AI-Driven Energy Efficiency Monitoring System for Large Buildings

A Conceptual Implementation of Edge-Based AI for Sustainable Operations

Fisayo Jassey Jabarr

Adebanke Damola-Fashola

ITAI 3377 - AI at the Edge and IIOT Environments

Professor: Patricia McManus, MMkt, MBA, MScMIS

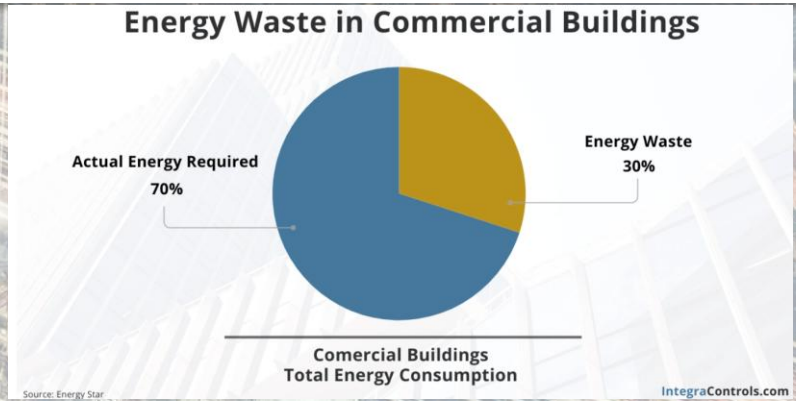
April 29, 2025

Problem Statement

Challenge: Large buildings waste 20-30% of energy due to inefficient systems management

Impact:

Financial: Unnecessary operational expenses	Environmental: Excessive carbon emissions	Operational: Suboptimal occupant comfort



Project Overview

Use Case: AI-powered hybrid edge-cloud architecture for real-time energy monitoring and optimization for large buildings (e.g., campuses, office complexes).

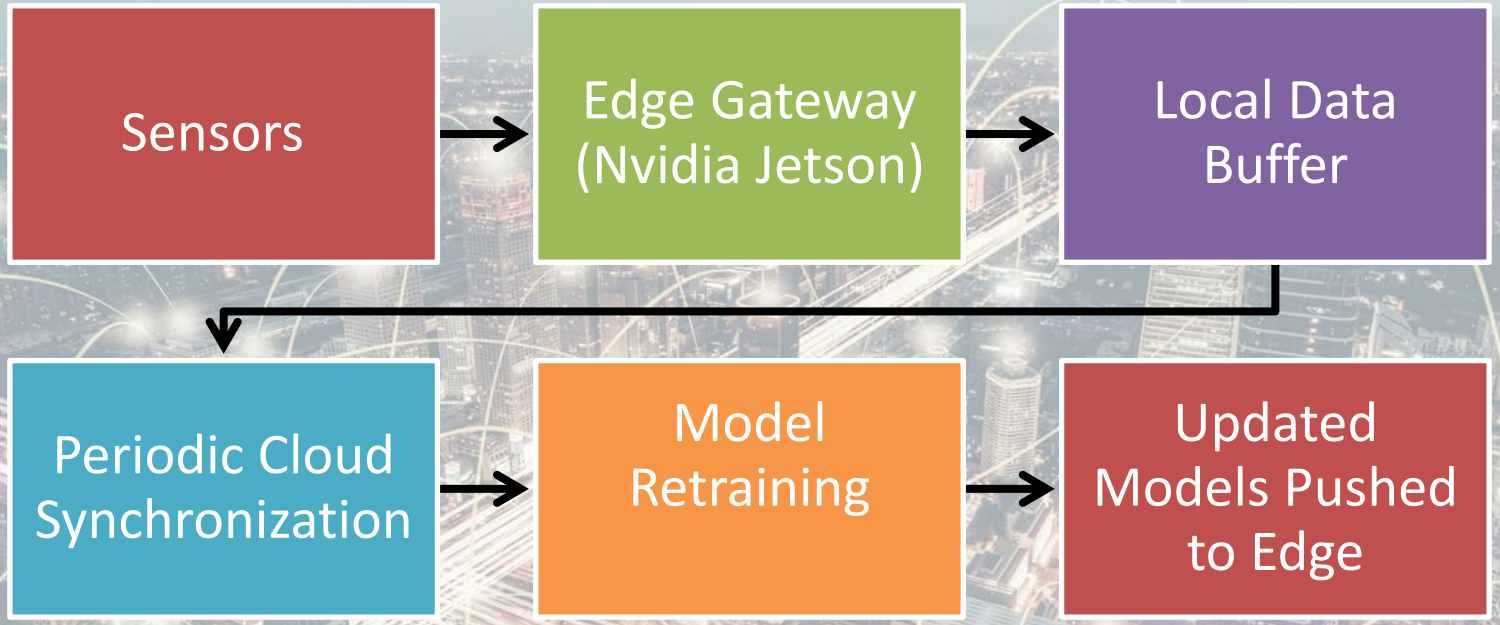
Goal/Value Preposition:

15-22% reduction in energy costs

ROI within 11-14 months

CO_2 reduction of 150-210 tons annually per building

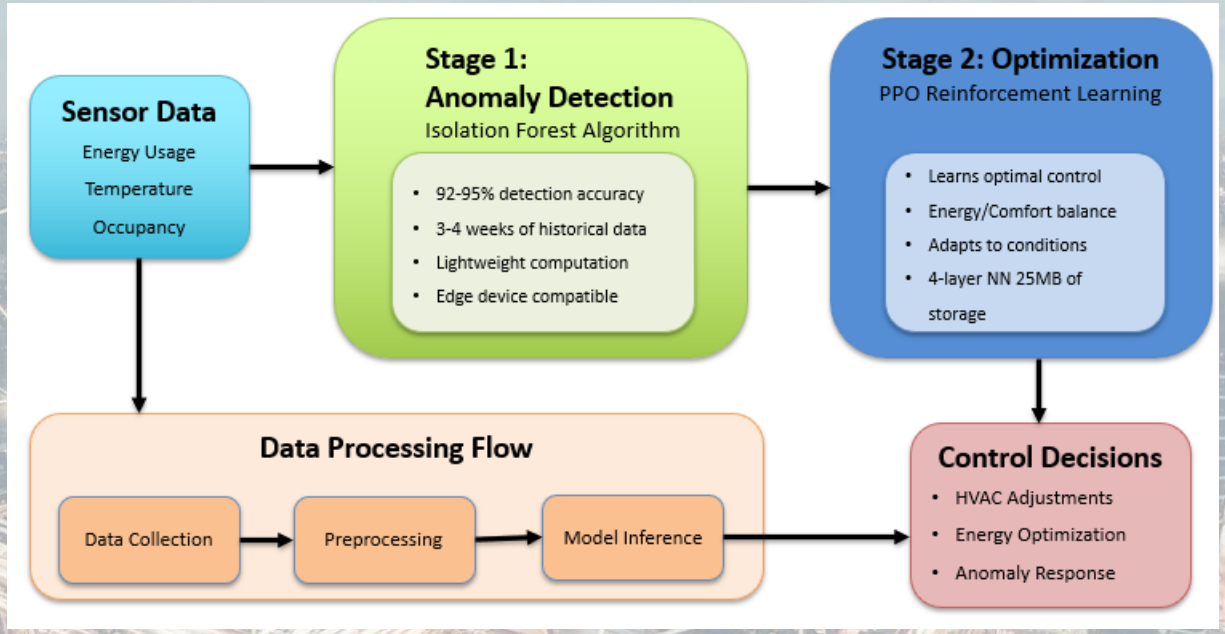
Conceptual System Architecture



Key Feature: Integration with existing Building Management Systems (BMS) via BACnet/IP protocol

Benefits: Real-time responsiveness with minimal latency

Two-Stage AI Model Architecture



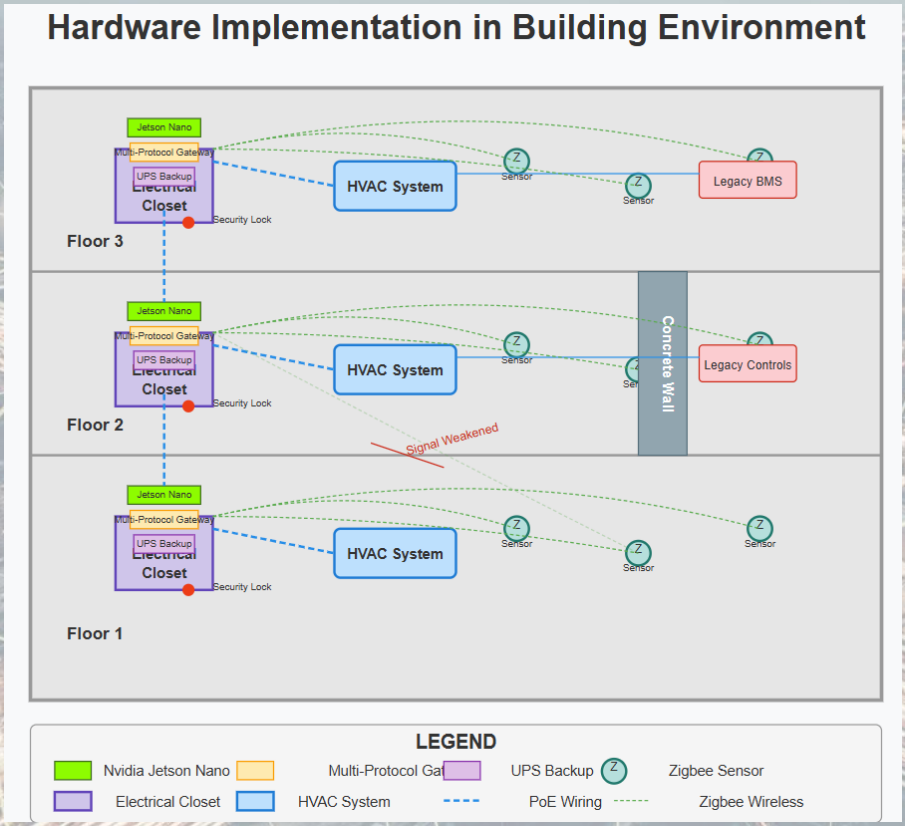
Two-Stage AI Model:

1. Anomaly Detection: Isolation Forest algorithm (92-95% accuracy)

2. Optimization Engine: Proximal Policy Optimization (PPO) reinforcement learning

Why Not GANs? More efficient resource utilization with proven technology.

Hardware Implementation



Edge Computing Device: Nvidia Jetson Nano (472 GFLOPS, 5- 10W power)

Connectivity: Multi-protocol gateway supporting BACnet, Modbus, LonWorks

Wireless Solution: Zigbee Pro mesh network for robust concrete penetration

Security Implementation

Device Security: X.509 certificate-based mutual TLS authentication

Network Security: Dedicated VLAN with explicit ACLs

Data Protection: AES-256-GCM encryption with 24-hour key rotation

Intrusion Detection: Suricata IDS with custom MQTT traffic analysis

Implementation & Testing Strategy

Theoretical Deployment:

- Deploy agent on Nvidia Jetson Nano
- Real-time data from sensors via MQTT
- On-device inference, no cloud dependency

Testing Scenarios:

- Stress test: 1,000 sensor reads/min
- Simulate unauthorized access
- Target: <500ms decision latency, 10% energy savings

Testing Strategy

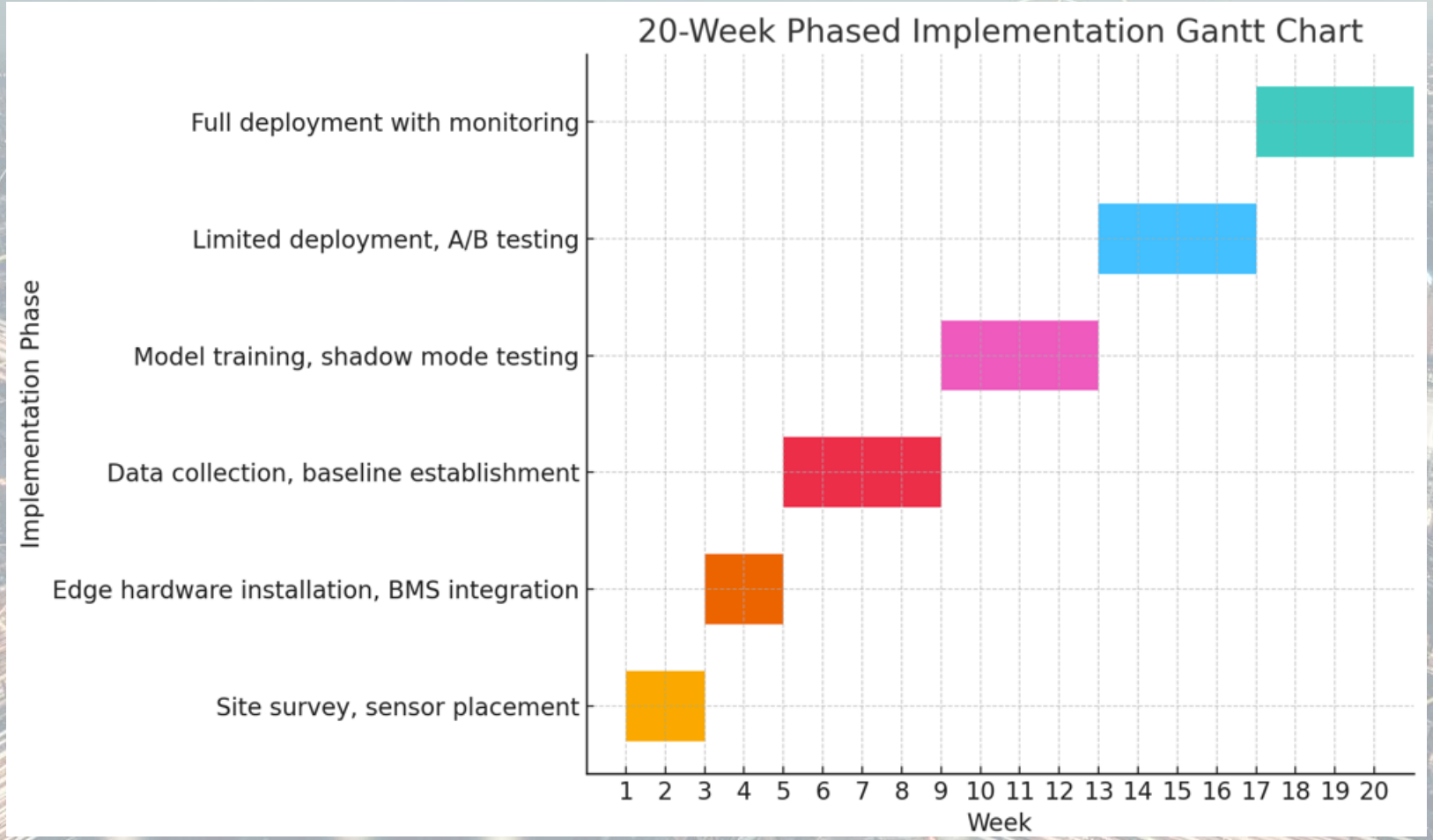
Phased Approach:

- Staged deployment (one zone first)
- A/B testing with control zones
- Shadow mode testing (recommendations without execution)

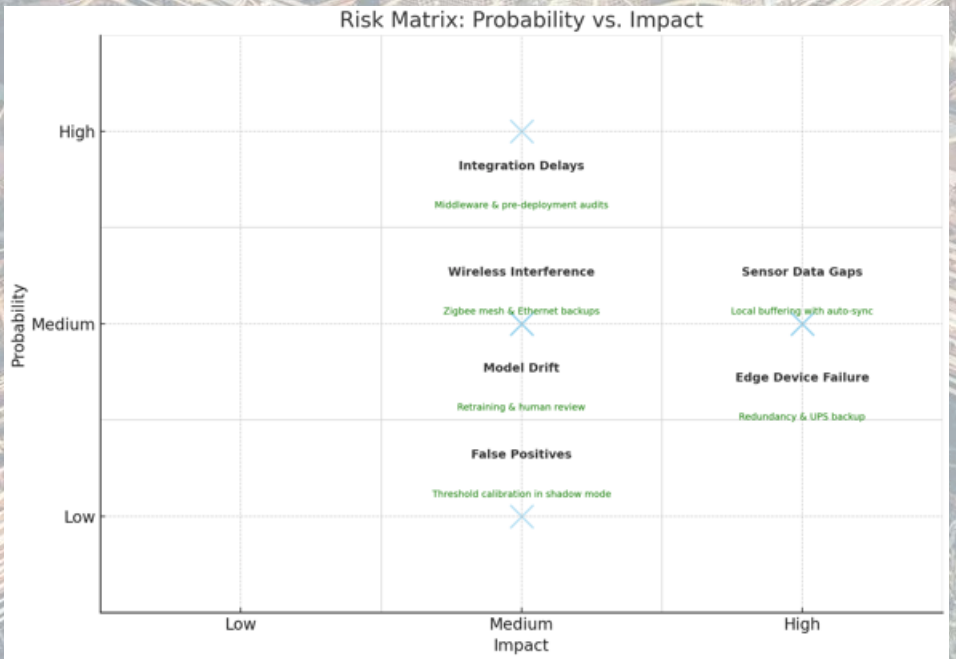
Performance Benchmarks:

- 750ms maximum response time
- < 5% false positive rate for anomalies
- < 40% sustained CPU utilization

Implementation Roadmap



Risk Assessment & Mitigation



Key Risks and Mitigations:

Sensor data gaps → Local buffering with auto-sync

Integration delays → Middleware translation layers

Wireless interference → Zigbee Pro mesh networks

Model drift → Regular retraining and human review

Edge device failure → Redundant critical nodes

Lessons Learned & Challenges

Model Complexity vs. Edge Capacity:

GANs and RL models can be heavy for edge devices

Trade-off between accuracy and processing load

Importance of Security & Real-Time Responsiveness

Synthetic Data Risks: Potential bias; addressed with statistical audits

Tools & Frameworks (Conceptual)

- TensorFlow Lite: Suitable for lightweight deployment on Nvidia Jetson Nano
- SciPy: Bias detection in synthetic datasets
- Mosquitto: MQTT broker for edge communication
- OpenSSL: Encrypt data transfers

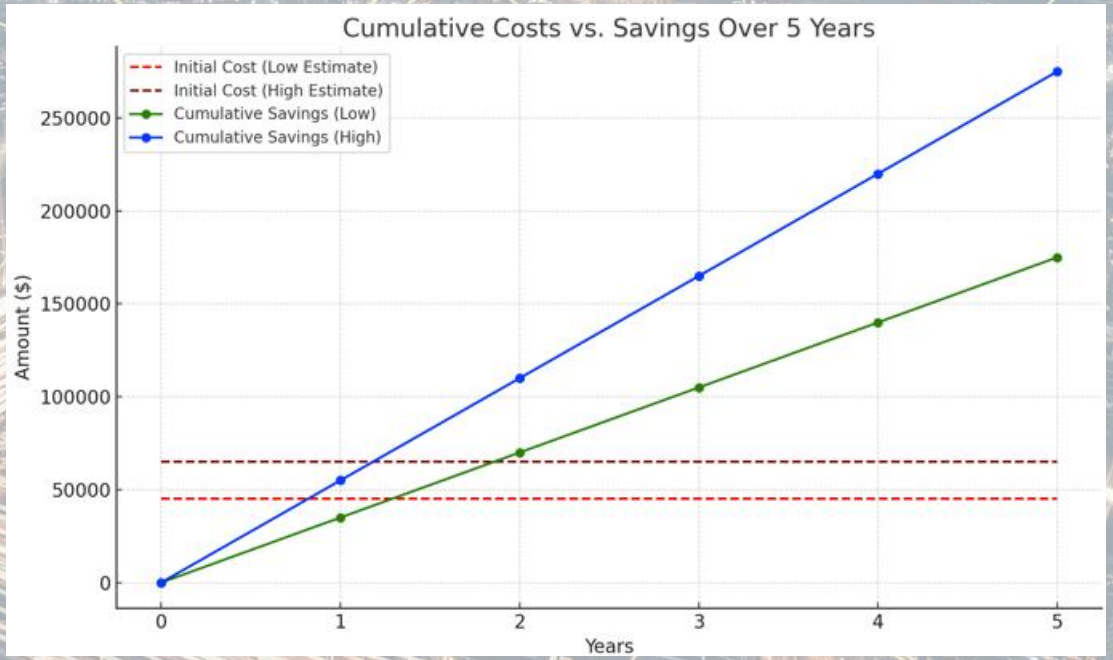
ROI Calculation

Implementation Costs:$45,000-65,000 per 100,000 sq ft building

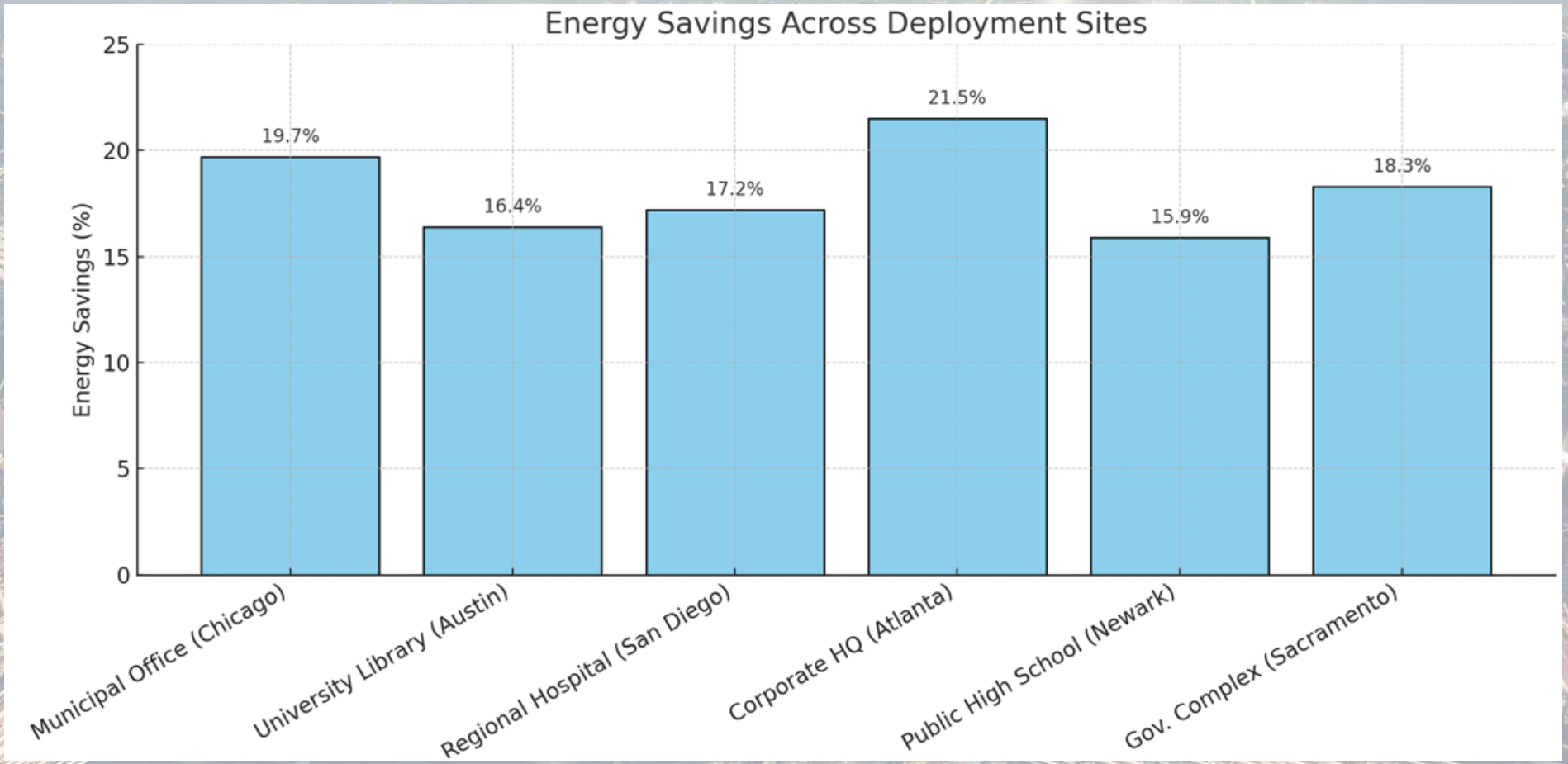
Annual Energy Savings: $35,000-55,000 (15-22% reduction)

Payback Period: 11-14 months

5-Year ROI: 320-410%



Proven Results



Environmental Impacct

Carbon Footprint Reduction

- 150-210 tons CO_2 reduction annually per 100,000 sq ft
- Equivalent to removing 3-0-45 cars from the road
- Supports ESG reportiing requirements
- Advances corporate sustainability goals

Broader Environmental Benefits

Reduced peak grid demand

Lower water consumption in cooling systems

Extended equipment lifespan through optimized operation

Decreased maintenance interventions

Scalability Impact

For 10 buildings: 1,500-2,100 tons CO_2 reduction annually

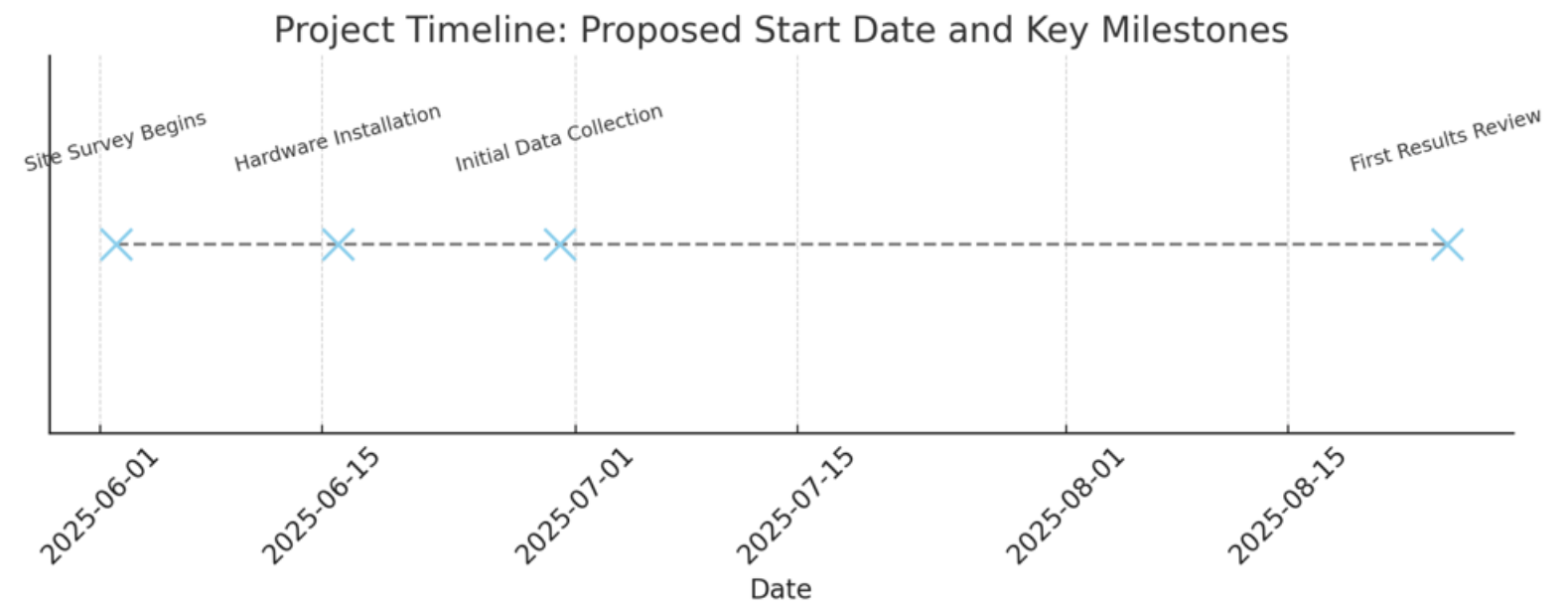
For 100 buildings: 15,000-21,000 CO_2 reduction annually

Environmental Impact

Next Steps

Proposed Action Items:

1. Approve Phase 1: Site Survey and Pilot Deployment
2. Select pilot building/zone
3. Establish baseline measurement period
4. Review first results in 90 days



Closing / Q&A

Conceptual plan delivers a practical, scalable energy monitoring solution

Focused on autonomous decision-making, low latency, and ethical AI use

Open to questions and discussion