



Energy Efficiency Challenges in hospital HVAC systems

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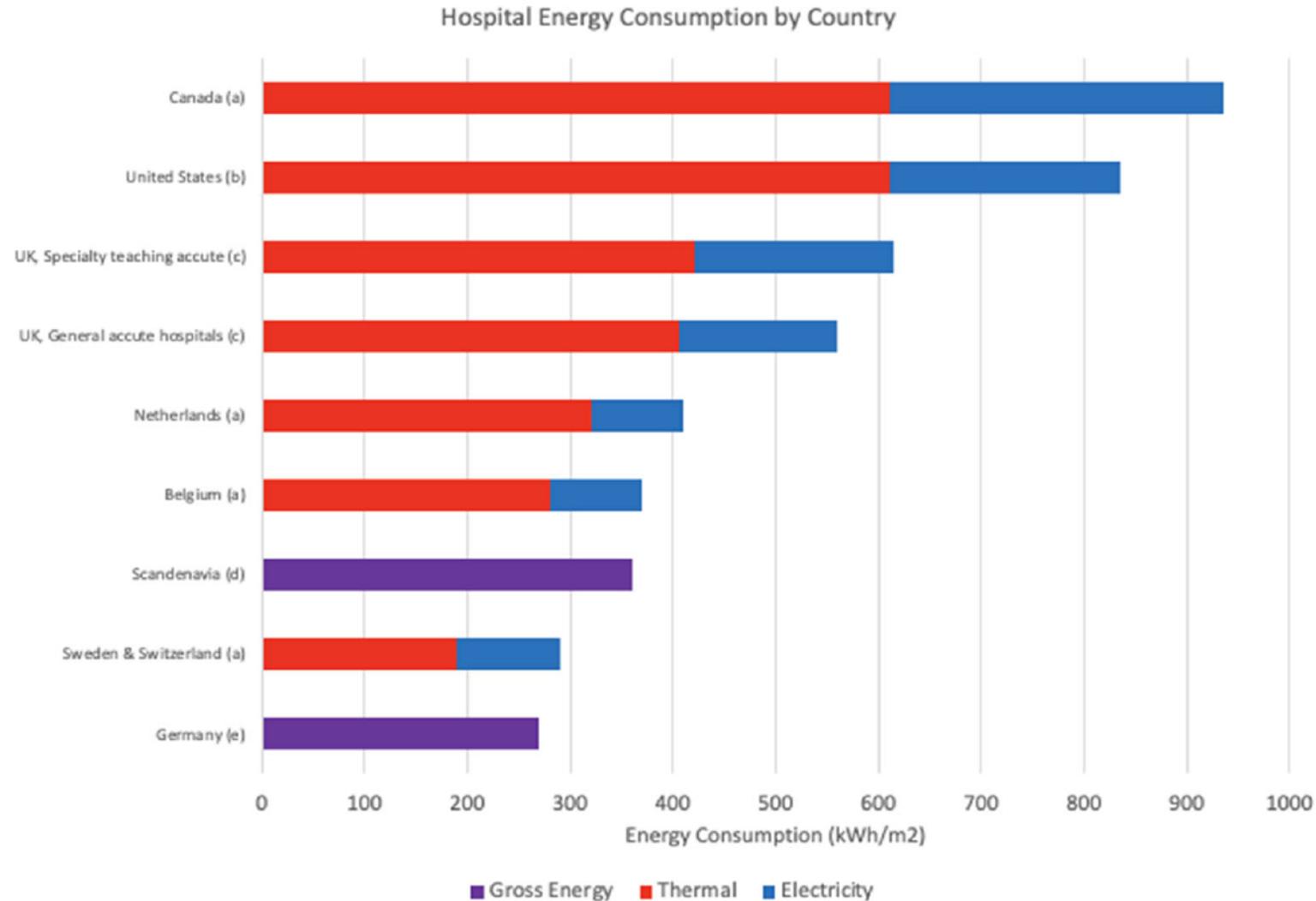


Why hospitals belong to the most energy-intensive building types?

Hospitals can consume up to **2–3 times more** energy than typical commercial buildings.



Why hospitals belong to the most energy-intensive building types?



Hospitals in EU can consume up to 400 kWh/m² of energy per year !



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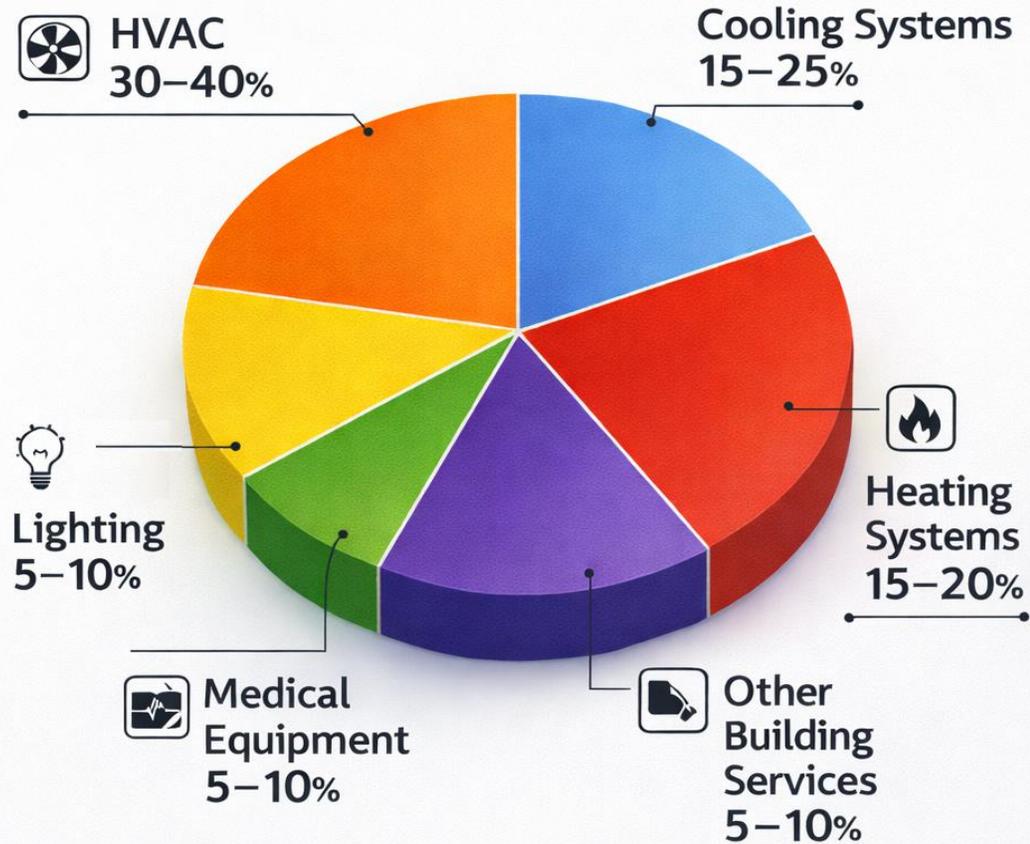


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Why hospitals belong to the most energy-intensive building types?



Typical Energy Distribution in Hospitals





Why hospitals belong to the most energy-intensive building types?

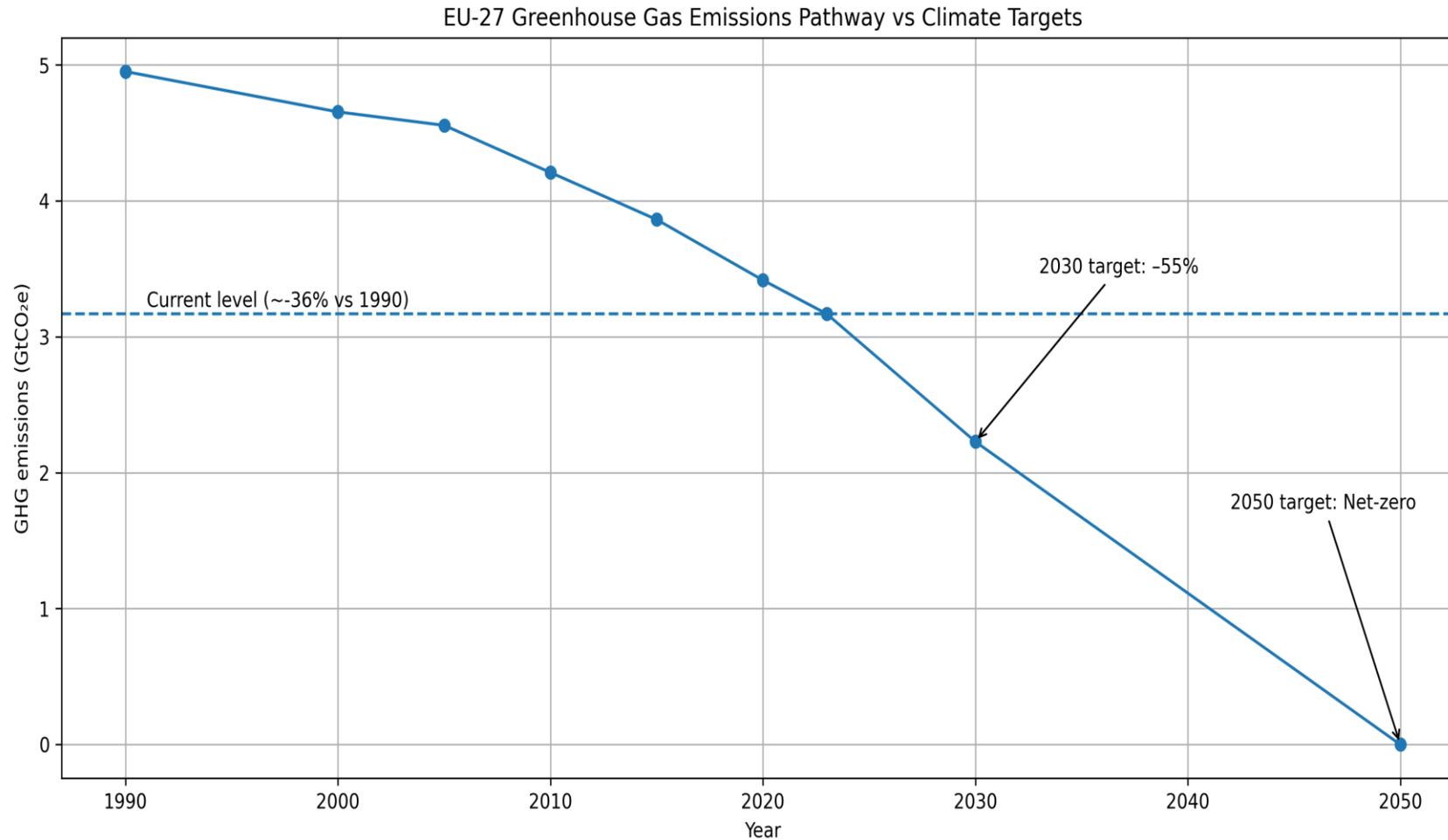
1. Hospitals operate 24 hours a day, 365 days a year
2. Indoor conditions must be continuously and strictly controlled to ensure:
 - patient safety and treatment
 - performance of medical procedures
 - infection prevention
 - proper operation of medical equipment and medical staff
3. Energy interruptions are not acceptable
4. Systems are designed for worst case conditions/scenarios
5. Redundancy and backups systems are in place but rarely in use
6. Reliability is often over efficiency and flexibility
7. The workload of patient's volume and medical procedures fluctuates over time.





Why hospitals belong to the most energy-intensive building types?

With high energy usage are hospitals possible to reach climate goals?





Ventilation systems as major contributors to energy consumption

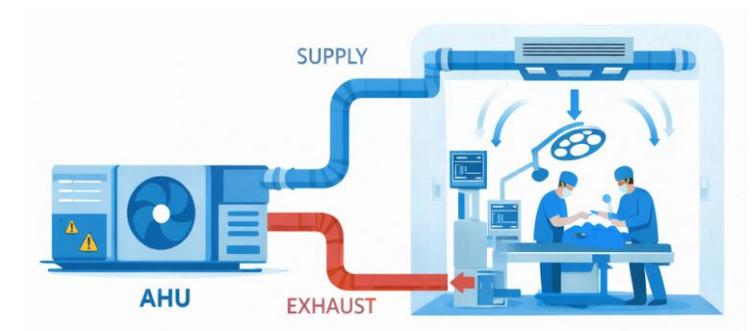
Key drivers of energy demand in hospital ventilation systems:

1. High ventilation rates:

- infection control requires 6–25 air changes per hour (ACH)
- large airflow rates increase air flow volumes and fan power demand

2. Intensive air preparation to maintain strict indoor parameters:

- temperature control
- humidity control
- cooling and dehumidification in summer
- heating and humidification during winter
- covering heat losses or gains from peoples and equipment



Ventilation systems as major contributors to energy consumption

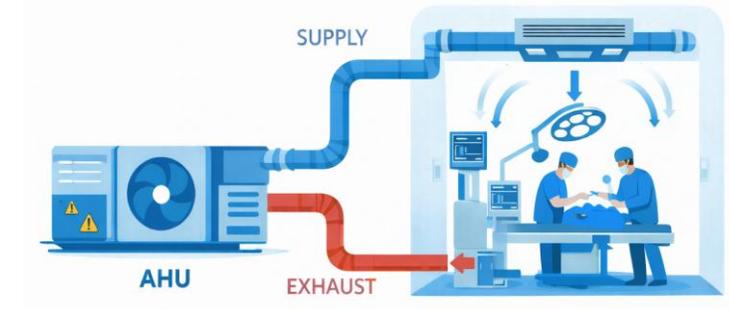
Key drivers of energy demand in hospital ventilation systems:

3. High pressure losses in ventilation systems:

- multi-stage filtration
- HEPA filters (H13/H14)
- complex and long duct networks
- increased pressures demand causes high fan energy consumption

4. Room pressurization requirements

- positive pressure (e.g. operating rooms)
- negative pressure (e.g. isolation rooms)
- typical pressure differences: $\pm 5 - 15$ Pa
- maintaining pressure balance requires continuous airflow control.



Ventilation systems as major contributors to energy consumption

Typical Ventilation Parameters in Hospital Spaces

Space type	ACH (Air Changes per Hour)	Temperature	Relative Humidity	Pressure relationship	Filtration
Operating room (OR)	20–25 ACH	20–24 °C	40–60 %	Positive (+5–15 Pa)	HEPA H13 / H14
Isolation room (AIIR)	≥12 ACH	21–24 °C	30–60 %	Negative (–5 to –15 Pa)	HEPA exhaust filtration
Intensive Care Unit (ICU)	6–12 ACH	21–24 °C	40–60 %	Neutral or slight positive	High efficiency filters
Patient room	4–6 ACH	21–24 °C	30–60 %	Neutral	Standard hospital filtration

LAF
Laminar Airflow



MV
Mixed Ventilation



TcAF
Temperature-controlled Airflow





Ventilation systems as major contributors to energy consumption

Different countries – different demands, different norms, different practices

Country / Document	Operating Room Class	Particle Count $\geq 0.5 \mu\text{m}$ (n/m ³)	Filtration Stages	Air Velocity (m/s)	Overpressure (Pa)	Air Changes (n/h)	Supply Type	Temperature (°C)	Humidity (%)
DE [1]	1a	According to ISO 5	F7–F8/F9/ HEPA H13	Not specified	Positive pressure required (range not specified)	300 in protected zone	UDF	19–26	30–65
	1b	According to ISO 7	F7/F9/ HEPA H13	Not specified	–	20–25	MV	19–26	30–65
ENG [2]	Ultra Clean (UCV)	≤ 10	F5/F9/ HEPA H14	0.38–0.54	15–20	22 (low-speed mode)	UDF	18–25	35–60
FR [3]	4	According to ISO 5 and ISO 7	F5/F9/ HEPA H14	0.25–0.35	15 \pm 5	≥ 6 fresh air changes under supply zone	UDF	19–26	–
	3	According to ISO 5 and ISO 7	F5/F9/ HEPA H13	–	15 \pm 5	≥ 15	UDF or MV	19–26	–
ES [4]	Class I	Reference to ISO 5 and ISO 7	F5/F9/ HEPA H13	0.25–0.35	10–15	15–30	UDF	22–26	45–55
PL Guidelines [5]	S1a	According to ISO 5	G4 / F7 / F9 / HEPA H13–H14	0.20–0.30 (1.2 m above floor)	≥ 10	≥ 25	LAF	19–23	30–65
	S1b	According to ISO 5	G4 / F7 / F9 / HEPA H13–H14	0.18–0.25 (1.2 m above floor)	≥ 10	≥ 25	LAF	19–23	30–65
	S1c	According to ISO 7	G4 / F7 / F9 / HEPA H13–H14	0.15–0.25 (1.2 m above floor)	≥ 10	≥ 25	MV	19–23	30–65
CEN EU [6],[7]	CL-1a	According to ISO 5	F7/F9/ HEPA H13	0.24–0.45	≥ 5 between rooms	≥ 25	UDF	18–26	<60
	CL-1b	According to ISO 5	F7/F9/ HEPA H13	0.10–0.15	≥ 5 between rooms	≥ 15	MV	18–26	<60
	CL-2	According to ISO 7	F7/F9/ HEPA H13	0.10–0.15	≥ 5 between rooms	≥ 10	MV	18–26	<60
R3 Nordic [8]	CL1	According to ISO 5	F7–F8/F9/ HEPA ISO 35H	0.25–0.45	≥ 10	≥ 12 in protected zone	UDF or MV	18–26	<60
	CL2	According to ISO 7	F7–F8/F9/ HEPA ISO 35H	Mixing dependent	≥ 10	≥ 24	MV	18–26	<60
USA ASHRAE [9]	Class I	≤ 3520 (ISO 5 equivalent)	MERV 7, MERV 14, HEPA H13–H14	0.18–0.25	≥ 2.5	≥ 20	LAF	20–24	20–60

Opportunities for energy optimization without compromising safety

Steps for Improving Energy Efficiency in Hospitals

1 User demand & Behaviour

zzZ
21°C

2 Reduce Energy Demand

Insulation → Variable air volume → LED light → Monitoring

3 Apply Sustainable & Energy Sources

Solar panels Wind turbines Biomass power

4 Energy Exchange & Storage

Underground → Battery buffer → Energy exchange

5 Efficient use of fossil energy

Boilers Chillers Heat pumps Cogeneration

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Opportunities for energy optimization without compromising safety

Key strategies for improving energy efficiency in hospital HVAC systems:

1. Energy recovery technologies

- heat recovery from exhaust air
- plate, twin-coil, rotary heat exchangers
- air recirculation

2. Variable Air Volume (VAV) systems adjusted to:

- occupancy
- operational mode
- indoor air quality
- stand-by and reduction of fresh air

3. High-efficiency system components

- low-pressure-drop filters
- high-efficiency EC fans, fan walls
- optimized duct design
- energy-efficient chillers and heat pumps

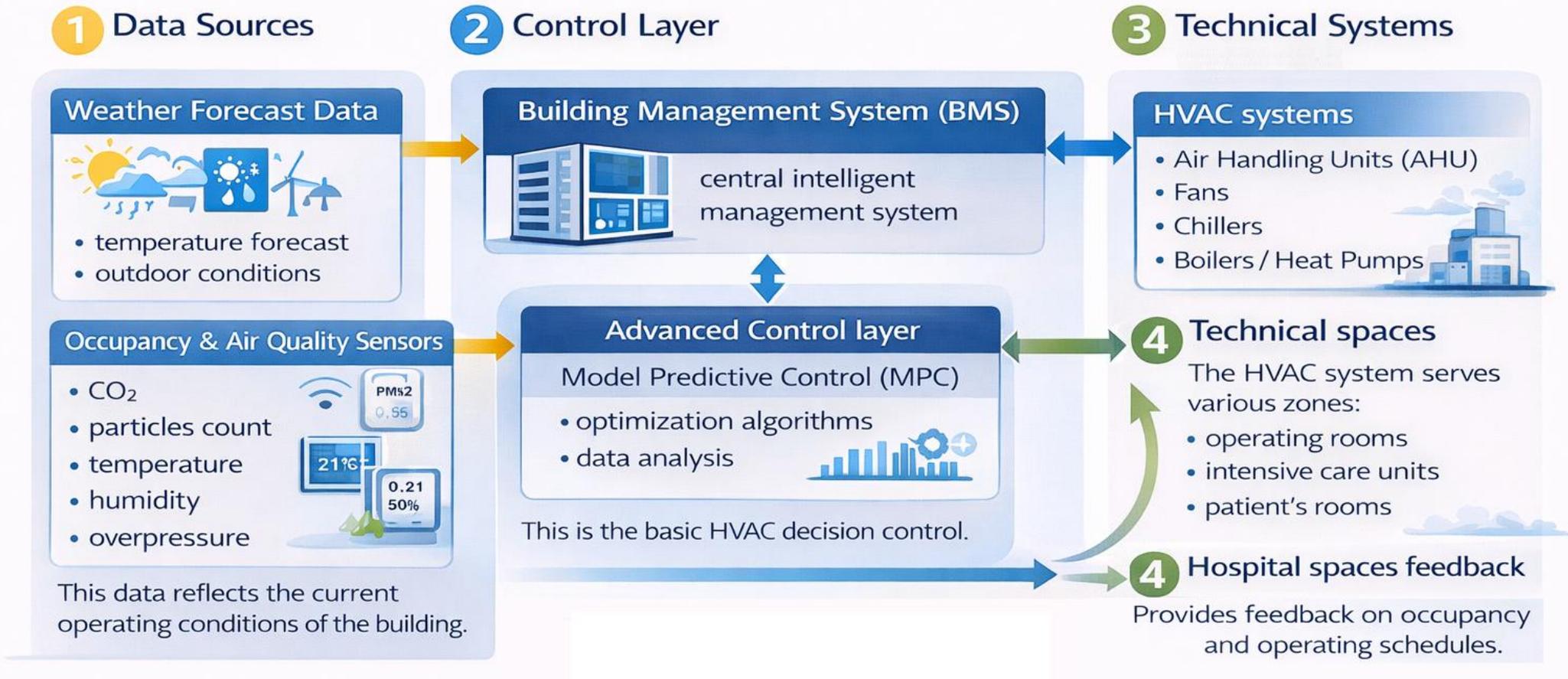
4. Advanced control strategies

- Building Management Systems (BMS)
- demand-controlled ventilation
- Model Predictive Control (MPC)

The role of control strategies and system integration

Conceptual Architecture of HVAC Control in Hospitals

Diagram shows the flow of information and control in a modern HVAC system.

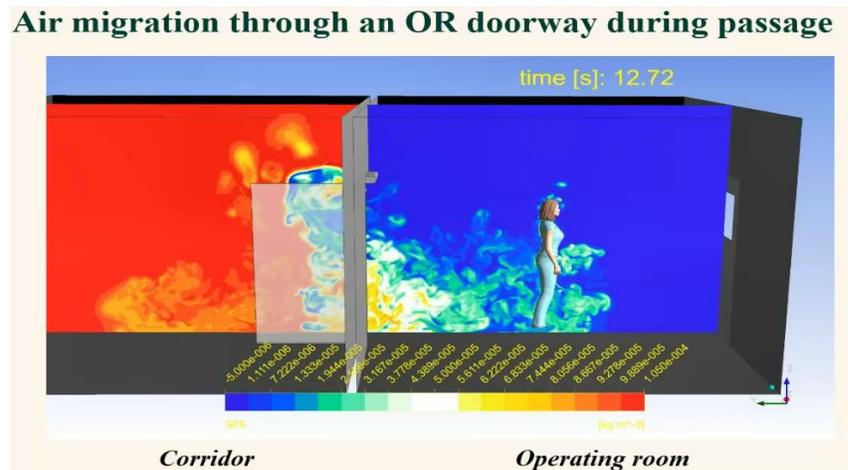


The role of control strategies and system integration

New control strategies:

Based on AI on-line camera and people presence detection HVAC system can adjust air flow volume according to actual demands.

Door openings can be also detected and change of air flow supply / exhaust can be change to prevent external air inflow.



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The role of control strategies and system integration

New control strategies:

BAMS (BioAerosol Monitoring System) is an instrument designed for real-time monitoring of airborne microorganisms and particles in controlled environments such as pharmaceutical cleanrooms, hospitals, and biotechnology facilities. It combines particle counting and fluorescence detection (LIF - Laser-induced fluorescence) to identify biological particles suspended in air in real time.

According to real time particle concentration measurements HVAC systems can modulate air volume (ACH) to remove pollutants.

Information for medical staff during procedures of alarming levels.





Conclusions

- Hospitals require exceptionally high energy use to ensure patient safety, infection control, and uninterrupted operation.
- Ventilation systems are a critical driver of energy demand, due to high air change rates, filtration, and strict environmental control
- The challenge is clear: improve energy efficiency without compromising aseptic conditions.
- Smart HVAC systems combining advanced controls, real-time sensing, and AI-based monitoring enable ventilation to respond to actual demand.
- The future of hospital HVAC lies in adaptive, data-driven systems that balance safety, air quality, and energy performance.

The challenge is not less or more ventilation, but smarter ventilation.



Every small step matters!

Thank for your attention.

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