Business Insight Report: The Smart Energy Dilemma

Team Name: CipherSci

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Executive Summary

EcoSmart Solutions, a global consulting firm specializing in energy optimization, was engaged by a leading real estate investment trust (REIT) to address rising energy costs, carbon penalties, and operational inefficiencies across a portfolio of over 1,600 commercial buildings in North America and Europe.

As part of the project, comprehensive exploratory data analysis (EDA) was conducted in R to uncover preliminary patterns in energy usage, including time-of-day consumption trends, building type profiles, and environmental influences. Building upon these findings, we developed a machine learning-driven energy forecasting model using historical electricity readings, building metadata, and weather data. Rigorous data preprocessing, leakage prevention, and feature engineering ensured model integrity, resulting in reliable daily energy usage predictions across the portfolio.

Key business insights extracted from the analysis and modeling include:

- A potential **$858,000 in annual savings** from a **10% reduction** in energy consumption, and up to **$1.7 million** annually from a **20% reduction**.
- Identification of the top **10 underperforming buildings** with significant anomalous overconsumption, representing prime candidates for targeted energy audits and retrofits.
- Exploratory analysis revealed that **energy usage peaks between 1 PM to 3 PM,** and **health and educational facilities** were among the highest consumers across the portfolio.

- Weather sensitivity analysis indicated that **humidity (dew point)** and **sea-level pressure** had stronger influences on energy demand than temperature alone, highlighting the need for broader environmental monitoring strategies.
- A **+5°C warming simulation** during the summers indicated modest but cumulative long-term risk, while an **extreme +8°C summer heatwave scenario** projected a **2.5% spike** in annual energy consumption, emphasizing portfolio vulnerability during peak load periods.

These findings provide a data-driven foundation for strategic energy management, operational resilience planning, and informed infrastructure investment decisions. **EcoSmart** Solutions is now positioned to deliver actionable recommendations that enable **REIT** to proactively target high-impact energy interventions, optimize operational costs, and build long-term climate resilience across its building portfolio.

Business Insights From XGBoost Modeling and Exploratory Analysis

The machine learning model developed by EcoSmart Solutions, alongside exploratory data analysis conducted in R, provided critical insights into the REIT's energy consumption patterns, operational risk areas, and future resilience challenges. Leveraging XGBoost predictive modeling analytics, the baseline annual energy consumption across the portfolio was estimated at over **71 million kWh**. Simulation scenarios demonstrated that achieving a 10% reduction in energy use could unlock savings of approximately **$858,000** annually, while a 20% reduction could yield up to **$1.7 million** in annual savings, emphasizing the substantial financial opportunities tied to operational efficiency improvements.

Model-driven residual analysis uncovered a subset of ten buildings exhibiting anomalously high energy consumption relative to their predicted baselines. These high-risk buildings represent immediate priorities for targeted audits, retro-commissioning, and system upgrades, offering the potential for rapid cost recovery and energy performance optimization. Further EDA revealed that the top 20 highest-consuming buildings, including facilities like Hog Education (Janell) and Fox Education (Willis), accounted for a disproportionate share of total energy use, with average daily consumptions ranging between 1000 and 3500 kWh. In contrast, smaller buildings exhibited much lower and more stable energy profiles.

Daily usage analysis highlighted that energy consumption consistently peaks between 1pm and 3:00PM. The highest average energy demand (~169 kWh) was observed at 2:00PM, while the lowest energy demand occurred around 03:00AM. Building type analysis indicated that health facilities and education centers are the highest energy consumers, followed by utility and science buildings. Conversely, most other building types maintained significantly lower daily consumption averages, often under 100 kWh.

Weather sensitivity analysis revealed that humidity (dew temperature) and sea-level pressure had stronger correlations with energy consumption than air temperature alone, highlighting the need to broaden environmental monitoring beyond traditional

temperature metrics. However, air temperature also showed a positive correlation with energy use, where higher outdoor temperatures led to increased energy demand, primarily due to elevated cooling needs.

Finally, stress-testing the model against future climate variability using $0.12 parameter, showed that a global +5°C warming scenario would lead to a modest but cumulative increase in annual energy consumption, while an extreme summer heatwave scenario (+8°C) could cause a 2.5% surge in peak summer energy usage resulting in almost $6,000 extra yearly energy bill.

Recommendations

1. **Audit and Upgrade Anomalous High-Consumption Buildings:** Prioritize immediate energy audits and targeted retrofits for the top 10 buildings exhibiting anomalous energy consumption as detected by model-driven analysis. These buildings significantly exceed predicted usage patterns, representing critical opportunities for rapid efficiency gains. Strategic interventions — such as system rebalancing, retro-commissioning, and modernization of energy-intensive equipment — can deliver immediate cost savings, reduce operational waste, and improve sustainability metrics across the portfolio.
2. **Pursue 10–20% Energy Reductions Portfolio-Wide:** To unlock estimated annual savings between $858,000 and $1.7 million, building-specific initiatives should focus on upgrading HVAC systems, retrofitting lighting with LED and smart controls, and enhancing insulation and window sealing to minimize energy loss. Investments in advanced building automation and energy management systems (EMS) will further optimize operations, while deploying occupancy-based controls and promoting energy-conscious behaviors among staff and tenants will help sustain long-term reductions.

3. **Expand Weather-Based Operational Controls:** Enhance building management systems to respond not only to temperature but also to humidity and atmospheric pressure, optimizing energy use under a wider range of weather conditions.
4. **Prepare for Global Warming Phenomenon and Peak Load Stress:** In anticipation of possibly hotter summer conditions and increased peak energy demands, it is recommended to upgrade cooling systems to high-efficiency models capable of handling extreme temperatures. Additionally, implementing advanced peak-demand management strategies, such as load shifting, smart thermostatic controls, and energy storage solutions will help mitigate the projected **2.5% rise in energy consumption** during summer heatwaves, protecting both operational resilience and cost stability.
5. **Target High-Consumption Building Types for Specialized Efficiency Programs:** Given that health and education facilities consistently rank among the highest energy consumers, specialized energy efficiency programs tailored to the unique operational needs of these building types should be developed. Initiatives may include advanced HVAC retrofits for healthcare environments, optimized scheduling for educational buildings, and targeted tenant engagement to drive behavioral savings.
6. **Optimize Building Operations for Time-of-Day Peak Load Management:** Since energy consumption peaks consistently between **1:00 PM and 3:00 PM**, load management strategies such as automated demand response, peak load shifting, and real-time energy monitoring should be implemented. This would not only flatten peak loads but also reduce strain on building systems and lower operational costs during the most expensive periods of the day.

Conclusion

EcoSmart Solutions conducted a comprehensive, data-driven analysis to support the REIT's goal of reducing energy waste by 20% across its building portfolio. After rigorous data cleaning and preprocessing to correct timestamp errors, sensor noise, and missing values, a robust modeling-ready dataset was created. Exploratory analysis revealed critical usage trends by building type, time of day, and environmental factors.

Using XGBoost predictive modeling, baseline annual energy consumption was estimated at over **71 million kWh**, with simulations indicating potential annual savings between **$858,000 and $1.7 million** through targeted operational improvements. Anomalous high-consumption buildings, high-variability facilities, and strong environmental drivers such as dew temperature and sea-level pressure were identified, providing clear priorities for optimization. Climate stress-testing revealed additional risk, projecting a **2.5% surge** in peak summer energy demands under extreme heat conditions. These findings reinforce the need for cooling upgrades, peak load management, and climate resilience measures.

Collectively, this analysis offers the **REIT** an actionable pathway toward achieving its **20%** reduction target, while simultaneously strengthening operational efficiency, reducing carbon footprint exposure, and preparing the portfolio for future climate risks. **EcoSmart Solutions** stands ready to support the next phase of this journey, translating data-driven insights into real-world energy savings and helping the **REIT** deliver on its bold vision for a more efficient, sustainable, and resilient future.