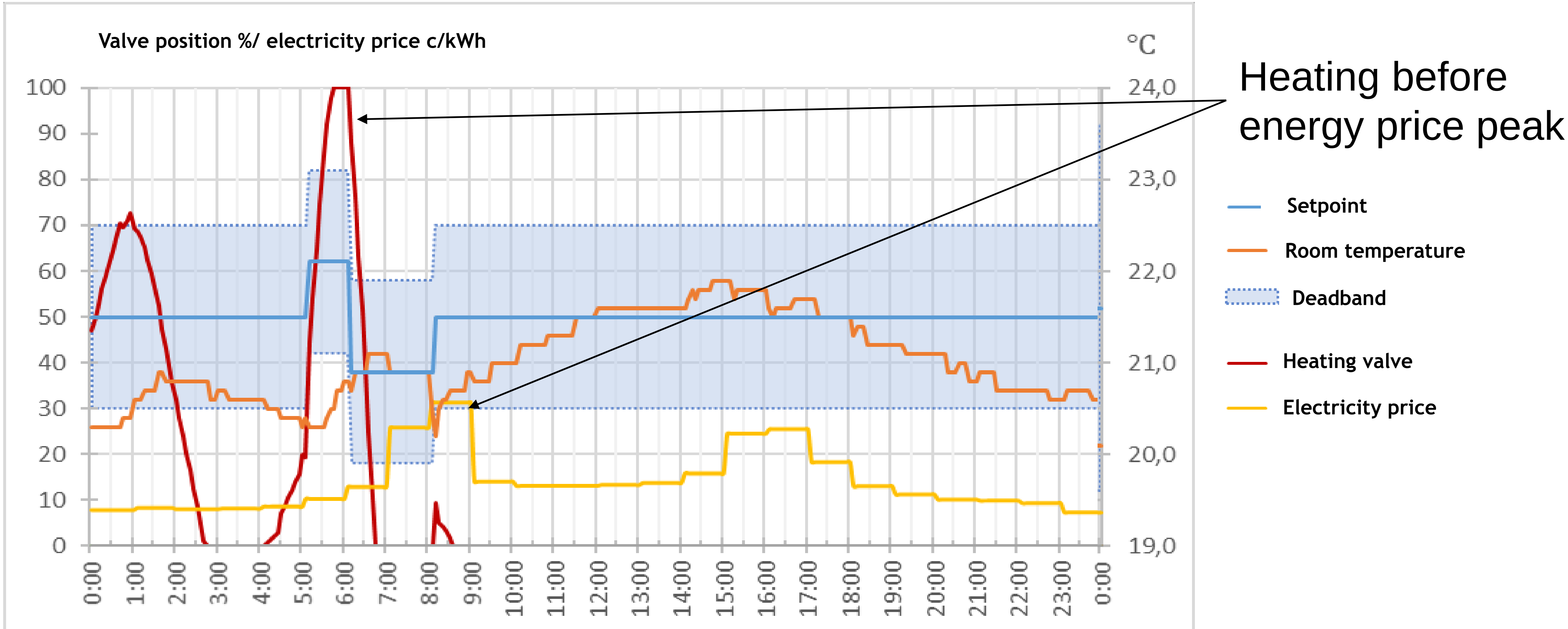
(Source: Yang et al 2021)

ML application areas at room/system level

- ML used in multi-objective optimization and predections
- Integrated room solutions
  - Shading, lighting and cooling
- System level energy, peak power and IEQ optimization
  - Heating
  - Cooling
  - Ventilation
  - Lighting

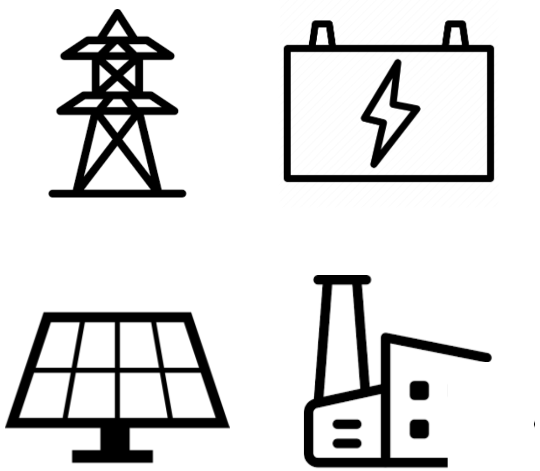


Room heating demand response

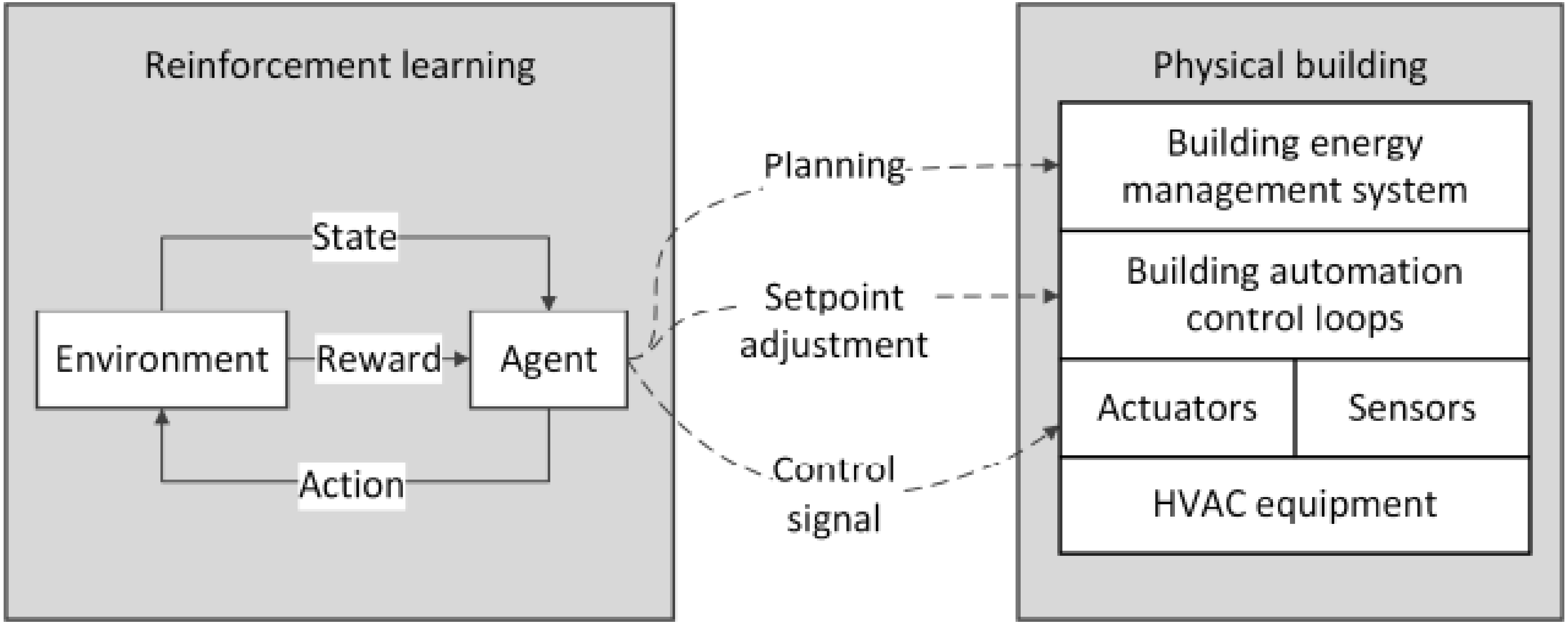


ML application areas at building level

- ML used in multi-objective optimization and predections
- Energy
  - HVAC and lighting
  - Energy storage
  - On-site production
  - Electric cars
- Demand response
  - Electricity; peak power, hourly price, reserve markets
  - Distric heating; peak power, seasonal price
- Neighbourhood level
  - Waste heat utilization



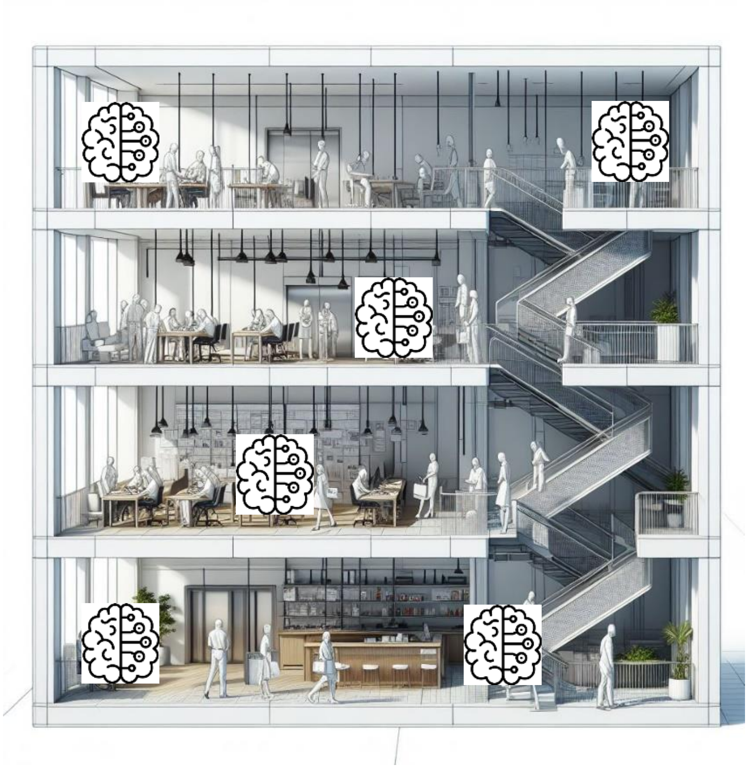
Reinforcement learning

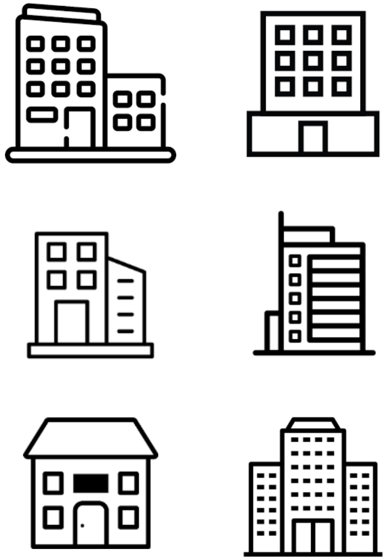


(Source: Sierla et al 2022)

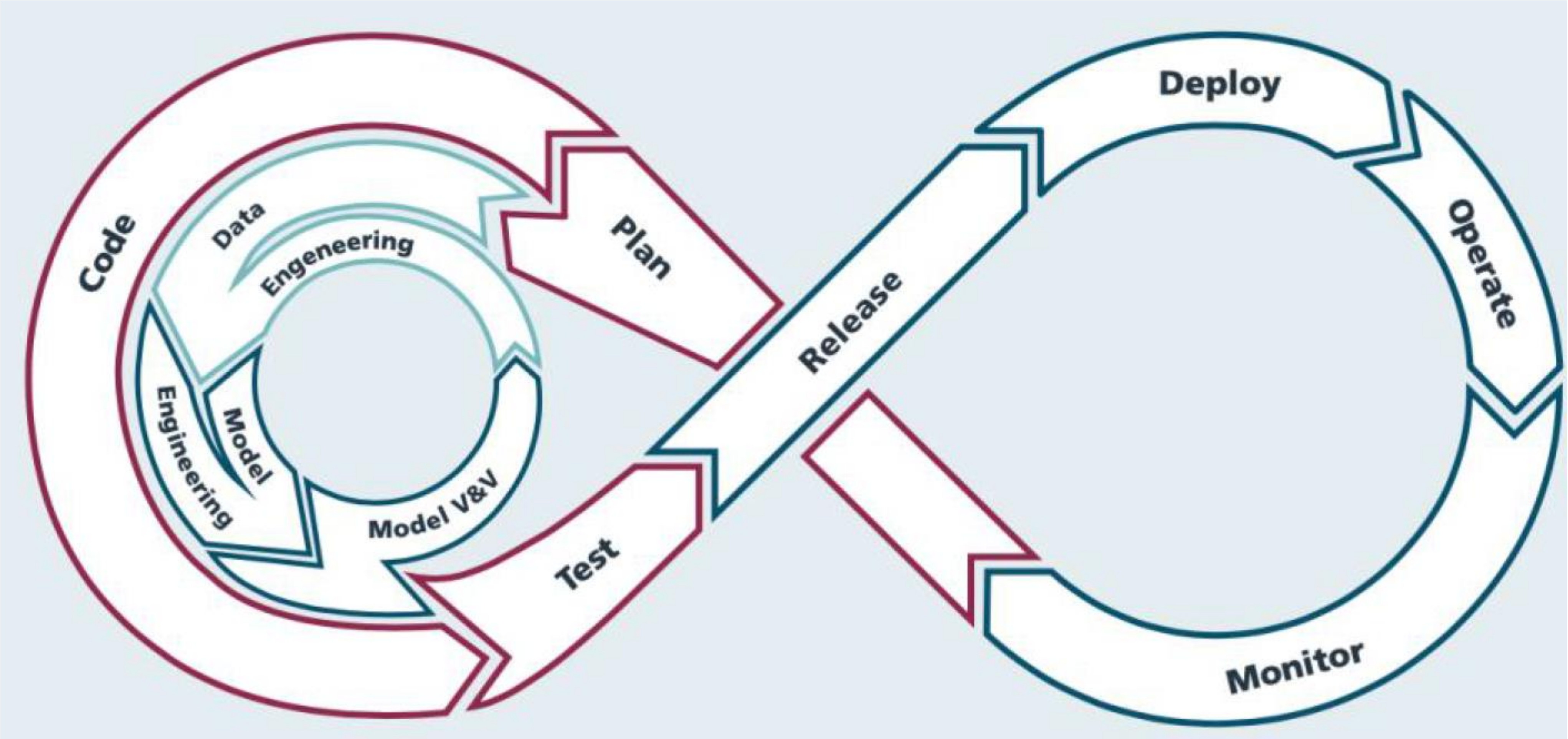
How to manage large amount of different ML models in a changing envinroment?

- Every building is unique
- Different combinations of technical systems
- Tenant changes and renovations
- Usage of building changes





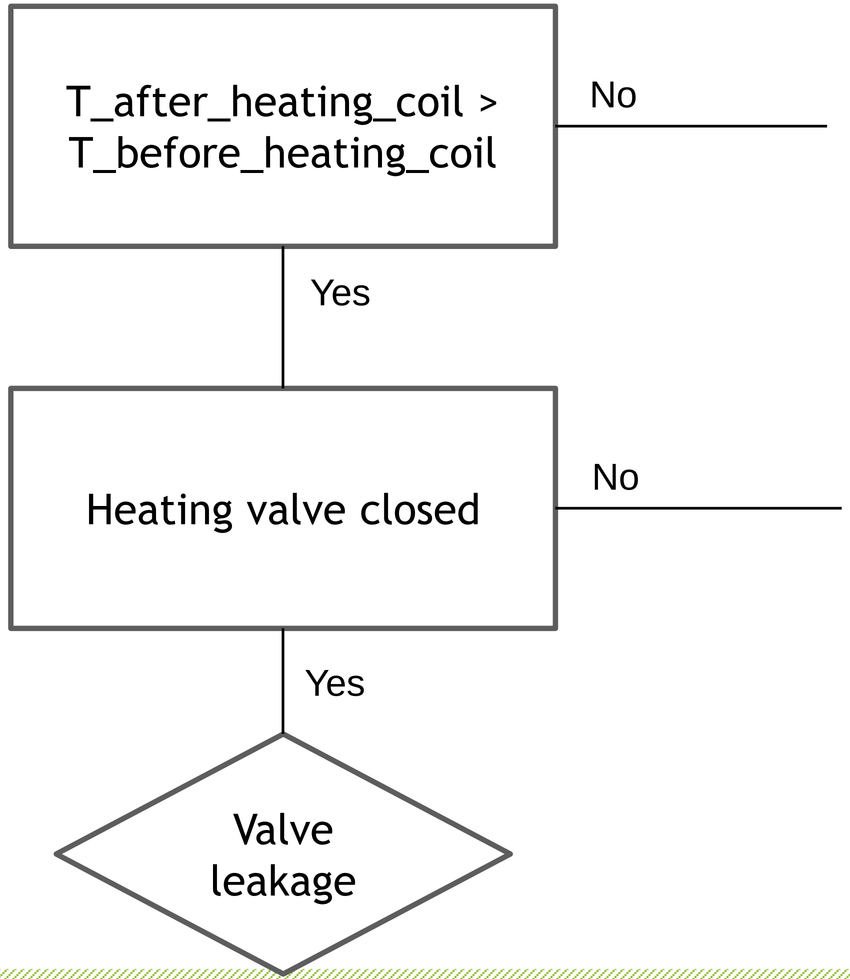
Machine Learning Operations (MLOps)



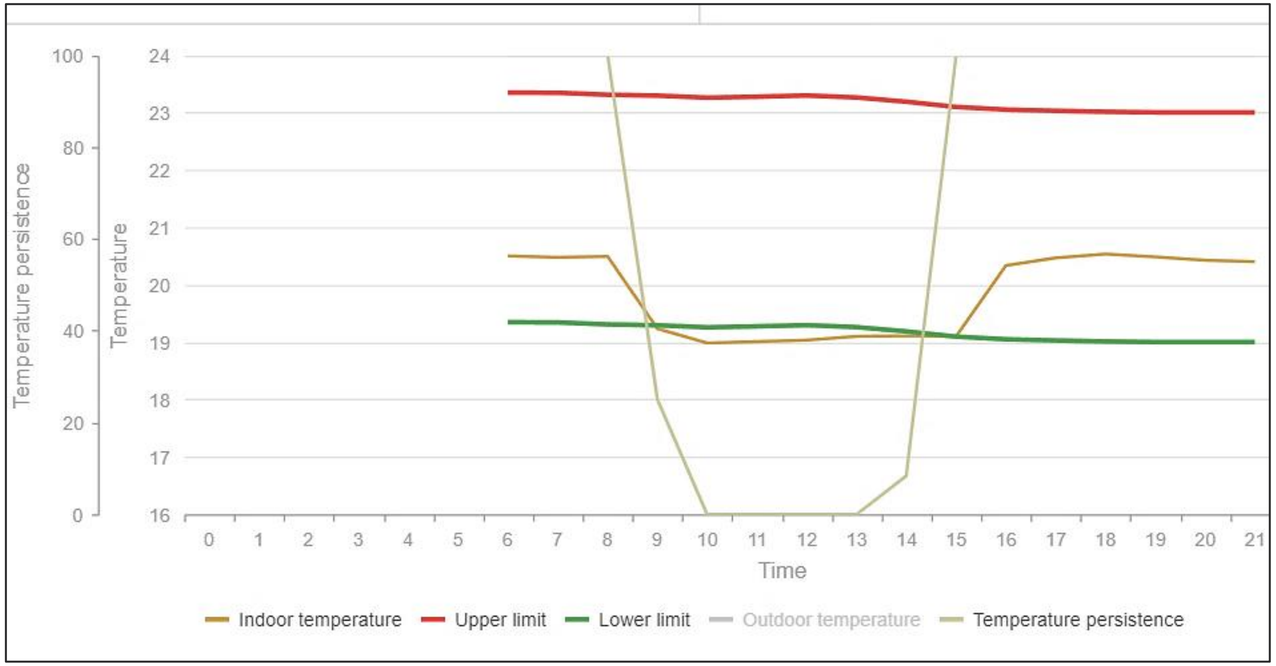
(Source: IML4E)

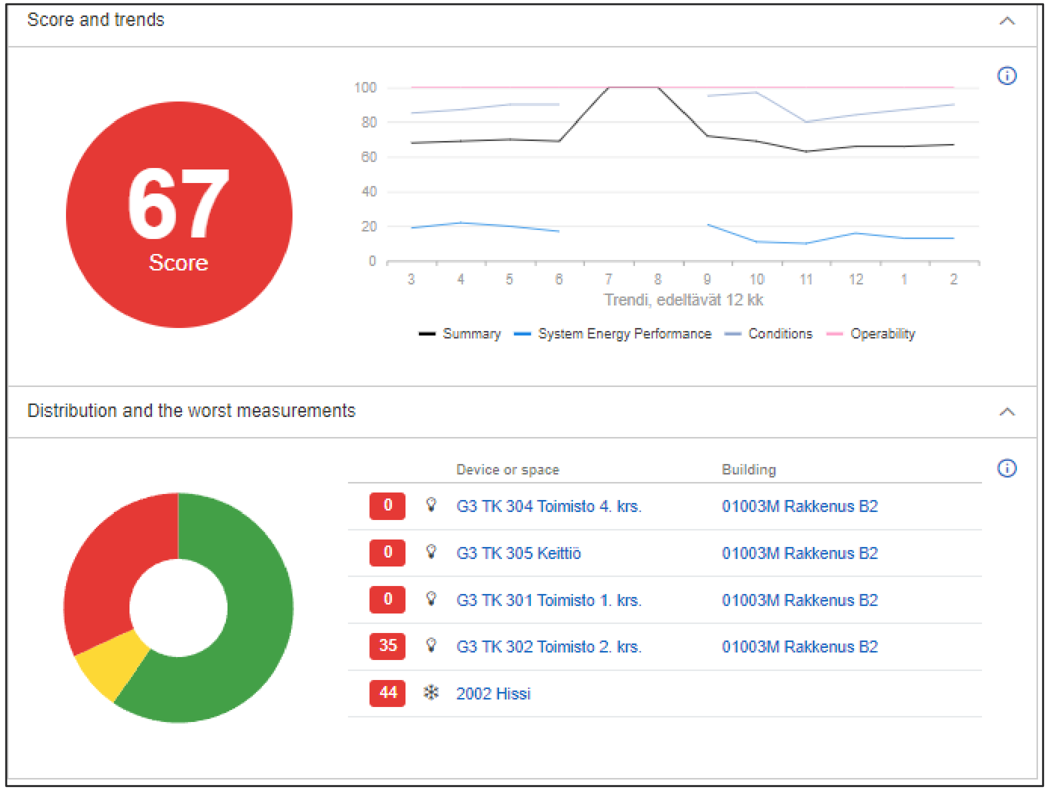
Fault detection and diagnostics (FDD) in buildings

- Background in the 80s
- Approaches
  - Model based
  - Knowledge based
  - Data driven

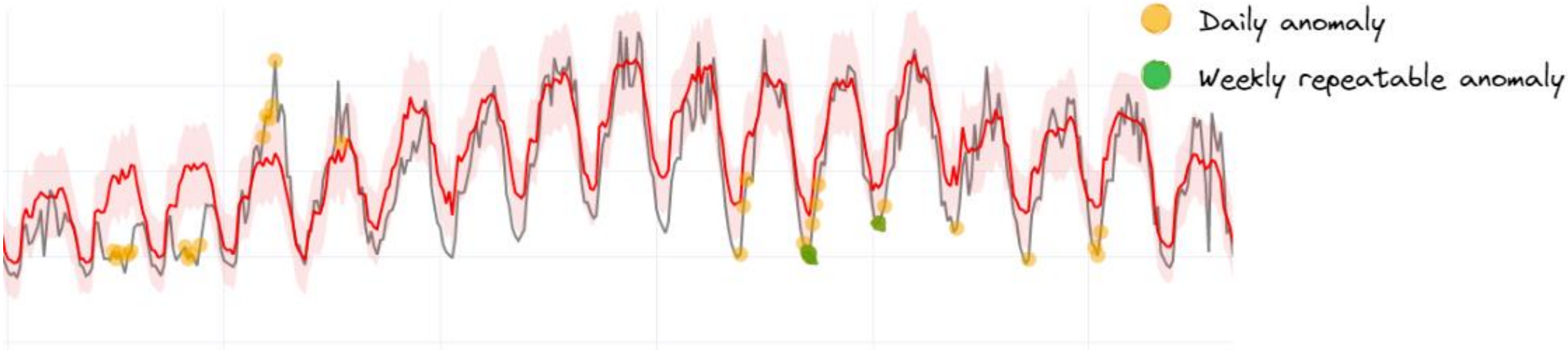


Knowledge based FDD

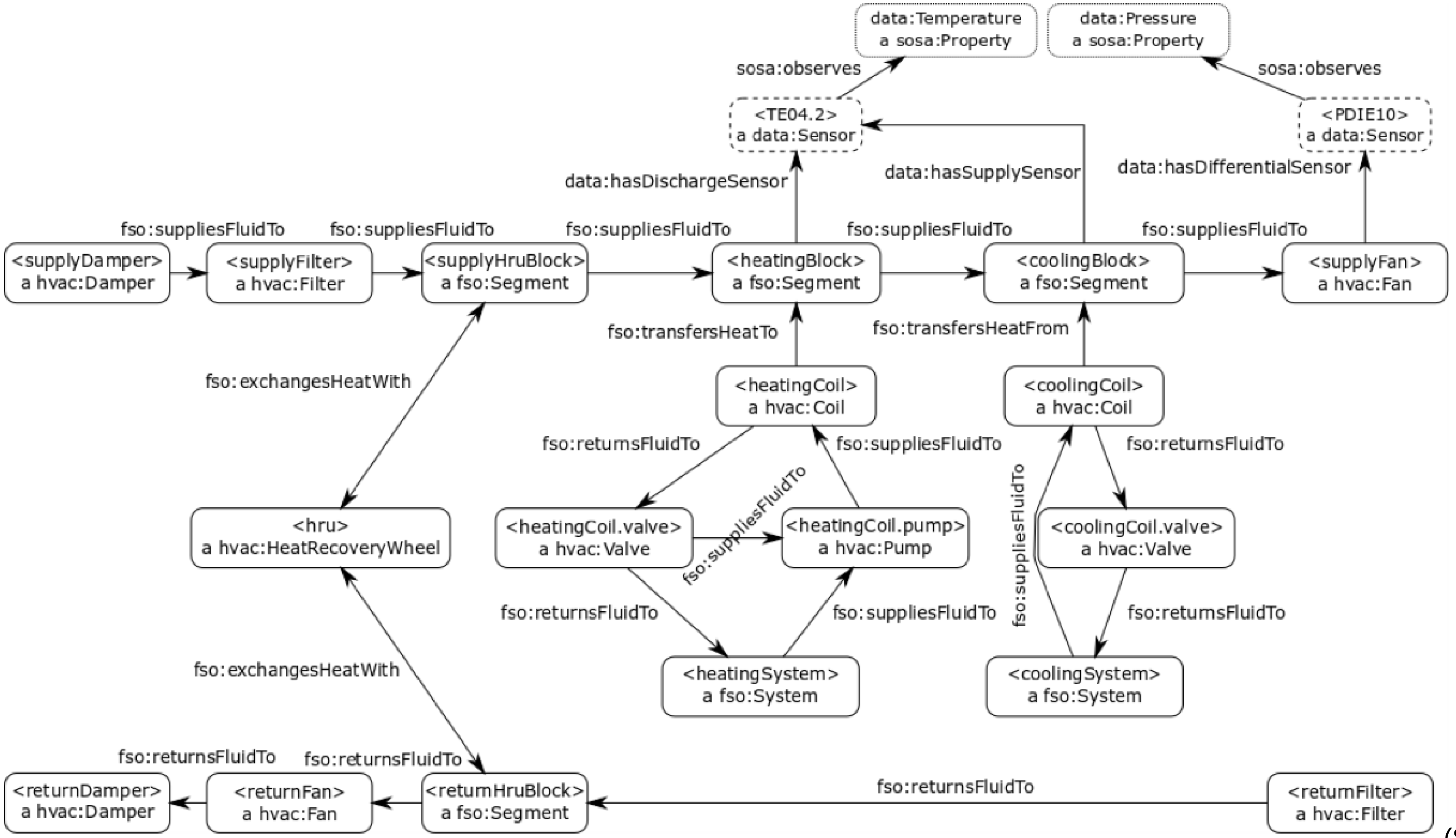




ML in detecting energy consumption anomalies



Ontologies to ease the implementation of FDD



(Source: Kukkonen 2021)

From fault detection to verifying the effects of corrective action

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