UW ME/ECE CAPSTONE · INDUSTRY SPONSORED PROJECT · 2026

Smart Occupancy-Driven HVAC Control for Lower Energy and Operating Costs

An AI sensor-based ventilation strategy that pairs **real-time people counting** with **ASHRAE 62.1 demand-controlled ventilation** to reduce energy waste in commercial buildings, where ventilation alone accounts for **~6% (234 TWh)** of U.S. electricity demand (EIA CBECS, 2018).

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FACILITY · AMAZON OFFICES

Departments of Mechanical Engineering & Electrical & Computer Engineering, University of Washington

SPONSOR: AMAZON · UW FACULTY MENTORS: SIRINE MAALEJ & ROBERT S. RUSHING

1 THE CHALLENGE

Large-footprint Amazon fulfillment centers condition vast volumes of air around the clock – yet HVAC outside air systems remain mostly static even with ever-changing occupancy throughout the building.

- Commercial buildings consume **~35%** of U.S. electricity, and ventilation alone accounts for **~6%** nationwide (U.S. DOE, 2024; EIA CBECS, 2018).
- Static schedule-based ventilation over-conditions empty zones, a hidden nationwide energy tax.
- The result: millions of dollars conditioning air for people who aren't there.

ENERGY · AUTOMATION · INNOVATION

THE OPPORTUNITY

If a fulfillment center can **see how many people are in each room in real time**, it can ventilate only what is occupied — turning a static schedule into a **demand-controlled, AI-driven loop** with measurable energy and cost savings potentially at **national scale** *(anonymous counting, no identification, GDPR compliant).*

FIG. 1 — Milesight VS133 AI sensor.

AI SENSOR

Milesight VS133

TECH	ToF + AI
ACCURACY	≥ 99.8%
RANGE	up to 6 m
FOV	108° × 84°
UPLINK	LoRaWAN

2 APPROACH & SENSOR DEPLOYMENT

- **VS133 + LoRaWAN gateway sensors** mounted above every zone doorway.
- **18 RTU service zones · 22 sensors** instrument Amazon Offices (7 + 11 + 4 sensors across three banks).
- **Net-flow counting** yields a live per-zone occupant total for the BMS.

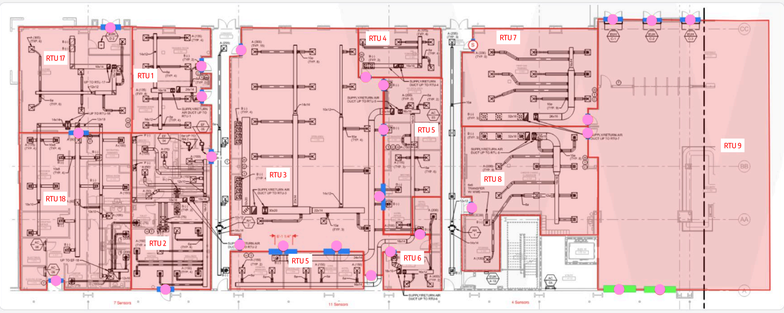


FIG. 2 — Amazon Offices floor plan: RTU zones (red) and VS133 sensor placements (blue/green).

RTU Zone (rooftop unit) · Doorway-separated · Open transition · VS133 sensor

3 THREE-LAYER CONTROL ALGORITHM

A closed-loop pipeline turns raw VS133 counts into ASHRAE 62.1–compliant ventilation, temperature, and lighting commands sent to a mock BMS every minute.

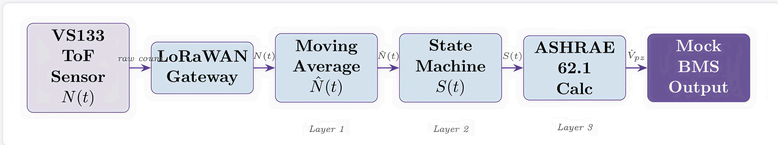


FIG. 3 — End-to-end OBC data flow.

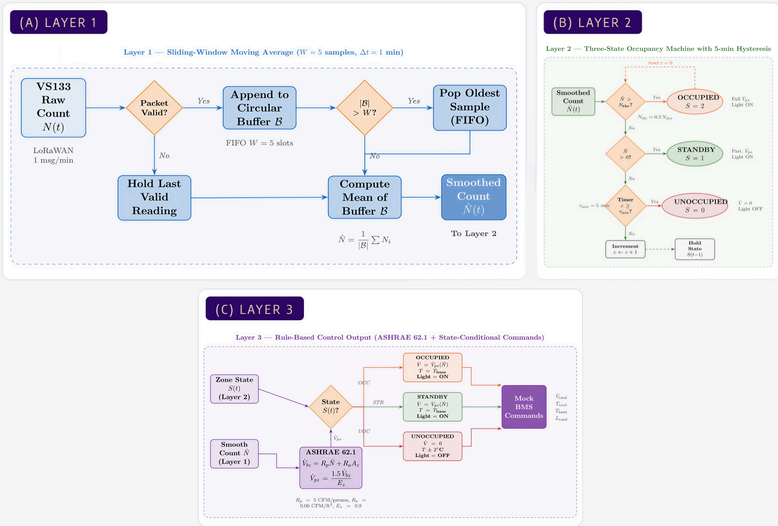


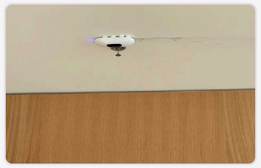
FIG. 4 — Three-layer process diagrams: **(a)** smoothing · **(b)** state machine · **(c)** control output.

Converts a live people-count into an HVAC control command, once per minute. A **5-minute sliding-window smoother** feeds a **three-state machine (Occupied/Standby/Unoccupied)** grounded in ASHRAE 62.1-2016 Note H, with **asymmetric 5-min hysteresis** that drops ventilation, air temperature, and lighting only after sustained vacancy — capturing 10–26% site-energy savings (PNNL-22072; Lu et al., 2022).

4 VALIDATION PLAN

Live at IEB G106

- AI Sensor mounted on ceiling above the doorway at **UW IEB G106**.
- Real-time **line-count test** passed — in/out events tracked accurately.
- Next: extend to **Amazon Offices** for industrial validation.



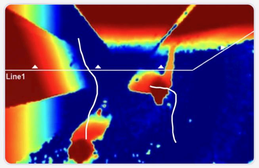


FIG. 5 — AI Sensor installed at IEB G106 doorway.
FIG. 6 — Live ToF heat-map of people counted.

5 EXPERIMENTAL RESULTS

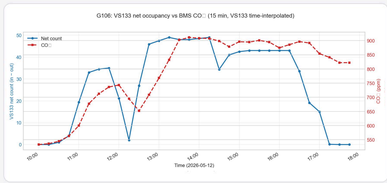


FIG. 7 — Real occupancy vs. CO_2 (IEB G106).

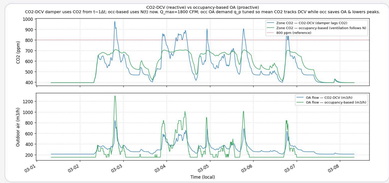


FIG. 8 — Simulated control comparison.

Measured — IEB G106 (2 days)

- CO_2 trails the room — rises slowly after people arrive, stays high **1+ hour** after it empties.
- HVAC Ventilation didn't match real occupancy.

→ In our G106 data, CO_2 reacted 2-3 hours too late to ventilate efficiently.

Simulated — occupancy vs. CO_2 baseline

- **~15% less outdoor air** moved over the week.
- **~268 ppm lower CO_2 peak** — never crossed 800 ppm (CO_2 control did, >7% of the time).

→ Our simulation suggests reacting to people instead of CO_2 may save air and improve IAQ (indoor air quality).

6 ENERGY MODEL & COST FORECAST

From floor plans to a dollar figure

- A **simulation** of the Amazon facility — built from scratch in Trane Trace 700, an industry-standard energy modeling platform.
- **17 RTUs and 61 rooms** make the model simulate day-to-day operations.
- Reusable framework for forecasting savings at any Amazon facility.
- Baseline modeled against our sensor algorithm to show energy usage comparisons and calculate cost savings.

High detail energy model mapped on a pilot facility; scalability requires further validation.

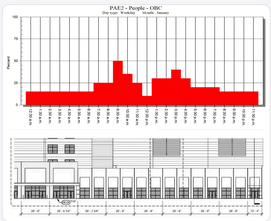


FIG. 9 — Trane Trace 700 model: per-RTU, Amazon facility.

7 PROJECTED IMPACT

At Amazon scale: projected multi-million-dollar annual recovery. *See limitations and assumptions.*

8.3% OVERALL ENERGY REDUCTION — Whole-building Btu/(ft²·yr)	**$0.09 / ft²·yr** ANNUAL COST RECOVERED — At $0.10/kWh, $1.20/therm
28.2% NATURAL GAS REDUCTION — Ventilation heating	**7.2%** ELECTRICAL DEMAND REDUCTION — Ventilation cooling

Trace 700 projections, scaled to Amazon's footprint.

- **~$70K+** saved per facility every year (~800K ft² typical).
- **Projected tens of millions** in annual savings opportunity across Amazon's North American fleet.
- **~$35–40K** in sensors pays back in **~6 months** per site.

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REFERENCES

1. ASHRAE Standard 62.1-2022, Ventilation for Acceptable Indoor Air Quality, ASHRAE, Atlanta, GA.
2. Milesight IoT, "VS133 AI Workplace Sensor Datasheet," Milesight Technology Co., Ltd., 2024.
3. U.S. Energy Information Administration, "Commercial Buildings Energy Consumption Survey (CBECS)," 2018.
4. Milesight IoT, "People Counting Series Presentation," 2024.
5. Figs. 1–6 and Table 1 generated by the project team; floor plan adapted from Amazon Offices mechanical drawings (used with sponsor permission).

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LIMITATIONS & ASSUMPTIONS

- Validated in a single room over a short period; broader applicability not fully tested.
- Projected savings based on simulation, not full-building deployment.
- Sensor accuracy depends on placement and traffic patterns.
- Results may vary with building conditions, occupancy behavior, and HVAC systems.

METHODOLOGY NOTES

Occupancy validated at UW IEB G106 against manual ground truth. Baseline ventilation and CO_2 drawn from measured BMS data (Amazon and IEB); occupancy in baseline records is estimated from CO_2. Comparative figures (~15% outdoor-air reduction, ~268 ppm lower CO_2 peak) are simulation results on measured data, not yet field-measured. Projected Amazon-facility energy and cost savings are pending the final Trane Trace 700 model run.