

# Fault Analysis Engine for HVAC systems in Commercial Buildings

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## HVAC Maintenance

### ❖ HVAC systems contribute:

- 25%-40% of electricity
- 40%-55% of primary energy

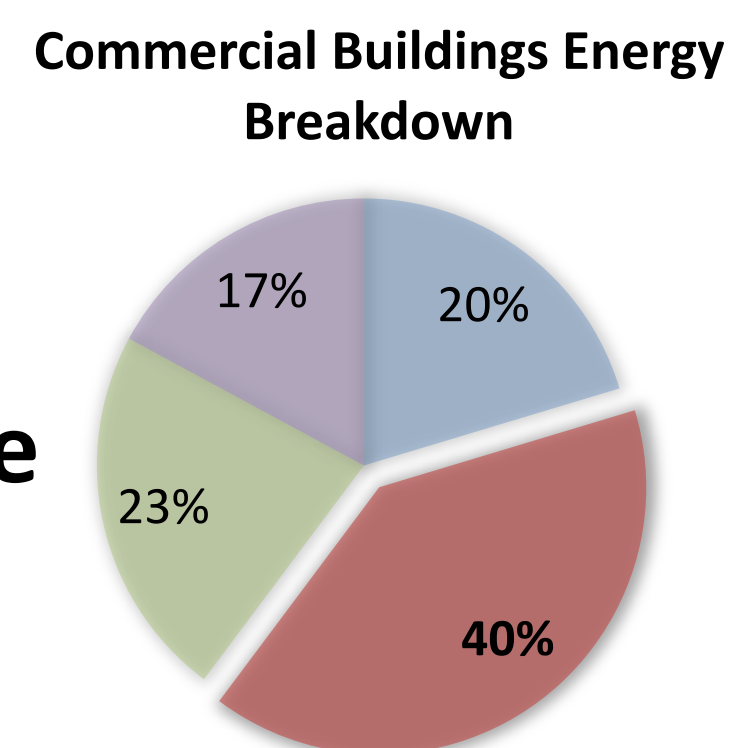
### ❖ Faulty equipment and out of tune system leads to:

- Energy wastage
- Occupant discomfort

**Proper maintenance saves 10%-25% of HVAC energy**

### ❖ Modern fault management systems:

- Are elementary, do not prioritize faults
- Require significant manual analysis
- Not intuitive nor accessible

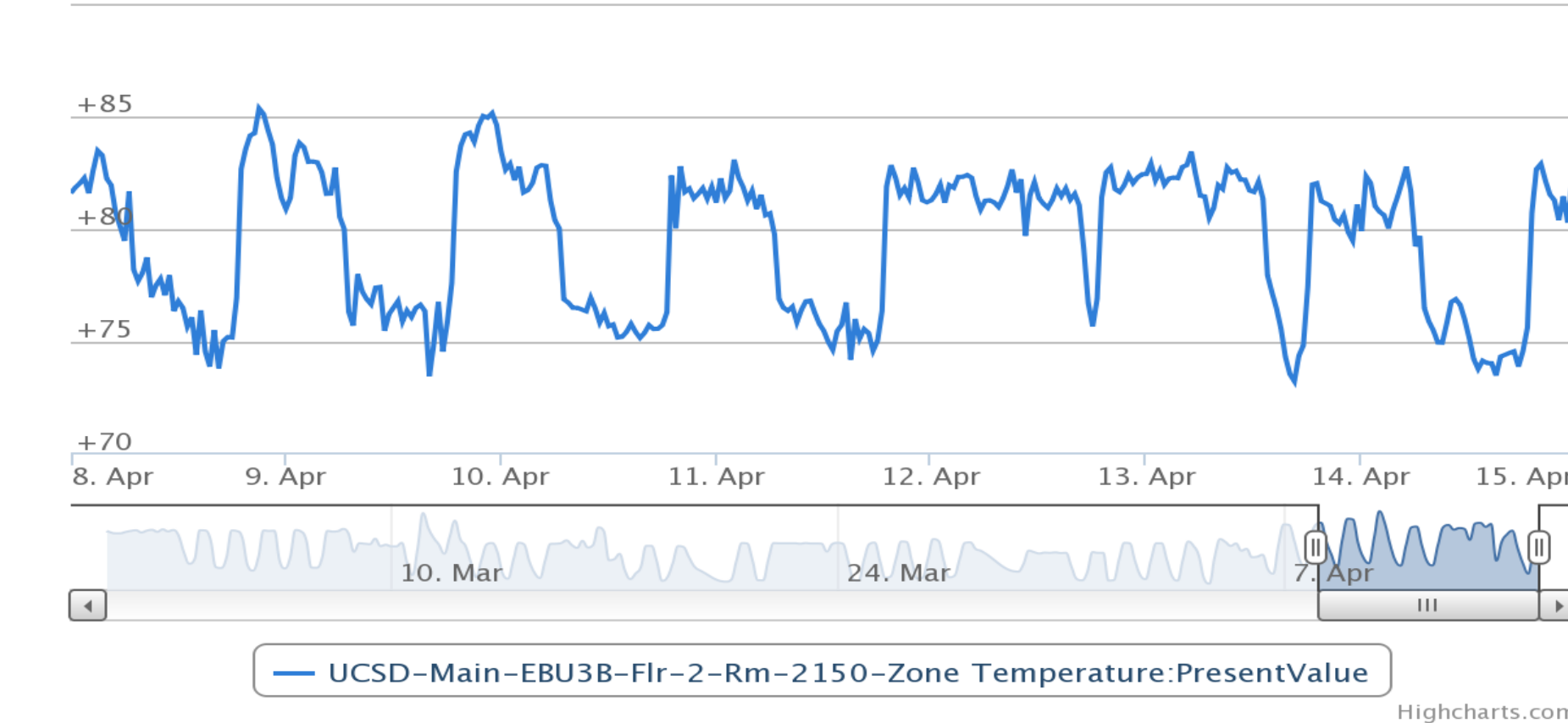


## BuildingSherlock: Faults Dashboard

### ❖ Faults analysis:

- List of faults using data driven analysis
- Possibility score for a fault across different detection algorithms
- Energy wastage estimate for each fault
- Filter faults by category and prioritize faults
- Analyze each fault using historical data

UCSD-Main-EBU3B-Fir-2-Rm-2150-Zone Temperature:PresentValue



### ❖ Subsystem overview:

- Visualization of subsystems with detailed sensor data
- Single click shows equipment details
- Historical trends for each sensor point
- Faults for specific part of the subsystem highlighted



### ❖ Fault algorithms management:

- List of algorithms currently enabled with adjustable threshold
- Fault algorithms flag a group of possible faults based on failure symptom detected
- Detailed analysis of each fault by analyzing corresponding sensor data
- Algorithms which report false faults punished

### ❖ Fault overview:

- Overview of major subsystems in the building
- Breakdown of power by end use
- Highlight major and minor faults
- Single click shows details of subsystem

HVAC Faults Overview

Cooling System	Heating System	Machine Room
Faults(Major): 0	Faults(Major): 0	Alarm(Major): 0
Faults(Minor): 0	Faults(Minor): 0	Alarm(Minor): 1
Electrical Power: 34.1 kW	Electrical Power: 0 kW	Electrical Power: 21.3 kW
Cooling Power: 0.5 MBTU/hr	Heating Power: 0.2 MBTU/hr	Cooling Power: 0.4 MBTU/hr

Basement	1st Floor	2nd Floor
Faults(Major): 1	Faults(Major): 1	Faults(Major): 0
Faults(Minor): 0	Faults(Minor): 0	Faults(Minor): 0
Electrical Power: 24.9 kW	Electrical Power: 1.8 kW	Electrical Power: 2 kW
Cooling Power: 77.1 MBTU/hr	Cooling Power: 6.7 MBTU/hr	Cooling Power: 29.3 MBTU/hr
Heating Power: 0 MBTU/hr	Heating Power: 4.2 MBTU/hr	Heating Power: 5.6 MBTU/hr

3th Floor	4th Floor
Faults(Major): 0	Faults(Major): 0
Faults(Minor): 2	Faults(Minor): 2
Electrical Power: 2.3 kW	Electrical Power: 5 kW
Cooling Power: 38.2 MBTU/hr	Cooling Power: 24.6 MBTU/hr
Heating Power: 0.8 MBTU/hr	Heating Power: 1.7 MBTU/hr

## Faults Analysis

### ❖ Modern buildings centralized management system for HVAC operation and maintenance:

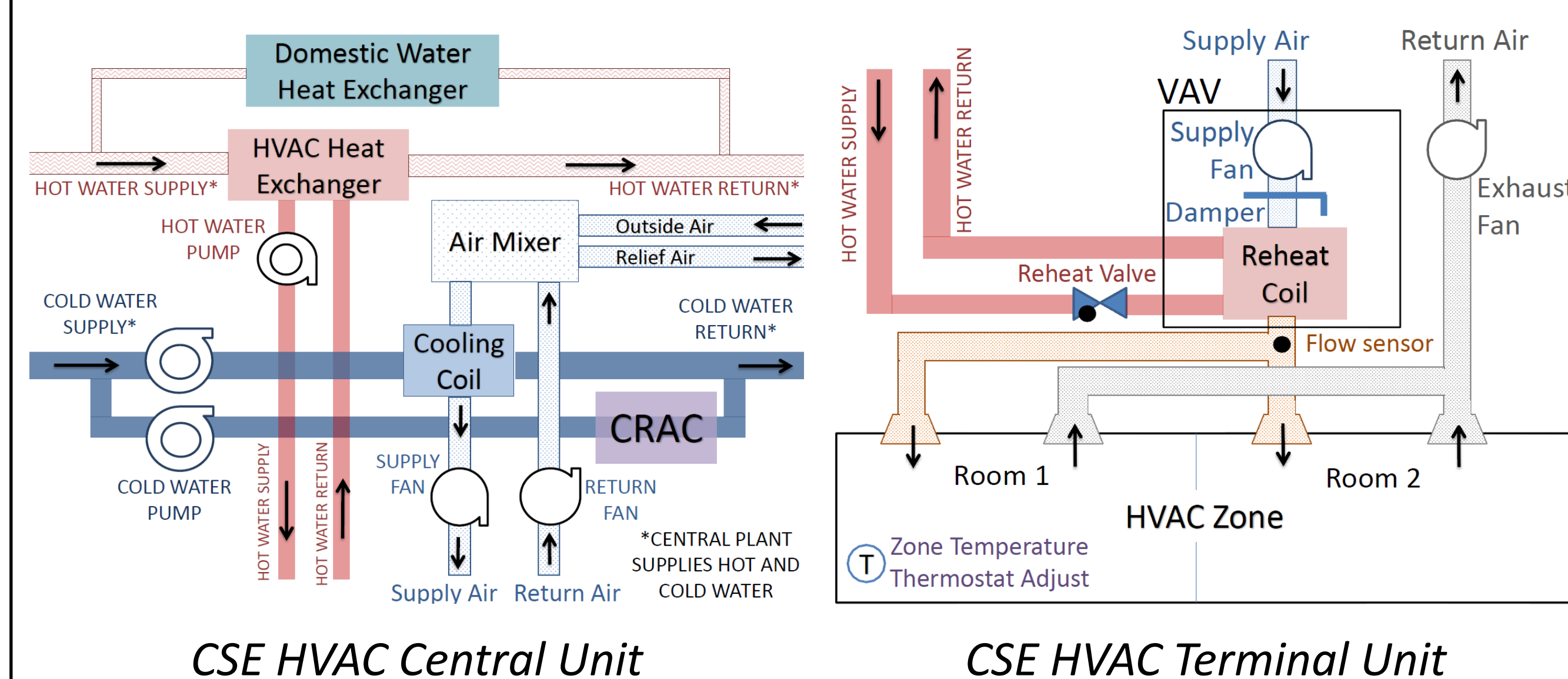
- Thousands of sensors for monitoring and control
- Standardized network protocol – BACnet
- Can be leveraged for data driven faults analysis

### ❖ Fault detection algorithms already exist:

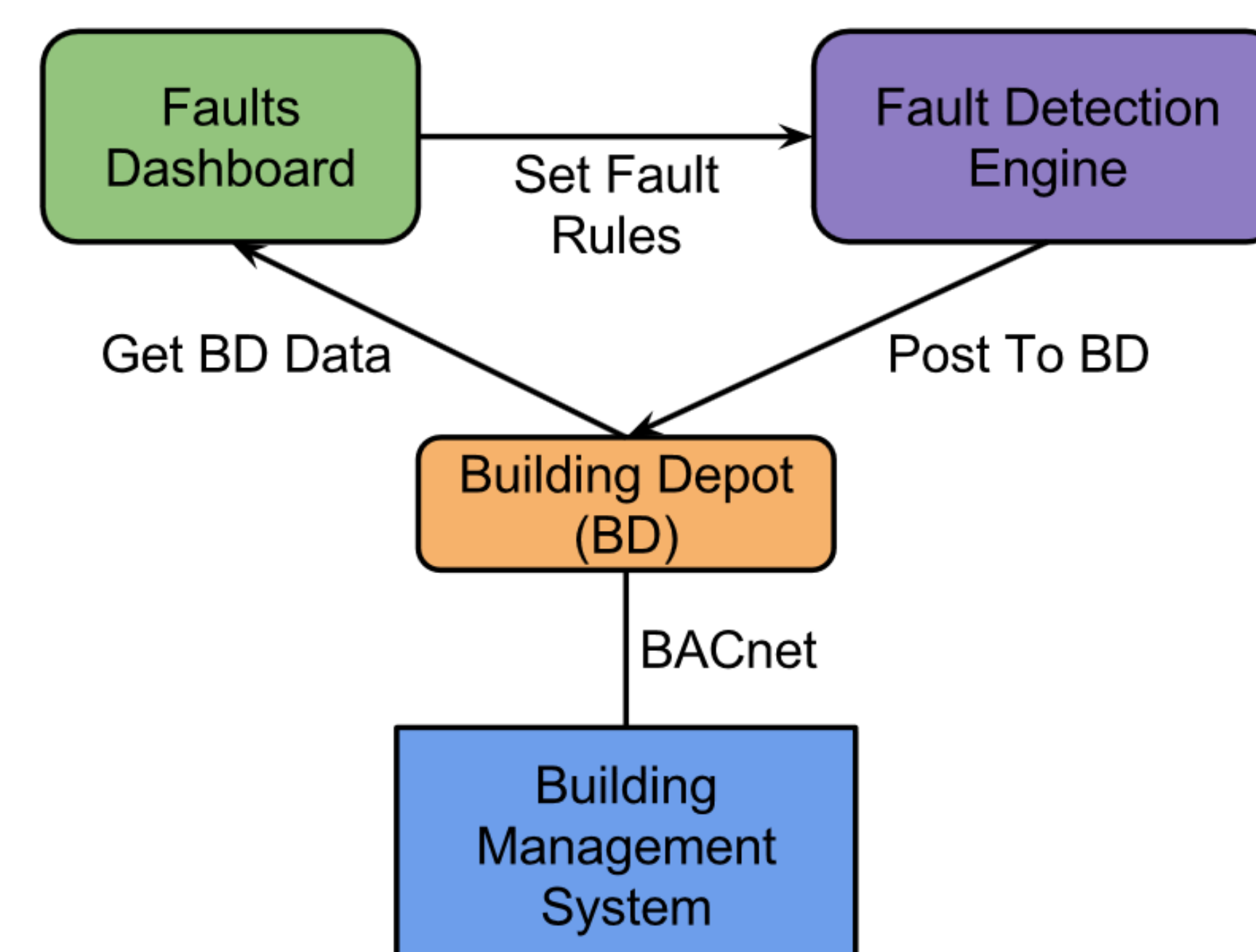
- Rule-based analysis based on HVAC configuration
- Machine learning based black box anomaly analysis

### ❖ Requirements for assisting building manager:

- Faults dashboard for overview of HVAC condition
- Priority list of faults detected using algorithms
- Tools for manual analysis of faults detected



## System Architecture



System Architecture of BuildingSherlock. The system is designed as a RESTful web service for ease of access, application development and scalability

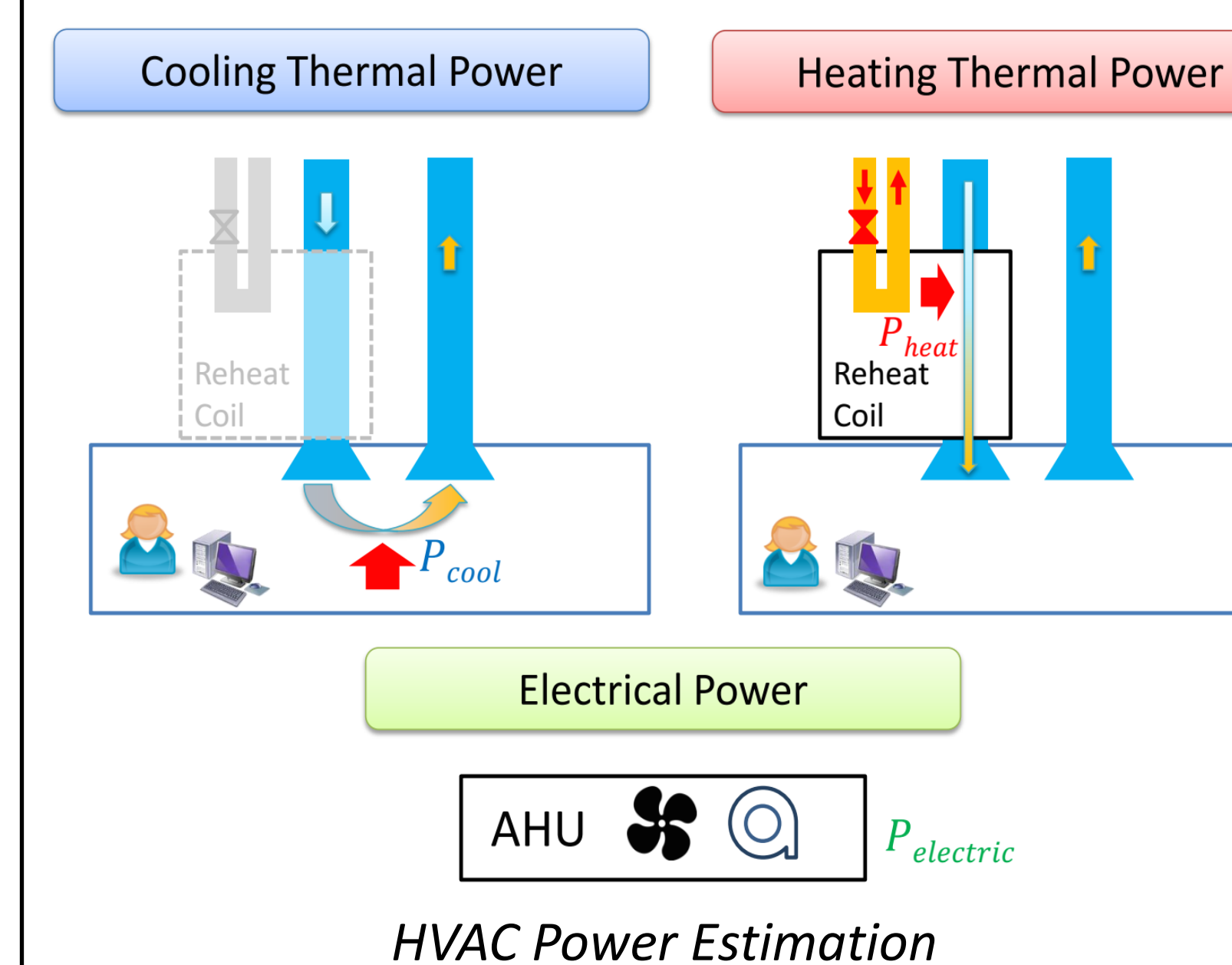
### ❖ Building Depot (BD):

- Datastore for building sensors
- HTTP RESTful APIs
- Data and user management
- Access control and sensor groups
- Scalable to other buildings

### ❖ Fault detection engine:

- Faults registration APIs
- Faults reporting with relevant sensor data
- Algorithms report faults with confidence score
- Weights allotted to algorithms as per success rate

## HVAC Zone Power Estimation



### ❖ Zone power estimation benefits:

- Faults analysis based on end use energy breakdown
- Quantifies savings due to fault repair
- Energy feedback to both facilities and occupants

### ❖ Cooling thermal power:

- Heat transfer equation – uses room temperature, outside temperature and airflow sensors

### ❖ Heating power:

- Reheat valve analysis – uses valve control sensor

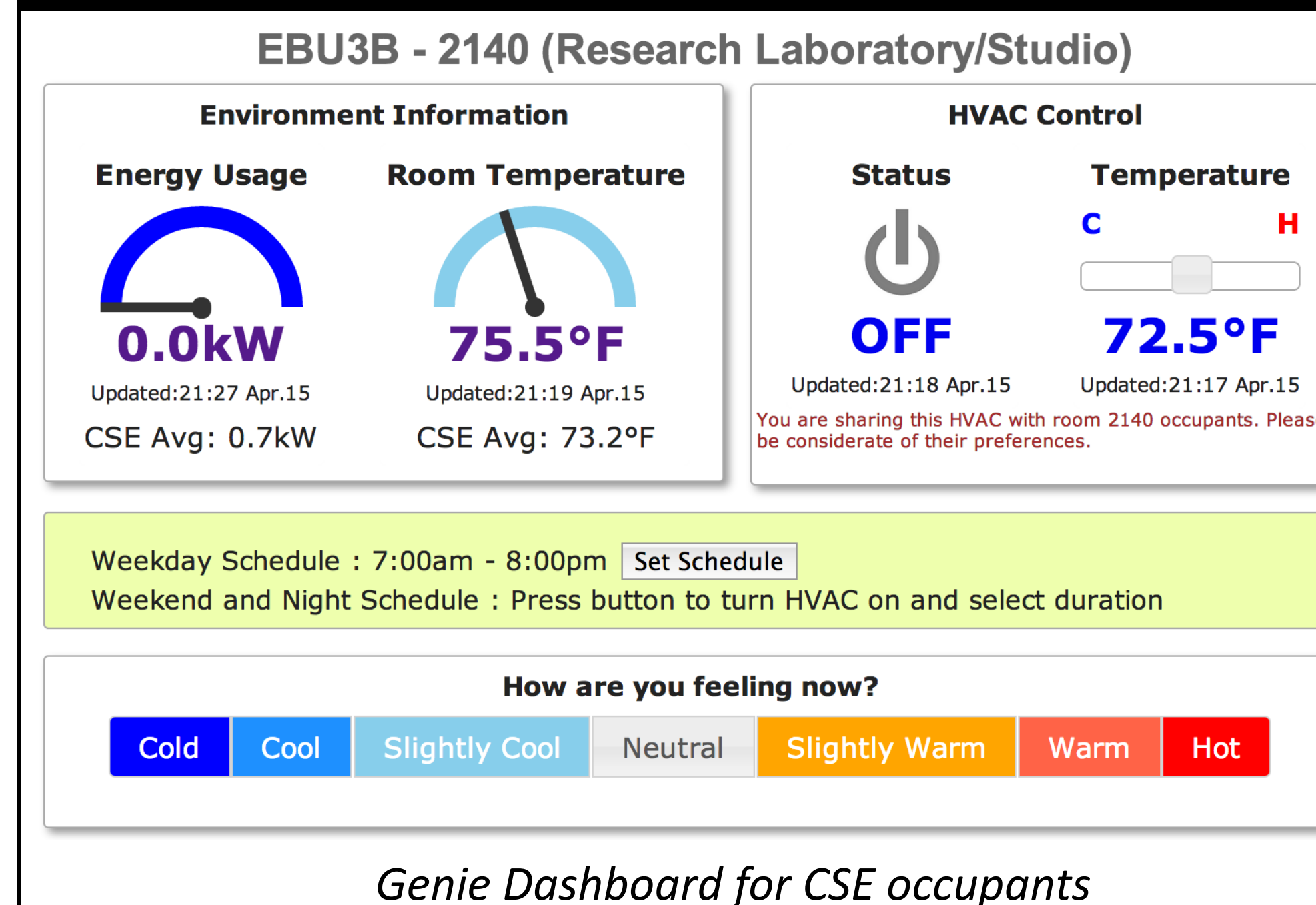
### ❖ Electrical power:

- Proportional to cubic of fan speed. Uses airflow sensor

### ❖ It will provide:

- Feedback on energy savings and wastage
- A single parameter to analyze faults
- Feedback to building managers and occupants

## Genie: Occupant Dashboard



### ❖ Current HVAC status:

- Room temperature
- Estimated power usage, average CSE usage
- Current HVAC settings and schedule
- Historical trends of each sensor point
- Tips to view Genie and save energy

### ❖ Control of HVAC:

- Turn On/Off the HVAC system at zone level
- Change temperature within 6F band
- Thermal feedback (too hot or too cold)
- Send complaint to building manager
- Set personalized schedule