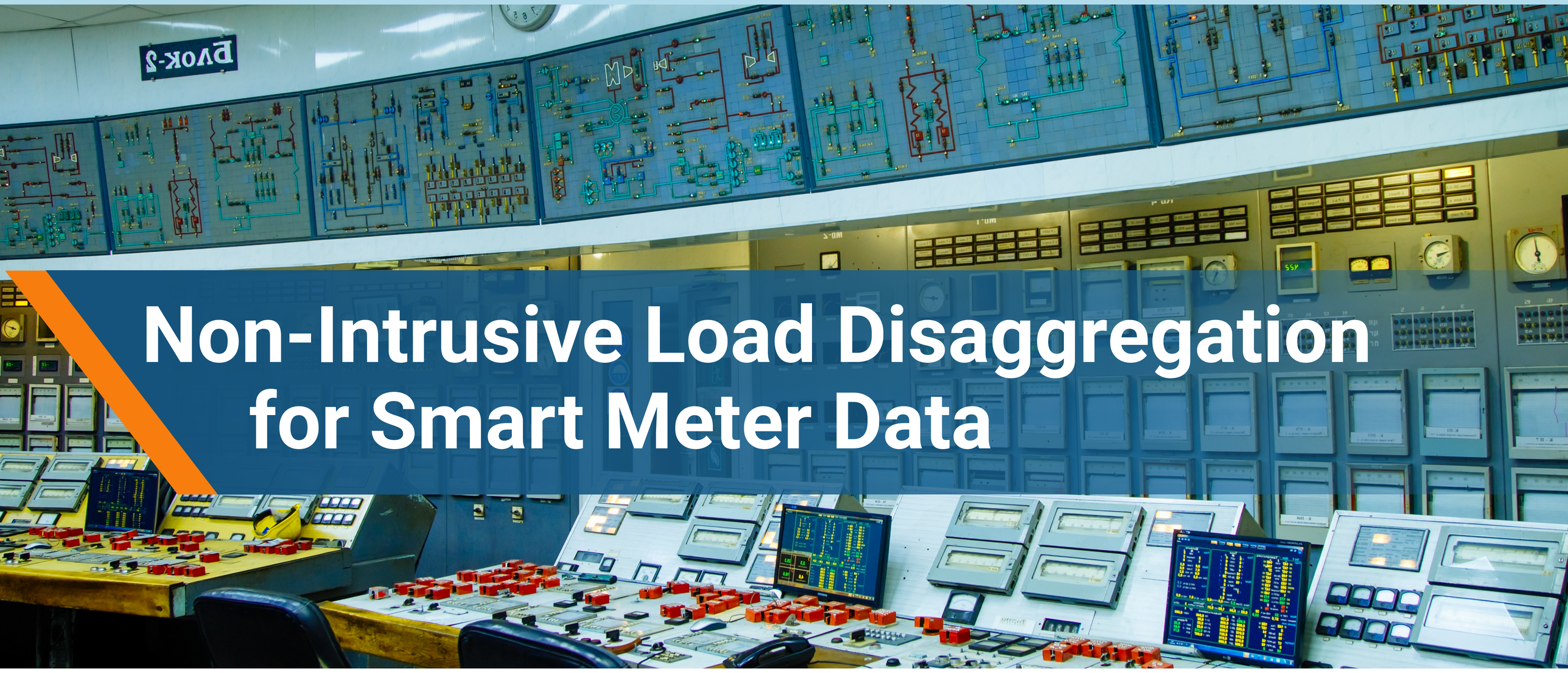


Non-Intrusive Load Disaggregation for Smart Meter Data

What This Is About? Understanding Non-Intrusive Load Disaggregation

As energy utilities embrace smart metering, the potential to derive granular insights from consumption data has grown exponentially. For the a large electricity distribution company in Middle East, understanding how individual appliances contribute to overall energy consumption at the consumer level has become a pivotal focus area. Non-Intrusive Load Disaggregation (NILM) provides a groundbreaking solution to achieve this goal without requiring additional hardware installations.

This project leverages the company's existing smart meter infrastructure to disaggregate total energy consumption into appliance-level insights. By analyzing patterns in voltage, current, and harmonic profiles, NILM identifies the contribution of specific appliances to the overall load. This data-driven approach not only supports the company's operational objectives but also empowers consumers with actionable insights to optimize their energy use.

How Was It Done? From Data to Insights: The Implementation Journey

In a game-changing collaboration with the company , Abjayon harnessed the power of advanced signal processing, Non-Intrusive Load Monitoring (NILM), and machine learning to transform the way energy consumption is understood and managed. The result? A cutting-edge energy disaggregation solution that dives deep into consumption data, revealing appliance-level insights with great accuracy.

At the heart of this transformation lies signal processing, where raw electrical data is dissected to identify patterns and anomalies.

Frequency Analysis

- By breaking down the electrical signal into its frequency components, we captured unique characteristics of appliances like the cycling patterns of HVAC systems or the steady consumption of entertainment devices.

Transient Detection

- Momentary changes in power such as when an appliance is switched on or off were captured to pinpoint usage events.

Harmonic Distortions:

- These subtle distortions in the electrical signal helped differentiate between appliances with similar consumption profiles.

This signal processing layer fed the NILM engine, ensuring a robust and accurate foundation for disaggregation.

Non-Intrusive Load Monitoring (NILM) techniques enabled the breakdown of aggregate energy consumption into appliance-level insights without requiring invasive hardware. Historical and real-time data were analyzed to identify unique appliance signatures based on power cycles, load shapes, and temporal usage patterns.

The AI/ML models classified consumption into five key categories:

- **HVAC:** High-frequency cycles reflecting heating and cooling patterns.
- **Cooking:** Short bursts of power during meal preparation.
- **Cleaning:** Intermittent spikes from devices like dishwashers and washing machines.
- **Entertainment:** Steady yet fluctuating usage of TVs, audio systems, and gaming devices.

  Others: Miscellaneous loads identified through residual analysis.

Impresa Solutions:

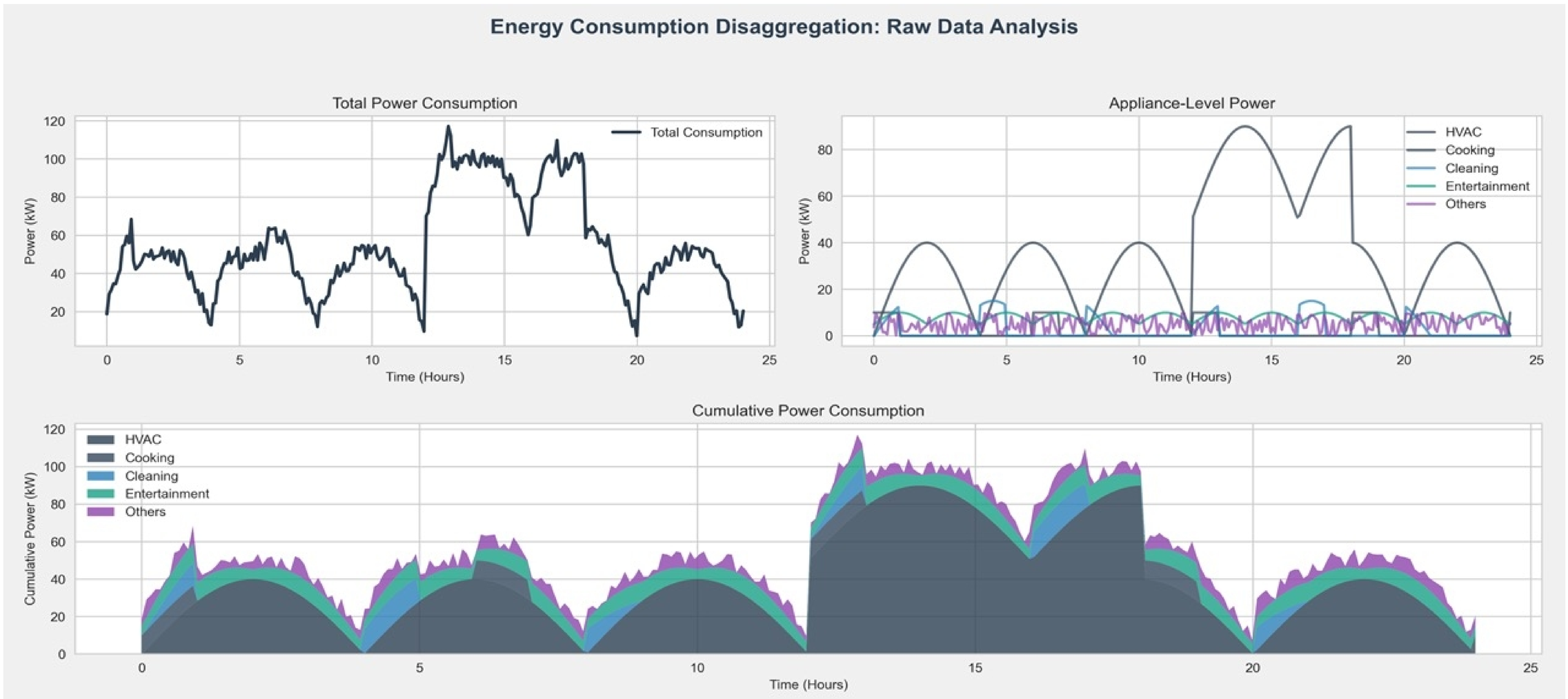
- Impresa Insights Platform
- Energy Disaggregation

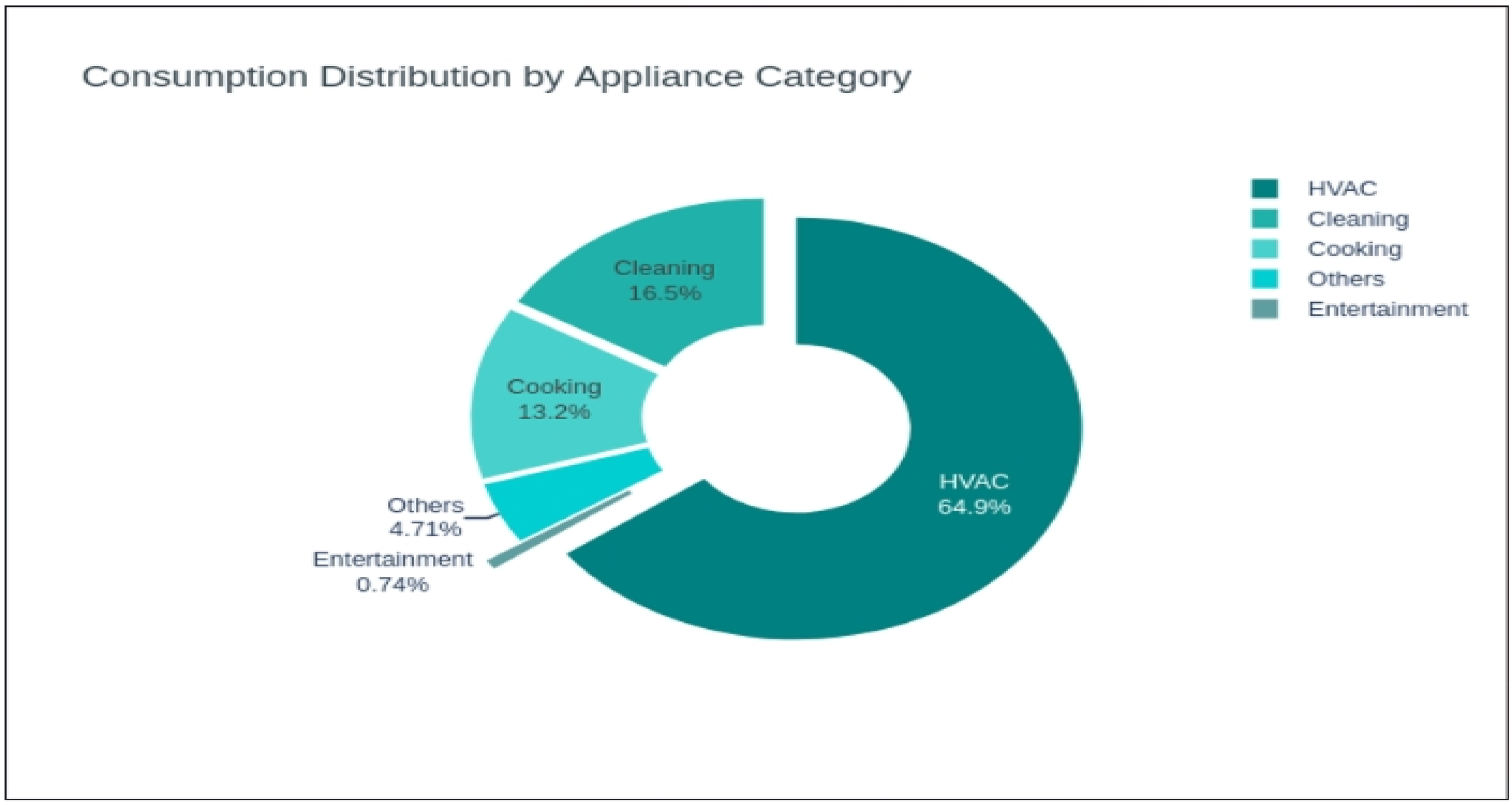
The AI/ML layer took signal processing outputs and applied deep learning techniques to refine accuracy and adaptability:

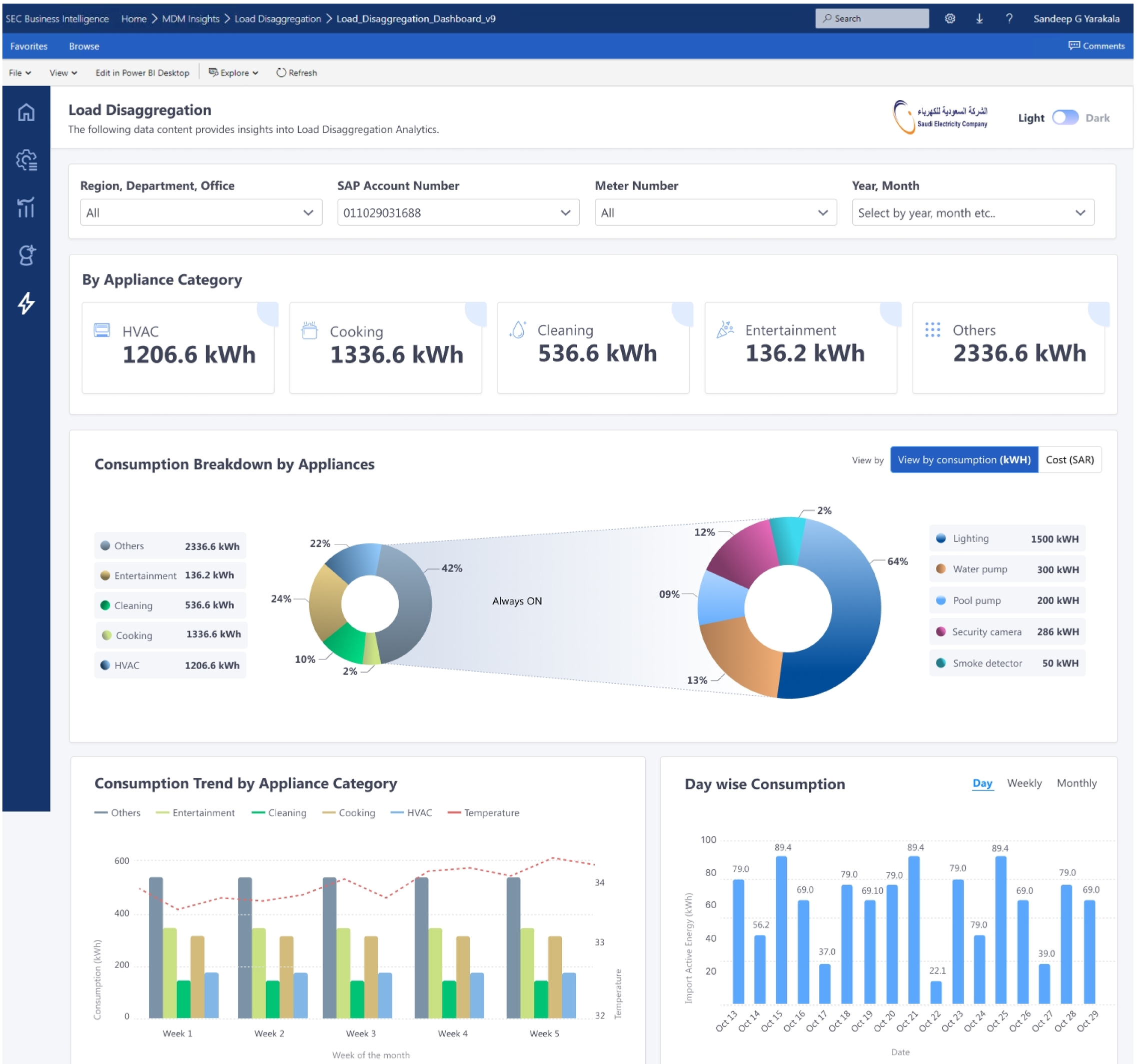
- **Feature Engineering:** Advanced features such as peak load trends, weather-driven usage patterns, and appliance runtime were extracted to enhance model inputs.
- **Model Training and Validation:** Historical data spanning several months was used to train the models, validated against real-world data to ensure adaptability.
- **Adaptive Learning:** The system evolved dynamically by incorporating feedback loops from real-world data, ensuring it stayed relevant in the face of changing consumer behaviours.

The insights generated by the system were visualized on interactive dashboards within the Impresa Insights platform. Operational teams gained a granular view of energy usage, while consumers received tailored predictions and reports integrated seamlessly through APIs into the company's customer-facing systems.

As the company and Abjayon gear up for Phase 2, the focus shifts to appliance-specific disaggregation. By applying advanced signal processing and AI/ML techniques, the system will provide even more granular insights—empowering consumers to take charge of their energy usage like never before.







How It Benefitted the company? Strengthening GIS Accuracy and Utility Operations

The benefits of the NILM project extend across the company's operational landscape and its customer base. For the company, the disaggregated insights provided a robust foundation for optimizing energy efficiency programs and crafting data-driven tariff structures. By understanding the dominant categories of energy consumption, the company gained valuable inputs for demand-side management strategies, further supporting grid stability and sustainability goals.

Consumers, empowered with category-specific data in Phase 1, gained actionable insights into their energy usage. This transparency fostered better energy management practices, enabling households to reduce costs and align their consumption habits with sustainability objectives. With the rollout of Phase 2, consumers can expect even greater value through detailed appliance-specific insights, promoting deeper engagement and smarter energy usage.

Conclusion: Driving Energy Intelligence Beyond Categories

The Non-Intrusive Load Disaggregation project showcases the company's commitment to leveraging data for operational and consumer benefits. Phase 1 successfully established category-level disaggregation, while Phase 2 aims to redefine precision by introducing appliance-specific insights. Together, these advancements represent a paradigm shift in how energy consumption is analyzed and understood.

By integrating AI/ML capabilities into smart meter data analytics, the company is not only addressing operational goals but also fostering a culture of informed energy use among its consumers. This initiative underscores the company's leadership in innovative energy solutions, paving the way for a more sustainable and efficient energy ecosystem in the country.