Continuous Monitoring and Real-time Simulation as Support tools for Adaptive Control and Energy Aware Operation

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Challenge of Infection Risk in Hospitals

According to World Health Organization 1 in 31 patients face the challenge of healthcare associated infections (HAIs)

As per the data from the European Center of Disease Prevention and Control 4.3 million patients in hospitals in the European Union are affected by HAIs per year

Spendings of billions of dollar in extra healthcare costs annually

Funded by
the European Union

Current monitoring Situation in Healthcare Settings

Lack of real time monitoring

Conventional HVAC runs on fixed set-points, blind to real pathogen loads or infection risks

Absence of Adaptive control that hinders situational awareness

Energy Intensive Operation

HumanIC

Why the need of Continuous Monitoring?

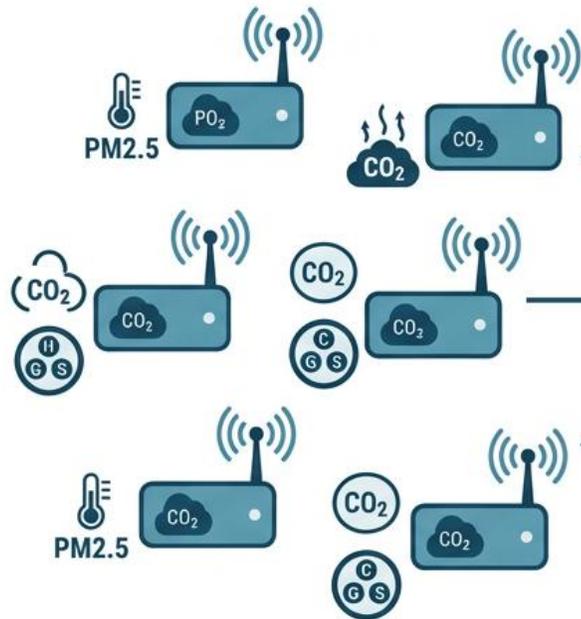Early detection of infection risk

Infection risk responsive control

Energy efficient HVAC control
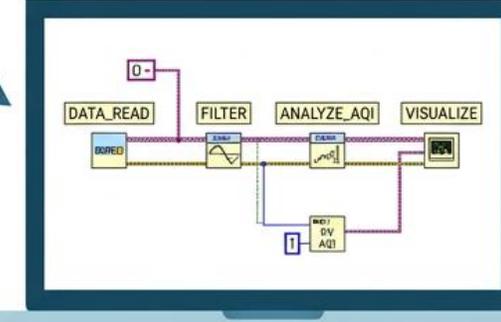
Methodology

IoT-enabled air quality sensors
Advanced sensor technology

ML-based data analytics

IoT Platform

IoT Platform

Advanced sensor technology

LabVIEW control & visualization

Methodology

IoT enabled air quality sensor

Focus on Advanced Sensors

LabView Programming

Machine Learning based data analytics

Funded by
the European Union

Interactive Simulation Tool
An exposure dose and infection risk calculator

Occupancy Data

Air Cleaner data & control

App control

HumanIC

BioEmission Source

active | 1000 Pfu/min

Half-life time (h) 1

PFU / quanta 120

K Factor 0.01

Caughing | C Mult. Factor 10

Sneezing | S Mult. Factor 100

Contaminant Source

Occupants

Present

Nr of Occupants 20

Height (m) 1.7 | Weight (kg) 70

Metabolic Rate 1.2

Air Exchange Rate (h-1) 6

740 G CO2 (g/h)

60000 G (Pfu/h)

AirCleaner ON

Q_Purif (m3/h) 1000

Efic Purif (%) 80

START

Simulation Time (h) 1

STOP

Save to File Yes

CONCLUDE

Use of Mask (Emitter) non active | Mask_Efic (%) 70

Use of Mask (Receiver) active | Mask_Efic (%) 70

Use of Masks

Cini CO2(mg/m3) 680 | Cext CO2(mg/m3) 680

C ini (Pfu/m3) 0 | Cext (Pfu/m3) 0

Initial & Outdoor Concentrations

Q fresh air (m3/h) | Room Vol (m3) 150

900

Fresh Air Flow Rate

Speed of simulation

Concentration (Pfu/m3) 33

Time Evolutions of Doses

Dose with Mask (Pfu) 1882 | Dose no Mask (Pfu) 6274

Conc CO2 (ppm) 834 | Conc CO2 (mg/m3) 1500

Infection Risk (%)

No Mask@Rcv 41

Mask@Rcv 15

Infection Risk Sliders

Statistical Data | Avg | Max | Mini | Std Dev

C (Pfu/m3) | 39.9 | 57.7 | 1.11 | 11.8

C (mg/m3) | 1368 | 1500 | 694 | 192

Statistical Descriptors Data

Data saved in | C:\Simulation_Logs\ test_20250501_222000_150_1000_1000_6.00_.txt

Path of Recorded Data File

Time Evolutions of Concentrations

Simulator of the Time Evolution of the Mean Concentration of a BioContaminat and CO2 in an Uni-Zone Indoor Enclosure - Exposure Dose and Infection Risk Calculator

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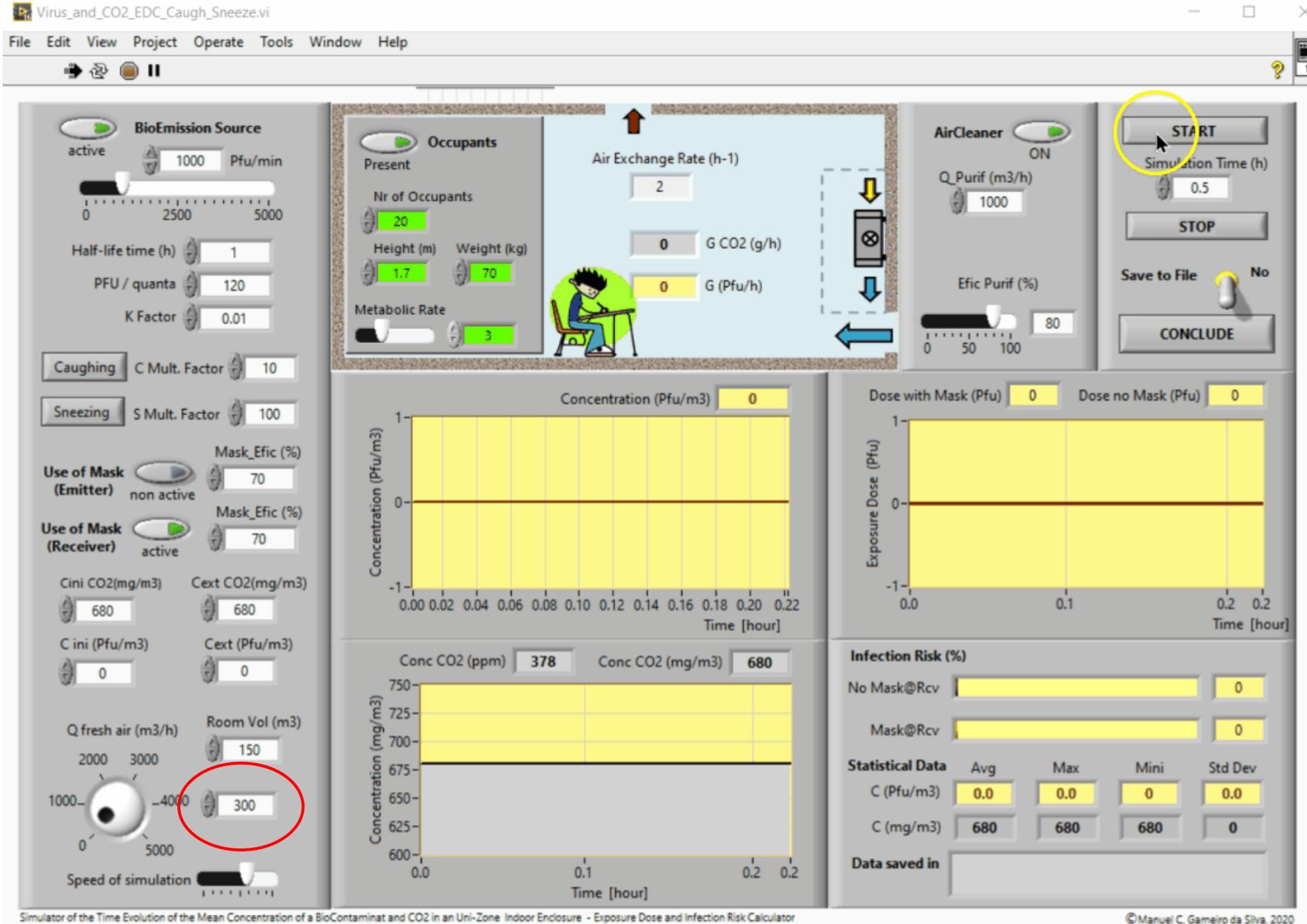
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Effect of the use of mask by the emitter
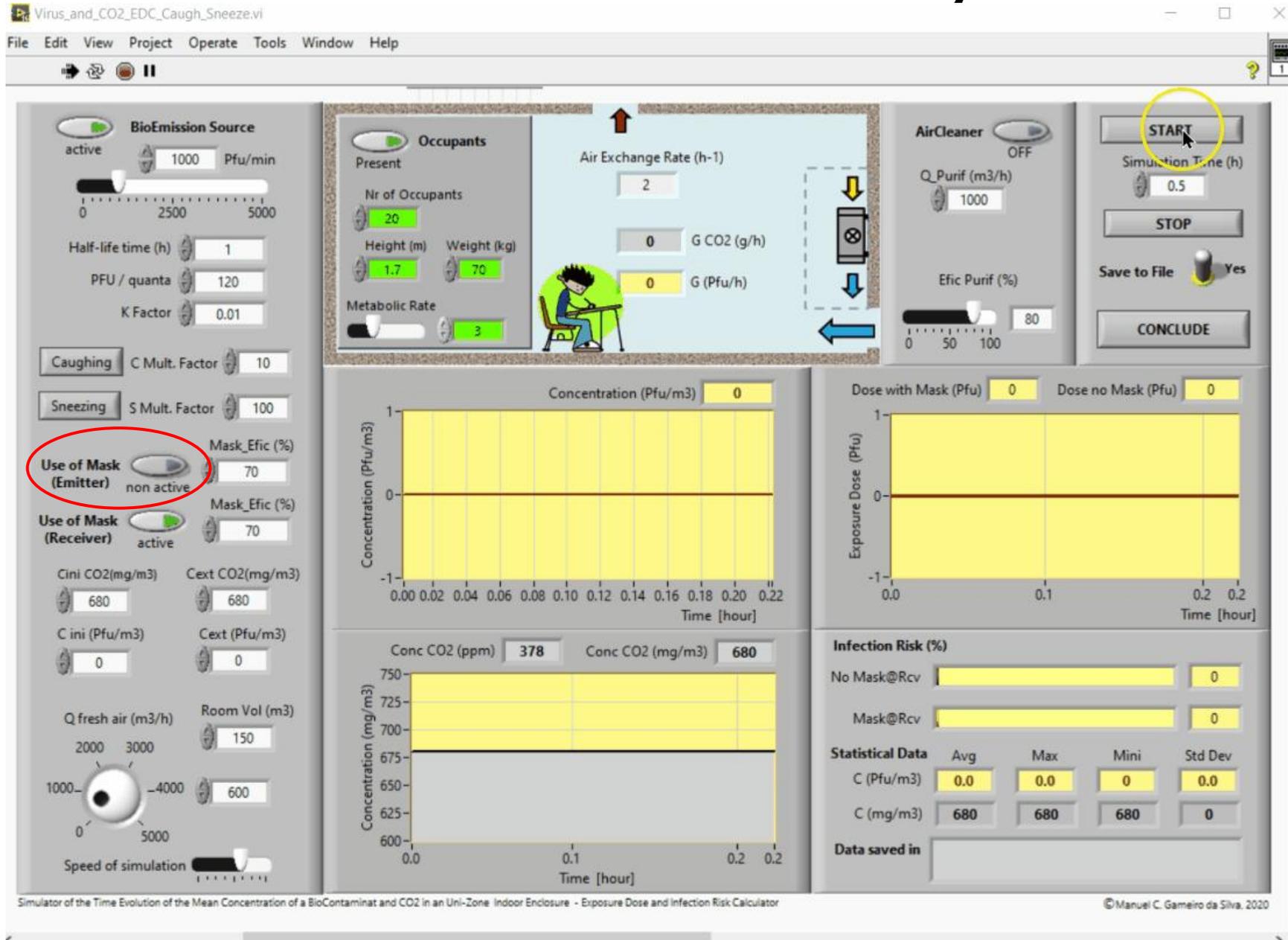
After 0.25 hours, the Emitter starts wearing a Mask

Effect of air exchange rate variation

After 0.25 hours, the fresh air flow rate changes from 300 m³/h to 900 m³/h.

Air exchange rate changed from 2 to 6 renews per hour, since the room volume is 150 m³.

Effect of the use of an air cleaner

After 0.25 hours, the Air Cleaner is switched on.

Effect of coughing and sneezing events

Coughing and Sneezing events are simulated

Increase in the Metabolic Rate of Receivers

After 0.25 hours, the Metabolic Rate of Receivers changes from 1.2 to 3.0

Multiple Actions

The effects of multiple actions are visualized along 1 hour

Adaptive Control

- Control policies adjust HVAC and air-cleaning parameters based on real-time risk.

- Feedback from sensors and digital twin replaces fixed worst-case set-points.

- Controllers learn dynamics over time and update models and thresholds.

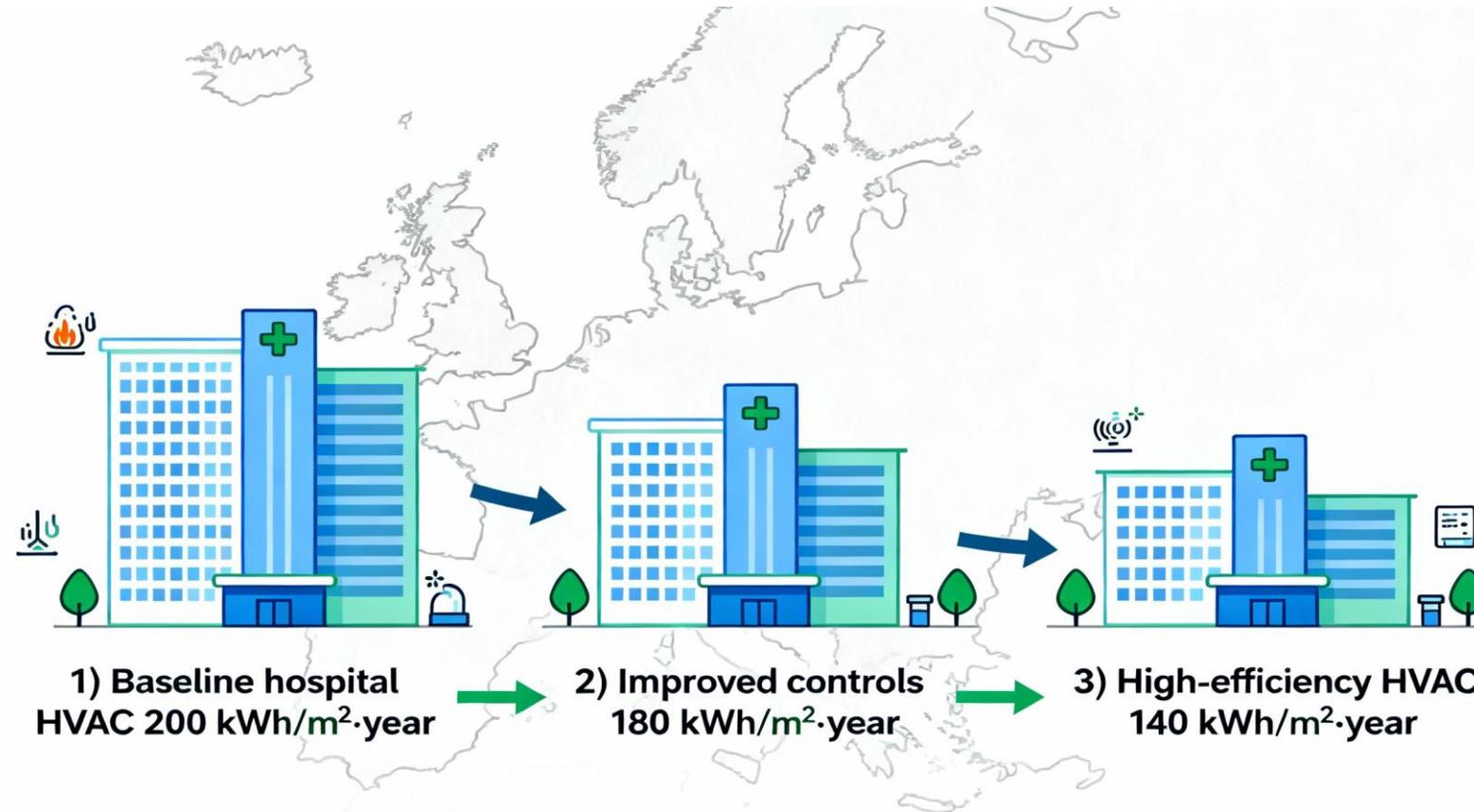- Objective: maintain infection risk below target while minimizing energy use.
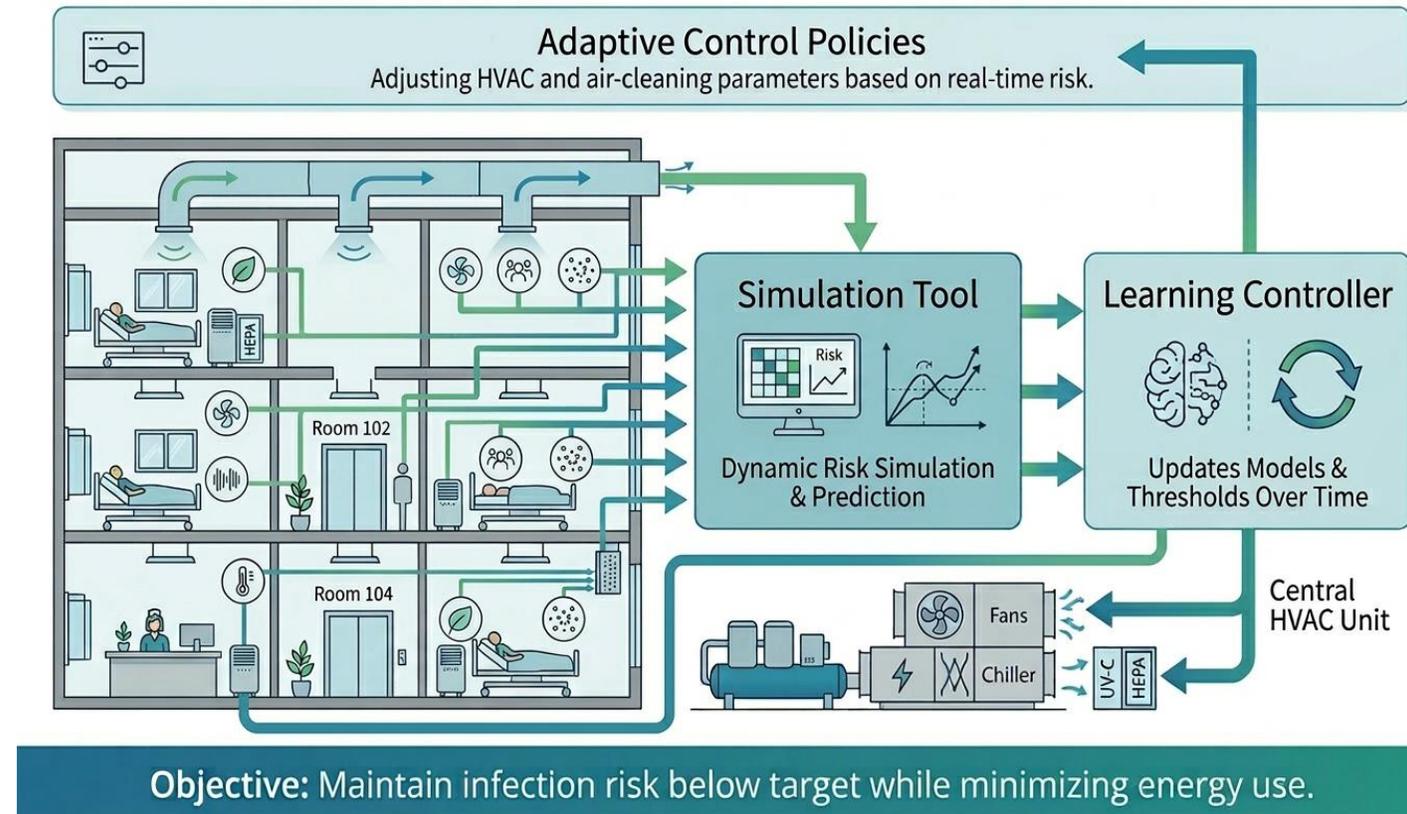
Example Adaptive Control Workflow

- Sensors detect rising CO_2 / aerosol counts in a treatment area.

- Simulation tool predicts airborne pathogen concentration

- Controller selects higher ACH and filtration mode to keep risk below threshold.

- When risk drops, system returns to energy-efficient baseline settings

Energy Efficiency and Demand Response

1) Baseline hospital HVAC 200 kWh/m²·year → 2) Improved controls 180 kWh/m²·year → 3) High-efficiency HVAC 140 kWh/m²·year

Integration in Healthcare Workflows

- Demand Responsive HVAC control.

- Dashboards for staff with live risk maps and alerts.

- Facility management interfaces to supervise control actions and overrides.

- Protocols that link environmental alerts to clinical actions.

- Data logs for audit, compliance and post-event investigation of outbreaks.

Thank you