Energy Flexibility Services: Paving the way for **smarter Energy Management**

Transform your energy management, reduce costs, and improve operational resilience.

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Introduction

The increasing integration of renewable energy and the electrification of key sectors present significant challenges for traditional energy management systems. These legacy approaches, reliant on manual controls and fixed schedules, are no longer capable of handling the complexities of modern energy systems. This paper introduces energy flexibility services as a solution, leveraging advanced technologies such as IoT, Digital Energy Twin, AI, and real-time monitoring to dynamically manage energy consumption, reduce costs, and enhance grid stability.

The complexity of **energy management**

As the world intensifies its focus on reducing carbon emissions, governments, corporations, and cooperatives are progressively aligning their strategies for a low-carbon future. This global shift is driven by legislative mandates, market forces, and a shared commitment to sustainable development, with renewable energy serving as the keystone to this combined effort. However, the integration of renewables is not without its challenges and the widespread electrification of various sectors, which is also largely reliant on renewables, brings significant challenges to managing increasingly complex energy systems.

The rise of renewable energy and the impact of electrification

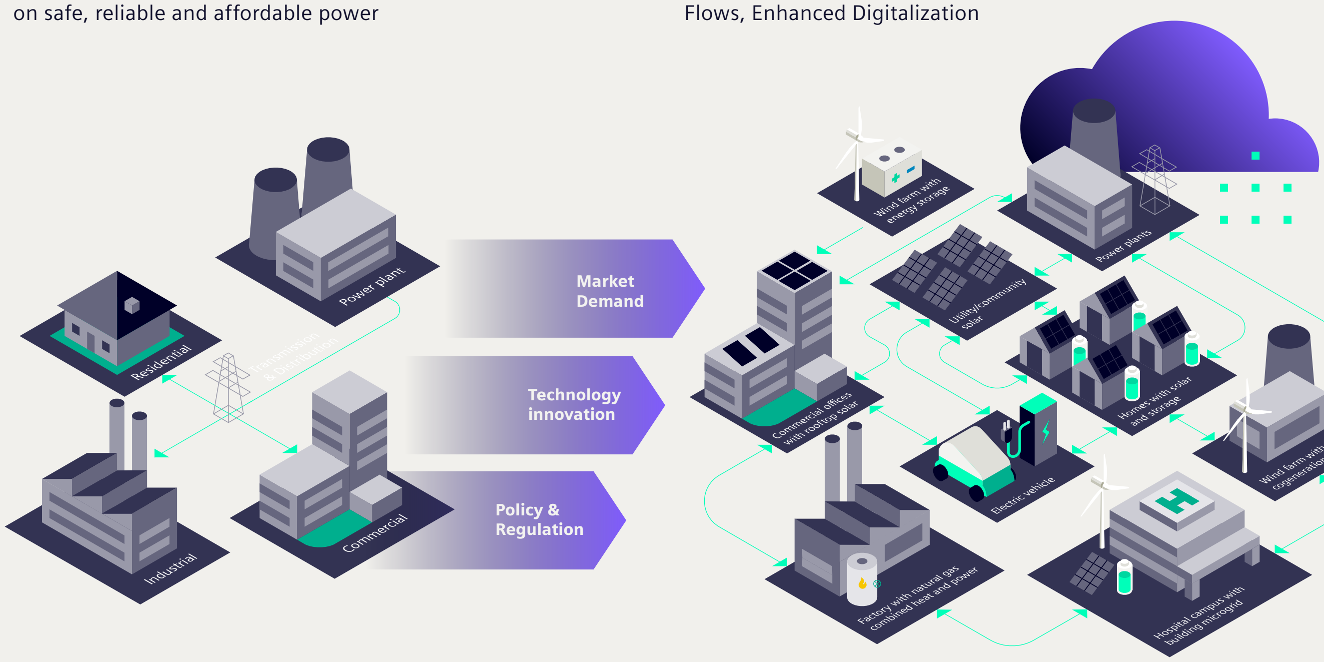
The renewable energy megatrend has gained momentum over the past few decades and is projected to accelerate at an even faster pace as nations work to meet ambitious decarbonization targets. The shift to renewables introduces new challenges, particularly with energy management. Renewable energy sources are inherently intermittent, with output fluctuating depending on weather conditions and time of day. This unpredictability makes it difficult to balance supply and demand and as a result, grid operators are challenged with maintaining stability, and producers and consumers face increased costs.

PAST

Central, One-Way Power System, focused on safe, reliable and affordable power

EMERGING

Distributed, Cleaner, Two-Way Power Flows, Enhanced Digitalization



Simultaneously, the electrification of major sectors such as heating, cooling, transportation, and industrial processes introduces new complexities, as energy systems become increasingly multimodal for the successful integration of diverse energy sources and technologies.

The energy transition also demands significant infrastructure investment. Upgrades to power grids, energy storage technologies, and smart systems are essential to support renewable energy integration, yet these come with increased costs for consumers. The intermittency of renewable sources also contributes to volatility in wholesale energy markets, leading to price spikes during periods of low generation.

Managing these systems requires advanced strategies to control and coordinate flexible loads, energy storage, and generation. The variability in energy demand and supply increases the need for intelligent and adaptive energy management solutions. These solutions must be capable of responding dynamically to fluctuations in energy availability and consumption patterns, ensuring both reliability and efficiency.

Traditional energy management methods

Traditionally, energy management has been achieved with the basic methods of manual control and fixed scheduling, typically without the use of automated or real-time optimization systems. Manual control relies on human intervention to turn on, turn off, or adjust energy-consuming devices or systems like lighting and HVAC.

Fixed scheduling involves pre-setting energy systems to operate according to a predefined, static schedule, regardless of real-time energy demand, cost, or system conditions. Devices or systems are programmed to turn on and off at specific times of the day, week, or season. The schedule is often determined based on typical usage patterns or operational needs but, like manual control, is limited in its adaptability.

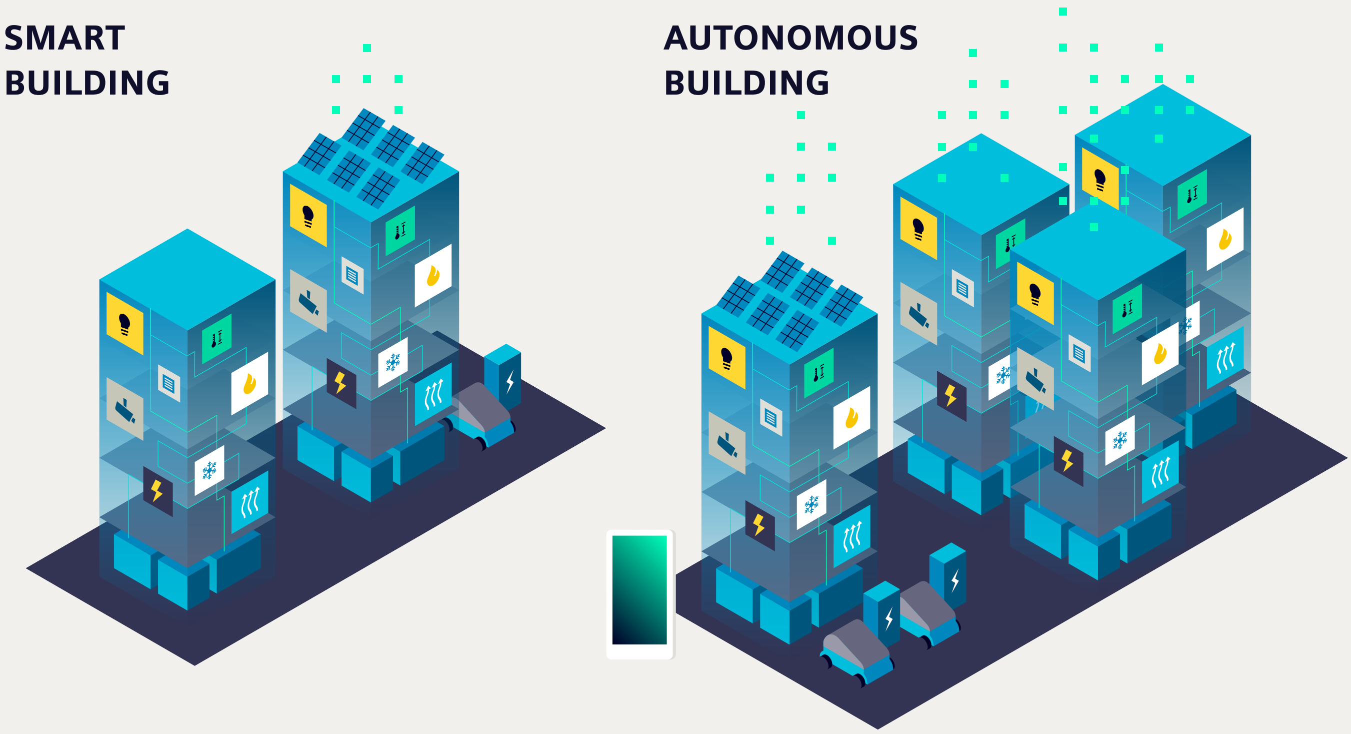
Limitations of traditional energy management methods

The limitations of traditional energy management methods can lead to several suboptimal outcomes, particularly in terms of efficiency and cost.

- **Increased costs:** Without automation or real-time adjustments, energy systems may run longer than necessary when demand is low, leading to higher costs.
- **Energy waste:** Operators may forget to turn off equipment, lighting, or HVAC systems when they are not needed, causing unnecessary energy consumption and additional cost.
- **Reduced system efficiency:** Reactive adjustments made by operators often lack precision and exclude factors such as fluctuating demand and weather conditions which results in reduced performance.
- **Lower operational flexibility:** Reliance on human intervention means that adapting quickly to changing energy needs or external factors, such as sudden spikes in demand is difficult.
- **Grid instability:** Failure to reduce or shift load during peak times may lead to grid instability, power outages, or higher peak power prices.

The case for smart energy management

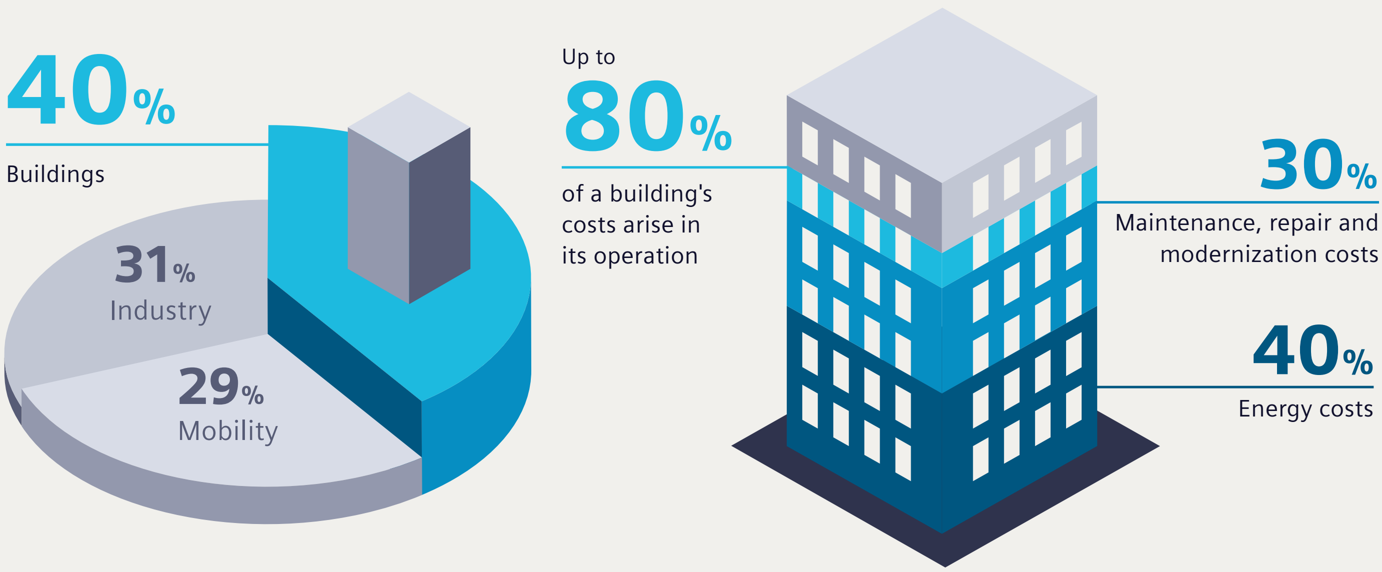
Managing modern energy systems requires adaptive energy management strategies. Intelligent solutions must be able to dynamically adjust to fluctuations in both energy supply and demand, ensuring reliability and efficiency are maintained across the grid. Smart energy management uses advanced technologies and systems driven by data and automation to optimize energy systems. By integrating IoT devices, AI, and real-time monitoring, it is possible to **optimize load**, so operations becomes more efficient, sustainable, and cost-effective.



Understanding **Load Optimization**

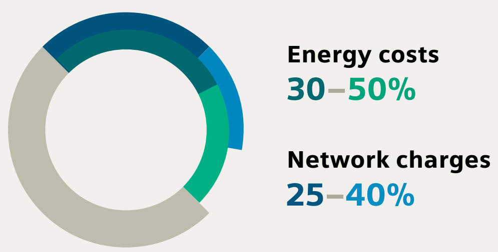
Load Optimization is a strategy to reduce strain on power grids by shifting energy use to off-peak periods or limiting usage during peak times through peak shaving. By lowering peak demand, it helps lower network charges tied to grid maintenance and congestion. Additionally, optimizing energy use during off-peak times also avoids higher energy prices and promotes greater use of cost-effective renewable energy.

EUROPE-WIDE ENERGY CONSUMPTION



What are we paying for?

Typical cost breakdown of an energy bill



Additional components

- **Environmental charges:** Costs associated with renewable energy programs, carbon pricing, or energy efficiency initiatives.
- **Taxes and Government Levies:** VAT, sales tax, or local energy taxes.
- **Administrative or retail charges:** For billing, metering, and customer services.
- **Miscellaneous fees:** Late payment penalties, reconnection charges, or green energy options.

A quick definition of costs and charges

Energy costs: charges in kWh for the electricity generated and consumed

Includes	Key factors influencing costs	Load Optimization strategies for cost reduction	
• Wholesale energy costs • Retail markups by electricity supplier • Fuel and operational costs of power plants	• Type of generation e.g. renewables, coal, gas, nuclear • Market conditions and fuel prices • Supply-demand dynamics	**Avoiding peak prices:** Shifting energy usage to off-peak times when demand is lower, consumers can take advantage of cheaper energy prices.	**Consuming renewable energy:** Aligns consumer energy use with periods of renewable energy generation. Renewables have lower marginal costs, so optimizing consumption during these periods lowers overall energy costs.

Network charges: Fees for using transmission infrastructure

Includes	Key factors influencing costs	Load Optimization strategies for cost reduction	
• Transmission charges • Distribution charges • Demand or capacity charges • Connection fees	• Infrastructure maintenance and upgrades • Grid losses during electricity transmission • Geographical distance from generation source • Local grid usages patterns	**Reducing peaks:** Lowering strain on the grid by shifting energy use to off-peak periods leads to lower peak demand, reducing the need for costly maintenance and lowering network charges.	**Decreasing grid congestion:** Minimizing congestion on the grid during high demand reduces the likelihood of outages, reducing associated costs that network operators pass on to consumers through higher network charges.

The relationship between network charges and demand charges

Network charges	Demand charges	Where demand charges are part of network charges	
• Cover the cost of maintaining and operating transmission and distribution infrastructure. Typically recovered through a mix of fixed charges, consumption-based charges (per kWh), and sometimes demand-based charges (per kW).	• Specifically reflect the cost of providing capacity to meet a customer's peak demand. • These charges may or may not be explicitly categorized under network charges, depending on how tariffs are designed.	**Integrated tariffs** In some electricity markets, demand charges are explicitly included as part of the network charge structure. For example: a portion of the network charge might be based on a customer's peak demand (measured in kW) to account for their contribution to grid capacity needs.	**Separate line items** In other cases, demand charges are listed separately on the bill and are not explicitly grouped under network charges. However, they still serve the same purpose: to reflect the cost of grid capacity requirements.

Key use cases for effective Load Optimization

The following Load Optimization use cases provide significant opportunities for energy management and optimization. Each one can operate independently to achieve the required outcome, but when stacked, their impact on efficiency and cost saving is far greater. For example, combining load shifting and load shedding with AI-driven forecasting is a powerful strategy for reducing peak demand and lowering energy costs.

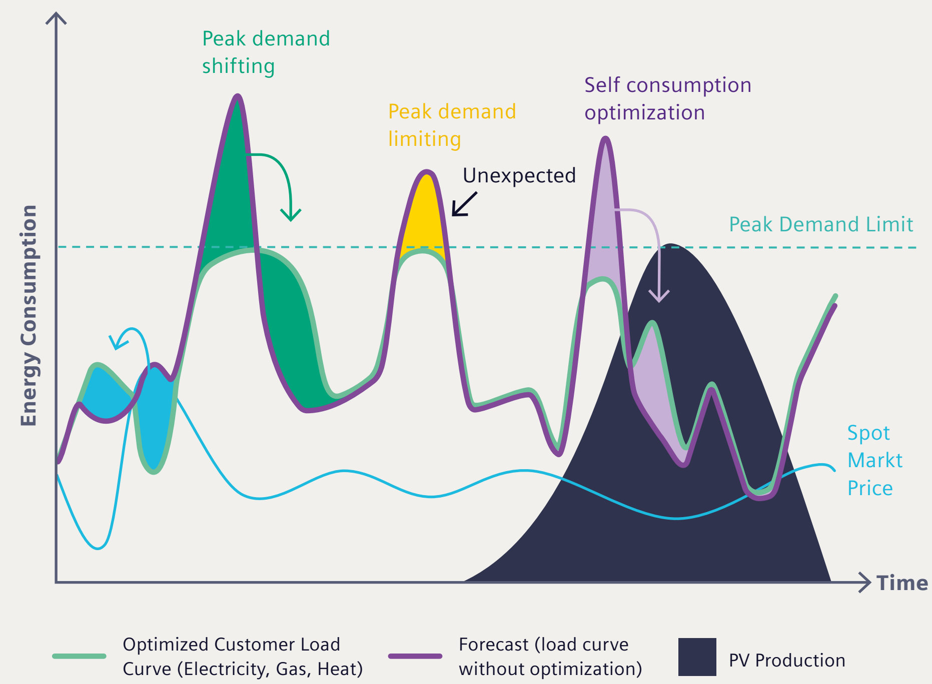
Load shedding reduces energy usage by adjusting the power of equipment during peak demand and by combining it with AI and load shifting its impact is maximized.

By using AI forecasts to pre-emptively shift load, the need for load shedding is minimized. This enables strategic energy reductions that avoid interrupting critical services. For instance, in commercial buildings, dynamic load shedding is implemented while maintaining comfort conditions and in hospitals, continuous operations are preserved without compromising patient care.

> If load shedding can reduce energy consumption by up to 12%, combining it with load shifting can lead to **savings of up to 30% on peak demand pricing.**

EXAMPLE 1 MW/H (GERMAN ENERGY MARKET)

+ Demand Response
+ Ancillary Services



Energy Market Optimization
277 €/a

Spot Market Price
+ Peak Demand Limiting
140.000 €/a

Self Consumption Optimization
87.000 €/a

Σ Customer Savings
417.000 €/a

SU Flex Service

- Continues Optimization
- 24/7 Operation
- Stacking Use Cases
- AI / ML Algorithm
- Adaptive Use Case Decision

Observability and controllability

Observability and controllability are key functionalities to be ensured for the proper management of a flexible power system. Working group 1 discussed about which are the DSO requirements for monitoring the status of the distributed resources, especially of those that nowadays have low visibility, and how to ensure reliable flexibility service activation.

Peak demand limiting (load shedding)

- Reduces energy use by adjusting the power supply to equipment when demand nears set thresholds and restores load as capacity becomes available.
- Smart building energy management systems dynamically adjust non-critical systems such as HVAC using real-time data to limit peak demand.

Energy flexibility (load shifting)

- Shifts energy use from peak to off-peak hours, balancing load and reducing network charges.
- Industrial facilities can reschedule energy-intensive processes during off-peak time to benefit from lower electricity prices.

Demand forecasting

- AI algorithms predict energy demand using historical data, schedules, and weather, optimizing systems to prevent blackouts and outages.
- Ensures sufficient energy for critical functions for buildings such as hospitals, while reducing overconsumption during non-peak times.

Demand response

- Enables commercial or industrial energy consumers to adjust usage based on market signals like price changes or grid needs to influence prices and enhance grid reliability.
- Allows consumers to reduce power or shift non-critical tasks during peak demand for financial reward. Particularly valuable to data centers that require significant energy for cooling.

Self-consumption

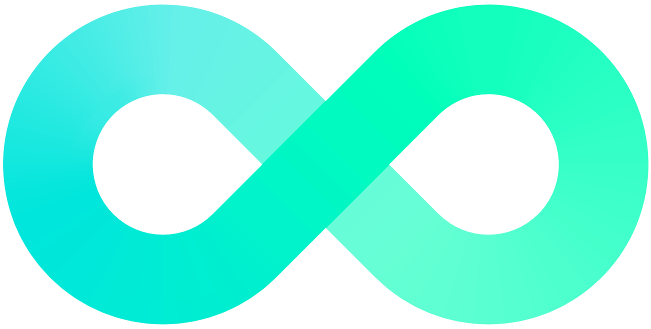
- Meets local energy needs with on-site generation such as solar PV panels, reducing reliance on grid electricity and cutting costs.
- Surplus energy can be sold back to the grid, generating revenue through feed-in tariffs or purchase agreements.

Energy storage

- Low-cost or renewable electricity is stored for use during peak demand to reduce costs and reliance on the grid.
- Supports continuous operations for large industrial facilities even during grid disruptions.

Intraday and day-ahead markets

- Short-term electricity trading allows energy to be bought based on forecasted demand (day-ahead) or adjusted for unexpected changes (intraday) to leverage price differences.
- Consumers can buy and store low-cost energy for use or resale during peak pricing benefitting, particularly, high energy use businesses like manufacturing plants or data centers.



The benefits of Load Optimization

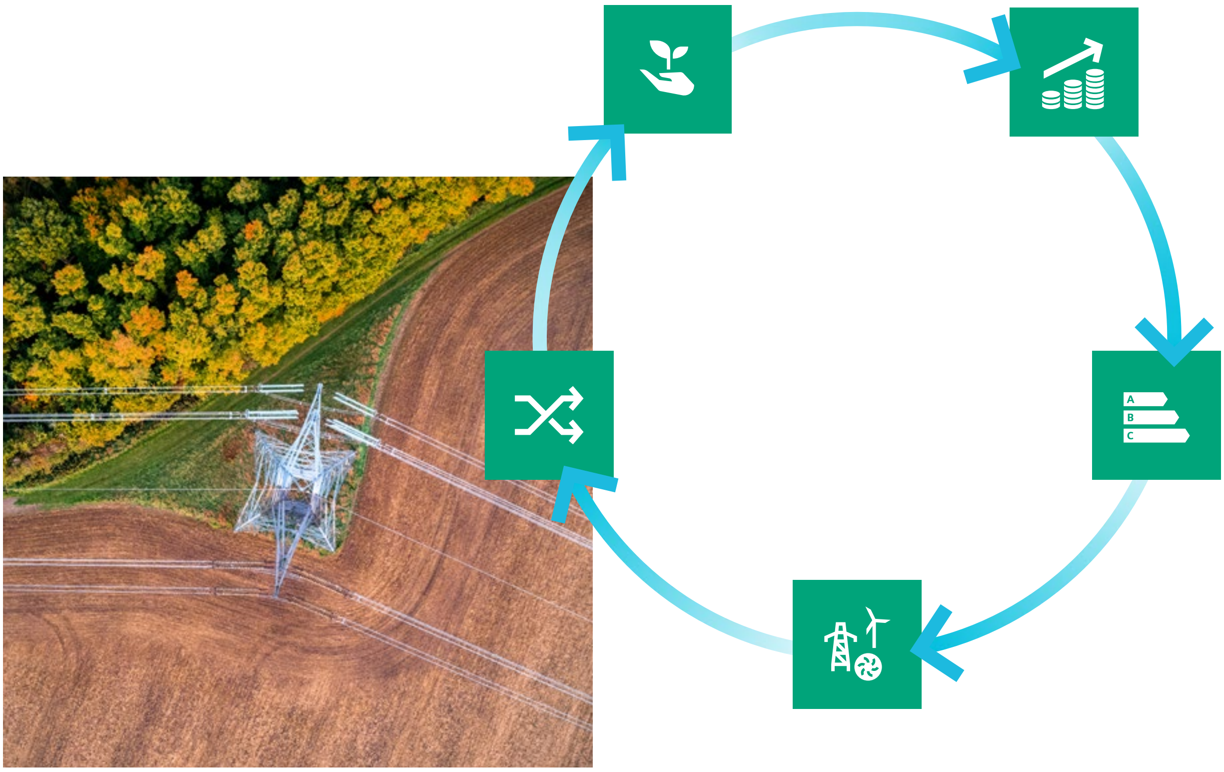
Cost savings: By shifting energy use to off-peak times when electricity rates are lower, significant savings on energy bills can be achieved.

Increased energy efficiency: Energy assets are used more effectively to reduce excess consumption and improve overall system efficiency. By avoiding overloading or under-utilizing equipment, Load Optimization can extend the lifespan of machinery and reduce maintenance costs.

Improved grid stability: Participation in demand response programs, where consumers reduce or shift their energy usage during peak demand periods, helps to stabilize power grids. By balancing energy loads, optimization helps prevent grid overloads and potential outages, creating a more reliable energy supply.

Flexibility and resilience: Flexibility in energy management allows organizations to adapt quickly to changing energy prices and market conditions. With optimized load management, businesses are better prepared to handle unexpected energy price spikes or shortages.

Enhanced sustainability: Load Optimization encourages the use of renewable energy sources during their peak generation times, leading to a lower reliance on fossil fuels and reduced emissions.



Practical application of Load Optimization in vertical markets

Commercial or Industrial Buildings

Buildings, both commercial and industrial, contribute significantly to peak energy demand, which puts strain on electrical grids and results in higher operational costs. Traditional building management systems (BMS) lack the capability to optimize energy consumption in real-time during peak periods, leading to inefficiencies and higher energy bills.

The implementation of a peak management service on edge-based infrastructure for buildings, aimed at reducing energy consumption during peak periods, lowers costs, and improves building energy efficiency.

The proposed solution enables real-time energy management at the edge, close to the building's critical systems, allowing for faster response times and better control over energy-intensive operations like HVAC, lighting, and equipment usage.

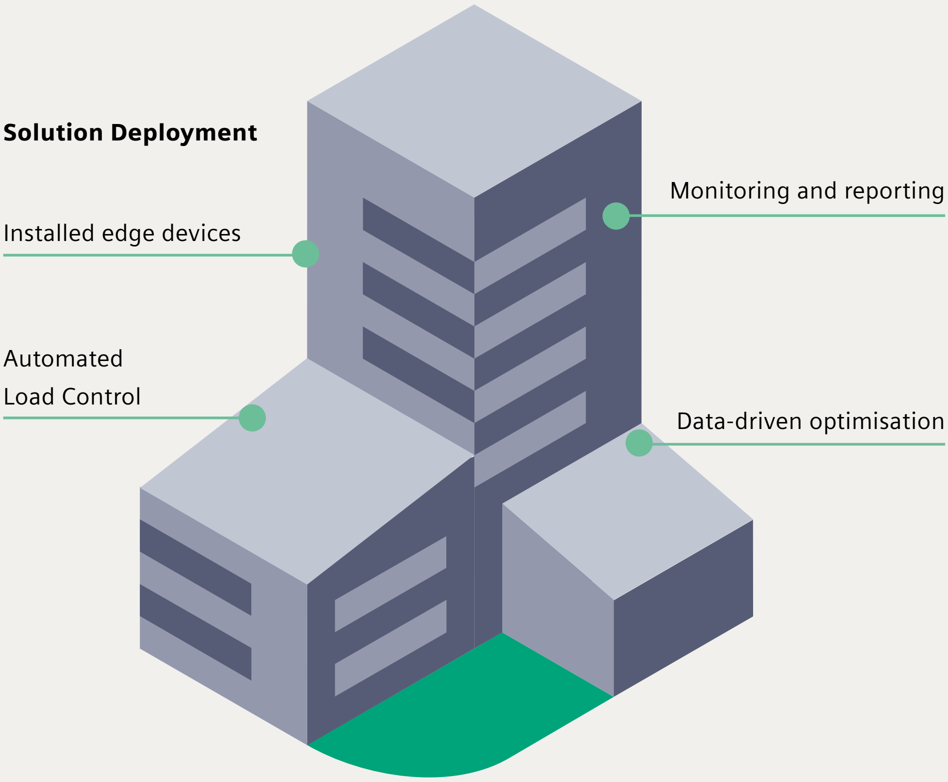
It is expected to reduce peak demand charges by up to 25%, improve building energy efficiency by 15%, and contribute to sustainability goals by lowering the building's carbon footprint.

Building Profile

Size: 500,000 square feet commercial office space.

Annual Energy Consumption: 12,000 MWh.

Current Energy Challenge: The building experiences high energy costs during summer afternoons when HVAC demand spikes. The building's peak demand charges account for 30% of its total.



Expected Results

Energy Savings: A projected 20% reduction in peak energy demand, translating into annual savings of $120,000 in energy bills.

Improved Efficiency: Overall building energy consumption reduced by 10%, with better HVAC performance and occupant comfort maintained.

Return on Investment (ROI): Achieved within 18 months, based on energy cost savings and reduced demand charges.

How **Load Optimization** works

Advanced AI-based solutions offer sophisticated methods for optimizing dynamic energy assets. By integrating real-time data analysis, predictive control, and automated decision-making processes, these solutions deliver significant improvements in energy efficiency, cost reductions, and enhanced grid stability. Load Optimization follows three key phases, each of which contributes to integrated energy management.

1. Digital Energy Twin:

The initial phase of Load Optimization involves the development of a digital Energy Twin – a virtual replica of the building, campus, hospital or industrial facility. The digital Energy Twin maps all on-site energy assets – such as heat pumps, batteries, chillers, solar PV, CHP - alongside the network topology and the interconnections between these assets. The digital Energy Twin enables accurate simulation and optimization of the real-life systems, facilitating both predictive and reactive measures to be taken to maximize efficiency, minimize operating costs, and reduce CO_2 emissions.

2. Forecasting:

While optimization can happen in real time based on a system's current state, forecasting improves efficiency by predicting future energy needs. AI algorithms, in conjunction with the digital Energy Twin, analyze historical data such as energy prices, energy loads, on-site generation and weather forecasts to predict what demand will be within the next hour, day, or even week. By leveraging these forecasts, the system can accurately determine the best strategy for the following days to allow the consumer to run cost-optimized operations.

3. Optimization:

Optimization is where strategies are determined based on the consumer goals of cost saving, emissions reductions, or lower energy consumption. For example, the system can determine when to charge or discharge a battery, or when to operate a heat pump to balance operational efficiency with comfort conditions. The system can also identify and exploit additional flexibility within the building, determining whether to use it or offer it to energy markets to create revenue.

The entire process is automated and operates 24/7 with minimal human involvement. Using Application Programming Interfaces (APIs), the system integrates real-time market prices, weather data, and regulatory updates to ensure the system is responsive to these changing conditions. The digital Energy Twin and AI-derived forecasting evolves dynamically, allowing for simultaneous deployment of use cases. Depending on the current conditions, the system will prioritize the use case or combination of stacked use cases for the desired outcome.

REAL-WORLD CASE

Demonstrating the **potential of Load Optimization**

European campus tests flexibility optimization

Aspern is a new district on the outskirts of Vienna, designed and constructed as an innovative and sustainable energy efficiency demonstration project as part of Aspern Smart City Research (ASCR). One of its key objectives is to operate the electric energy system with minimal operating costs and with Siemens as its trusted technology partner has developed a solution to meet this target.

Energy flexibility solution

An energy flexibility strategy was implemented to optimize self-consumption and reduce costs. PV generated power is used in a cost-optimal way and takes into consideration a limit for grid feed-in as well as dynamic feed-in prices. The buildings use energy flexibility to bring in monthly peak power cost reductions and to optimize demand based on day-ahead electricity prices. Battery storage operation uses PV generation forecasts, base load forecasts, and dynamic tariffs for grid demand and feed in.

Results

Up to
30%
reduced peak power cost

Negative energy prices
through optimal planning of PV

Additionally, the customer achieved substantial cost savings and energy efficiency, and the integration of electric heaters allows surplus power to be used efficiently when prices are favorable to contribute to further cost reductions.

How to **become energy intelligent**

Benchmark
The journey toward energy optimization begins with a comprehensive audit of your assets and systems. This step provides a clear understanding of your current performance levels. Since every user's electrical load is unique, the initial analysis should take into consideration consumption patterns, energy supply, operational efficiency, and overall building performance. Collaborating with a trusted technology partner, such as Siemens, ensures the audit is both accurate and transparent.

Map
Strategic planning is essential for successful energy Load Optimization. Your trusted technology partner will enable you to map out future requirements, including growth plans, asset changes, and evolving usage patterns. By aligning these insights with your corporate sustainability objectives and revenue targets you can identify solutions that balance operational efficiency with long-term goals.

Consult
Energy management and optimization offer many opportunities to enhance performance and reduce costs. Engaging an expert partner ensures your specific use cases are carefully assessed to deliver the best solutions for your operations. A trusted advisor will help you implement strategies that meet your efficiency and cost-reduction objectives.

Sustain
Achieving energy intelligence is an ongoing process. Your technology partner will provide continuous support to help you maintain peak performance, maximize cost savings, and adapt to changing operational needs.

Conclusion

The growing complexity of energy systems makes **Energy Flexibility Services** an essential tool for modern **energy management**. We expect Energy Flexibility Services to become a common practice, integral to achieving both operational, financial and environmental goals. With advancements in AI, IoT, and predictive analytics, managing energy demand will not only be more efficient but also more critical.

Energy Flexibility Services is pivotal to achieving decarbonization targets. By enabling greater integration of renewable energy sources, reducing reliance on fossil fuels, and improving energy efficiency, these strategies can contribute significantly to lowering carbon emissions. Businesses that adopt Load Optimization are not just reducing costs but actively participating in creating a low-carbon economy.

Now is the time for organizations to take action. By exploring Load Optimization opportunities and investing in the right systems, solutions and partnerships, businesses can achieve substantial benefits and future-proof their energy strategies. Whether through the integration of AI-driven forecasting, demand response programs, or energy storage solutions, the possibilities are vast. To remain competitive, reduce costs, and support the global transition to a more sustainable energy future, companies must start adopting smart energy management solutions today.

By exploring Energy Flexibility Services opportunities and investing in the right systems, solutions and partnerships, businesses can achieve substantial benefits and future-proof their energy strategies.

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We create technology to transform the everyday, for everyone. Our world is changing at an unprecedented rate. Demographic change, urbanization, glocalization, environmental change, resource efficiency, and digitalization are presenting new challenges and opportunities.

Siemens Smart Infrastructure addresses these topics by combining the real and the digital worlds.

Our technology transforms infrastructure, across buildings, electrification, and grids, at speed and scale, enabling collaborative ecosystems to accelerate our customers' digital journey to become more competitive, more resilient, and more sustainable.

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