EUCloudEdgeIoT.eu

Market Pathways for Cloud Edge IoT in Energy Sector

WHITE PAPER

White paper

Author:

Autor: Hannah Funk (VDI/VDE-IT GmbH)

Contributors:

Daniel Lindén (Tibber Deutschland GmbH)

Blaine Mathieu (Pratexo, Inc)

Wilbert Prinssen (Technolution B.V.)

Robert de Leeuw (PIONIX GmbH)

Henrik Madsen (Center Denmark)

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1. Market Pathways for Cloud Edge IoT in Energy Sector

In addition to the energy transition necessitated by climate change, the energy crisis caused by geopolitical tensions has highlighted the heavy reliance on a single energy supplier, leading to rising energy costs and a slowdown in economic growth, pushing up the inflation rate.

The EU Data Strategy underlines the strategic importance of strengthening the European cloud-to-edge supply industry to ensure resilience and establish the EU as a leading global data hub. This strategy, supported by initiatives such as the IPCEI on Next Generation Cloud Infrastructure and Services and Horizon Europe, aims to create a robust cloud, edge and IoT computing ecosystem. By integrating cloud and edge computing, the EU can increase the efficiency and automation of energy systems, reducing energy consumption and improving flexibility, which is crucial for the transition to renewable energy sources. (European Strategy for Cloud and Edge)

With the initiative EU Cloud Edge IoT, the European Commission launched a funding program with the focus on cloud, IoT and edge computing technologies to de-risk the dependences on non-European cloud-computing providers, leverage the potential of multi-stakeholder open source communities and data driven value chains.

We would like to explore the technological challenges and solutions that enable a green and digital transition along with market pathways for the European companies. We will point out critical dependencies from non-European market players and highlight market pathways taken by the innovative European CEI solution providers in the energy sector.

1.1 Digital transformation of the energy sector

The main challenge in the energy sector is the transformation towards an efficient and resilient integration of flexible energy generation sources and storage solutions.

To meet the overall challenges the following objectives should be pursued:

- Flexibility: Integration of flexible energy sources
- Stability/resilience: Network observability, automation and controllability
- Efficiency: economic use of energy.

Seamless digitization of the energy sector is key to successfully shifting consumption/generation to another time and/or place. Cloud-Edge-IoT Continuum hence serves as an enabler for the transformation in the Energy Sector.

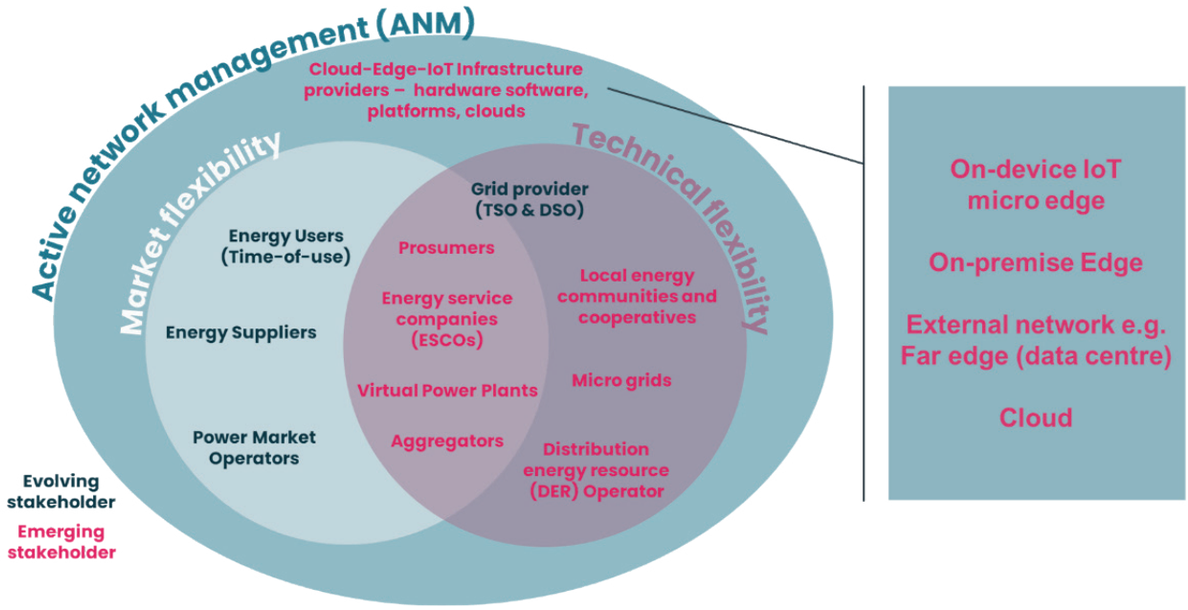

Figure 1: Non-Linear Energy Value Network Source: Adapted from D3.2[1]

In this sense, the formerly linear value chain needs to be updated to a non-linear value network, with evolving actors successfully operating in the existing energy market and new emerging actors disrupting the old business relationships in the existing value network. Cloud Edge and IoT (CEI) technologies play a key role in this transformation, as both market and technical flexibility are not possible without flexible and reliable digital infrastructure and services.

The energy transition brings with it new roles, regulations and opportunities in the energy system - such as prosumers or digital infrastructure providers to activate flexibility potential - but also stability and security concerns and additional challenges such as decentralisation, dependence on weather-dependent renewable energy sources and energy flows in multiple directions. The digitalization of the energy sector with CEI's smart grid and energy management solutions has become essential for a successful transition. Digitalization must penetrate the energy system at all levels.

1

2 Approach and analysis methodology

In the following, we would like to illustrate which innovative solutions and Cloud-Edge-IoT technologies are already available on the market and how they can enable the shift to renewable energy sources.

To understand the current state of this transformation process, we will look in to the CEI market dynamics in the Energy Sector, in particularly:

- Who are the big tech players in the CEI market and which services do they offer?
- How the big tech CEI players cooperate with big players from the Energy sector?
- Which players in the Energy sector provide new innovative solutions? And how these solutions contribute to the transformation in the Energy Sector?
- Where are the major dependencies from the big tech players and the resulting risks? What are market pathways and opportunities for CEI companies in the Energy sector?

Are CEI and energy markets ready for data sharing?

- Together with our partners IDC and Bluspecs, we identified basic building blocks that depict possible Cloud-Edge-IoT configurations for the technical infrastructures and services (see Figure 2).
- Each of these building blocks represents a domain that may require significant development and innovation to enable widespread adoption of the applications in the CEI continuum.
- To explore the innovation potential in these domains, we mapped the CEI players to the building blocks and conducted workshops supplemented by in-depth interviews with industry experts. We asked questions about how their products, platforms and services would contribute to innovation in the illustrated domains. In addition, we discussed the level of adoption of data sharing, open source software and hardware architectures by the demand side in the energy sector.

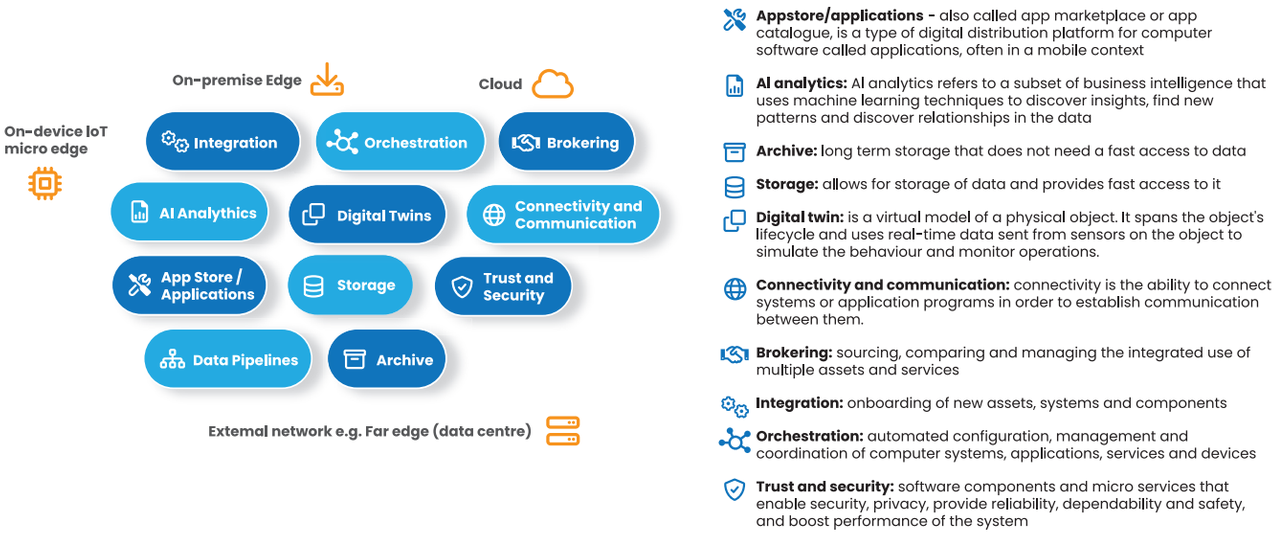

Figure 2: Cloud-Edge-IoT Building Blocks - Source: UnlockCEI

3 CEI infrastructure providers and the market dynamics in the energy sector

An analysis of CEI infrastructure providers in the energy sector and the mapping of cross-domain and energy sector-specific players to the CEI building blocks revealed the following: while major players such as AWS[2], Microsoft[3], IBM[4] and Bosch IoT are relevant to most of the CEI continuum building blocks in the energy sector, there are also a number of energy sector-specific players. Most of them can be found in a combination of CEI building blocks. Others offer very specific services. Overall a wide range of CEI companies are active in the energy Sector.

The following sections provide an overview of the current state of distributed data management in the energy sector, followed by some innovative solutions. Those solutions give examples of business models and governance structures that drive **open source solutions**. And discuss the following questions: What level of **data sharing** is necessary for solutions? Are CEI and energy markets as well as users ready for it? They also illustrate business models based on open source and provide insights into the governance structures of open source projects that foster an active multi-stakeholder contributor community.

3.1 Innovative solution by Tibber: Flexible electricity tariff and smart Energy Management for end-users

Tibber operates as a completely digital energy company and provides electricity to hundreds of thousands of households in Sweden, Norway, Germany, and the Netherlands. Employing digital technology, it acts as an **Electricity Retailer** that assists customers in minimising energy consumption and shifting usage to periods of lower electricity costs. They charge a monthly fee for their optimisation service and sell additional hardware products, while they pass on the original time of use energy price to the customer. By doing so, this business model differs significantly from "standard" energy providers whose charging models are based on energy consumption**.**

The **Smart Energy Management** is done in an App that integrates hardware such as heat pumps, solar panels, EV WallBoxes and Batteries (also sell a Battery "Homevolt", but integrate others as well) and smart home devices such as smart thermostats and connected appliances (e.g. washing machine). For the minimisation of the energy use and costs Tibber employs over 100 different services, to learn user patterns and enhance energy efficiency delivered by mainly non-European cloud providers (Azure,

Figure 3: View of Tibber App of electricity usage and dynamic tariff - Source: https://tibber.com/de/stromtarif/dynamischer-stromtarif

2 https://aws.amazon.com/iot-core/?nc1=h_ls
3 https://learn.microsoft.com/en-us/azure/iot-edge/about-iot-edge?view=iotedge-1.4
4 https://www.ibm.com/products/maximo/environmental-health-safety

also Google Deep Mind and in house developments) and incorporating artificial intelligence and machine learning algorithms.

They have also contributed to grid flexibility by selling flexibility (e.g. shifting EV charging times) to DSOs and acting as aggregators for TSOs. However, this service is only offered on a small scale and is not available in all EU countries.

For Tibber the following points are slowing down the transition to a smart energy system and their service:

1. The unavailability of energy data in many European markets.
2. Highly regulated networks, at TSO level, but especially at very local DSO level.
3. DSOs are often too small to invest in digitisation and need additional funding
4. Lack of pricing of flexibility needs of TSOs and DSOs.

Tibber is an emerging stakeholder that offers a promising solution for more flexibility, stability and efficiency in smart energy systems. However, their service relies heavily on non-European cloud providers, as this is currently the only business-wise feasible solution.

3.2 Innovative solution by Technolution: Edge hardware and horizontal architectures

Technolution focuses on the development of advanced electronics such as sensors, actuators and software to bridge the digital and physical worlds, and aims to give customers the freedom to choose the best technologies for each component, enabling faster innovation cycles and reducing the risk of obsolescence, particularly in markets such as mobility and infrastructure, security, high-tech industry and energy solutions. The company emphasises the need for a shift away from traditional vertical architectures towards more **horizontal architectures** that are more flexible, scalable and adaptable due to modularity.

One concrete **edge solution** in the energy sector is the Smart Cable Guard system, developed by Technolution in collaboration with DNV. Sensors and a control unit box are utilised to monitor mid-voltage cables in electricity grids. By placing sensors on both ends of the cable, the system detects patterns indicating cable degradation or partial discharge. This data is locally analysed to pinpoint the location and extent of the degradation, enabling proactive maintenance. The system has been installed globally.

Another solution offered by Technolution is edge computing for distribution system operator (DSO) substations, an area where integrating new IoT innovations can be challenging due to conservatism and cybersecurity concerns, as protection and control have traditionally been dominant in these systems. However, in collaboration with Alliander, a Dutch energy network and its subsidiary Alliander Locamation (now rebranded in Grid to Great), Technolution has developed voltage and current sensors for 50 kilovolt substations. These sensors not only share their data with the classic central control room of these stations for protection and control, but also use open protocol streams that enable data sharing for enhanced functionality on the edge platform. A data diode ensures one-way data flow, mitigating cybersecurity risks. The edge platform, powered by a powerful server, analyses high-frequency data streams from the sensors. This allows for the deployment of third-party apps, such as power quality analysis or asset monitoring, using open-source infrastructure like Linux and communication protocols like ZeroMQ or MQTT.

By performing local analytics at the edge, the system minimizes the need for data transmission to the cloud, reducing bandwidth requirements. Only derived information from advanced analytics is sent to central control rooms, enhancing operational efficiency. A Collaboration with Delft University on the Control Room of the Future project ensures an open, prototype-driven approach, fostering innovation in the electricity grid domain.

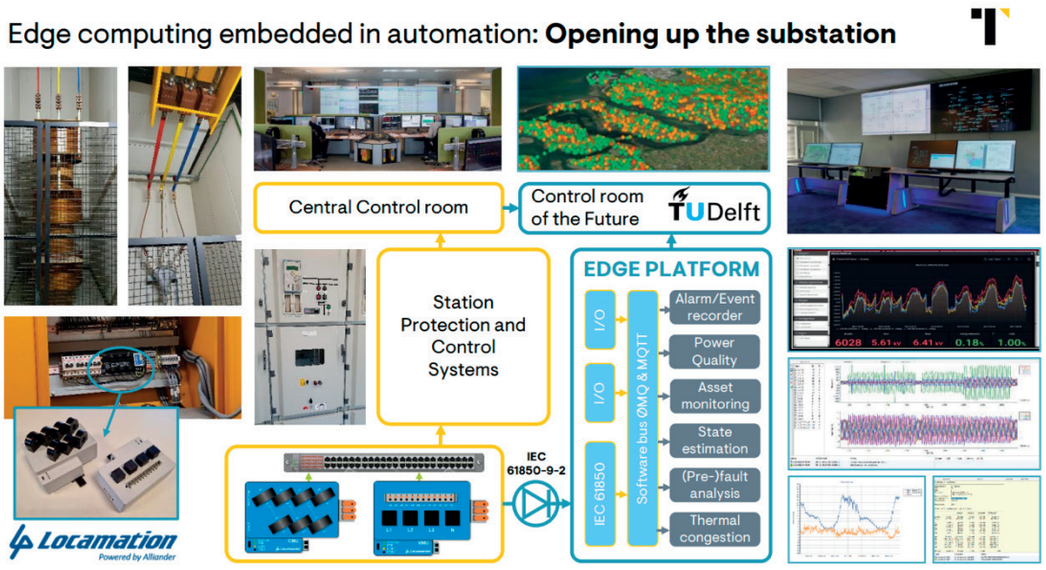

Figure 4: Technolution edge platform in DSO substation - Source: Wilbert Prinssen

In another collaboration Technolution partners with Dutch DSOs. Formerly smart meters were closed-source and required complete replacement for simple upgrades like modem changes. Currently Dutch DSOs are innovating smart meters to be more modular and adaptable. Technolution has implemented a demonstrator and prototyping projects to support the DSO's in the future smart meter programme (NextGen) run by the Dutch DSO's (combined in Netbeheer Nederland). The top box contains the modem and processing power, which are interchangeable, allowing easy upgrades without disturbing the high voltage insulation. Expanding beyond hardware modularity, Technolution and partners developed a demonstrator for modular software, including an app store for residents. This approach, tested at TU Delft Green Village living lab, promotes a federated data architecture, storing all data locally on the smart meter rather than in centralized data lakes. Residents gain control over their energy data, similar to managing smartphone apps, enabling various use cases that can increase flexibility, stability and efficiency of the energy system. Pilots include sharing data with in-house appliances and energy providers, empowering residents while ensuring privacy compliance. This initiative transforms smart meters into dynamic platforms, fostering innovation and user empowerment in energy management.

By integrating edge hardware with software capable of processing large volumes or sensitive data at the edge, Technolution improves operational efficiency and stability while also expanding flexibility options for energy systems. This approach ensures compliance with privacy and security requirements through measures such as one-way data flow.

3.3 Innovative Solutions by EVerest/Pionix: Open-source software at the edge

The EVerest project was initiated by PIONIX GmbH in 2021 with the goal of developing and maintaining an **open-source software stack for EV charging stations**. Since 2022, EVerest has been part of the Linux Foundation Energy and has gained support from key partners like Chargebyte and Qwello.

The problem: Charging station companies typically develop their own software or purchase different software components from other companies. This results in inefficiencies due to redundant development efforts and interoperability issues within charging stations, especially with the increasing number of new EVs on the market. Additionally, protocols between vehicles and charging stations must comply with evolving communication standards, safety standards,

regulations, and standards for grid or home automation connections to integrate EV charging into grid and home energy management systems.

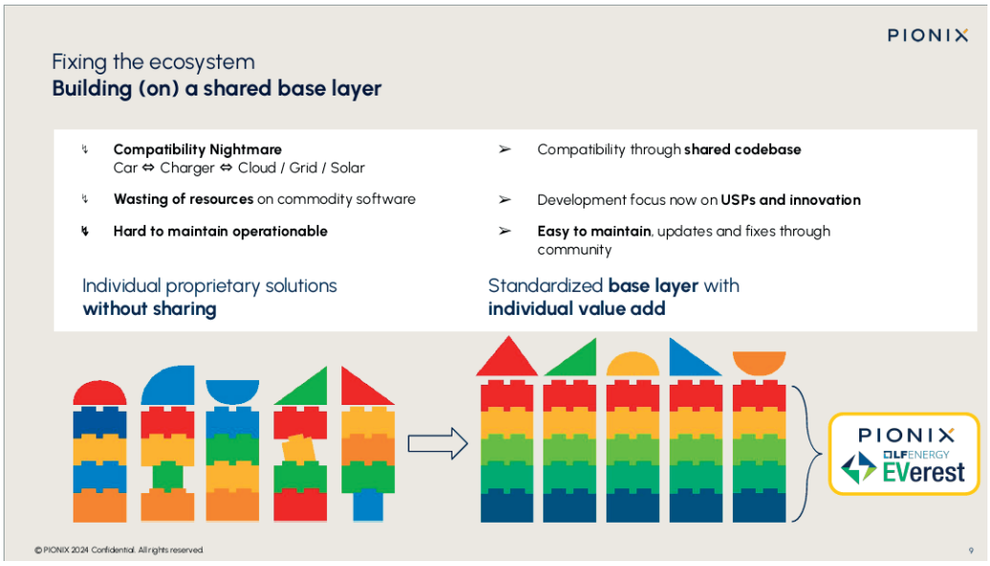

Figure 5: Advantages of open-source software stack for charging stations by Everest/PIONIX - Source: Robert De Leeuw

The solution: EVerest is a **community-driven**, open-source software stack for charging stations, designed to tackle the challenges of **integrating various protocols and standards**. By providing a standardized base layer, EVerest allows hardware producers to focus on adding their unique value, eliminating the need to implement numerous standard protocols. This simplifies the process for charging station manufacturers, and EV manufacturers benefit by needing to test with just one software instead of countless charging stations (see Figure 5). The shared codebase ensures compatibility, facilitates the development of new USPs and innovations, meets security requirements and is easily maintained through community updates and fixes. By abstracting the complexity of multiple standards and use cases, EVerest can operate on any device, from unmanaged AC home chargers to complex multi-EVSE satellite public DC charging stations with battery and solar support.

PIONIX initiated the Everest project but believes a successful open-source project should be managed by an open-source community, so they chose the Linux Foundation. To generate revenue, PIONIX offers a corporate-grade version of EVerest, which includes professional services and maintenance contracts.

This allows companies to outsource software maintenance without needing in-house software engineers. Additionally, PIONIX sells open hardware, such as the BelayBox, a charging station designed for developers.

Every project with the Linux Foundation requires a Technical Steering Committee (TSC). PIONIX is part of this committee, along with others, including the US Joint Office of Energy and Transportation since spring 2024. This US government body coordinates expertise between the Department of Energy and the Department of Transportation to advance zero-emission transportation infrastructure, significantly boosting EVerest's traction.

With increasing contributions, EVerest has divided the work into specific working groups: communication protocols to the car, communication to the cloud, testing and build pipelines, and the EVerest framework and tools. The community continues to grow rapidly. The broad community of active partners and customers consists of standardization bodies, academia & research, makers, hackers & enthusiasts, as well as component suppliers, charging station OEMs, and e-mobility service providers & utilities. EVerest is continuously working towards a global standard and is also

in contact with Chinese standardisation bodies, as the Chinese market for charging points and electric vehicles is very large. The key issue for the industry in Europe at the moment is that the EU does not require OCPP (Open Charge Point Protocol) for charging stations. Although OCPP is used as a standard by the industry, it is not defined by an international standards body. European regulations state that governments can't mandate a standard that lacks such official recognition. As a result, many countries require charging stations to meet certain standards, but can't enforce OCPP. Efforts are underway to make OCPP an IEC standard, but it's a slow political process.

Currently, OEMs collect and own data from their vehicles and charge point operators (CPOs) collect significant data from charging stations. In some countries, CPOs share this data with governments and universities for research purposes. However, CPOs are not yet sharing much data with transmission system operators (TSOs).

EVerest and PIONIX exemplify how open-source projects can address challenges such as incompatibilities, slow innovation, and vendor lock-in at the edge, facilitating the electrification of the mobility sector. Furthermore the open character of the project will simplify large scale collaborations between CPOs and grid operators, for using the potentials of smart charging opportunities for a more flexible, stabile and efficient grid in the future.

3.4 Innovative Solutions at Center Denmark: Digital infrastructure for sector coupling and activating energy demand-side flexibility

Center Denmark is a European non-profit and independent company that provides digital infrastructure that supports players in the energy sector to develop new data-driven solutions that take advantage of opportunities in sector coupling and accelerate the green transition. It aims at facilitating trusted Cloud-Edge-IoT solutions and spatio-temporal data spaces using open-solutions which put priorities in cyber security and in empowering the partners such that they are able to provide Digitalized and Efficient Smart Energy Solutions for People and Industry without being subject to disproportionate technical or administrative requirements, procedures and charges.

The **Smart-Energy Operating-Systems (SE-OS)** framework developed at Center Denmark can be used to develop, implement and test digital solutions for **optimising energy systems at all scales** between the Edge and the Clouds (see Figure 6) as well as the physical world and energy markets. It consists of layers for data, models, optimization, control, and communication, and is a mathematical key of controllers that uses **Minimum Interoperability Mechanisms (MIMs)/ flexibility functions** as a set of standards to ensure communication between these layers. To ensure temporal and spatial correlation for operations, simplified models are used with **real data-driven digital twins**. These simplifications prevent calculation times from exceeding operation times, unlike full-blown digital twins with overly complex models.

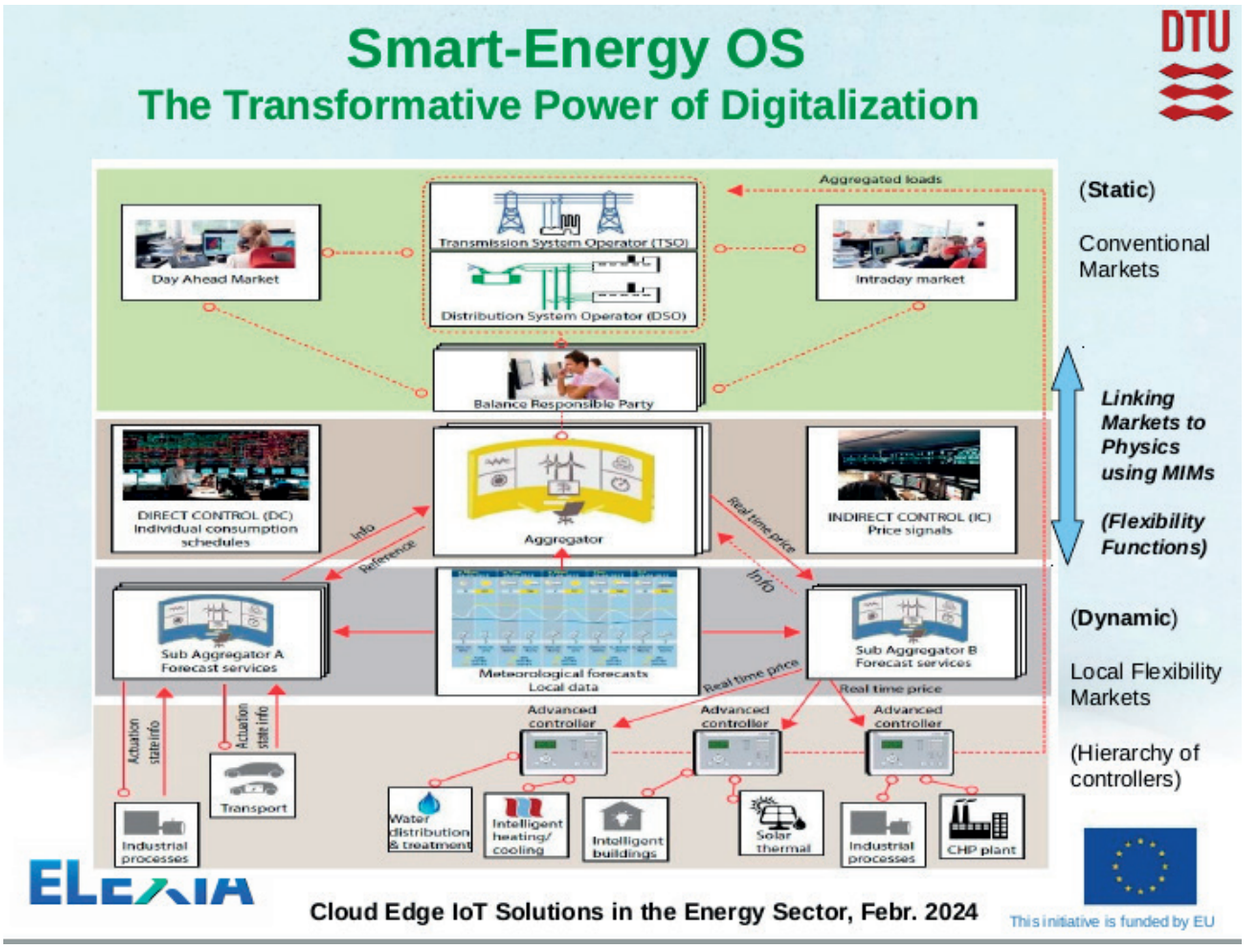

Figure 6: Smart-Energy Operating System linking markets to physiks using MIMs - Source Henrik Madsen

The SE-OS can integrate all energy vectors within the system, including e.g. hydrogen, gas, district heating, and wastewater treatment, in addition to the electricity grid. For instance, district heating, as a slower energy system, can play a crucial role in balancing wind and solar power effectively.

Center Denmark showcases the board applicability of the SE-OS approach in many European, but also several international projects in the mobility and energy sector using these MIMs plus APIs to connect the different dots.

One example is a collaboration with the holiday home provider NOVASOL, in which swimming pools in summer houses are used to store excess wind energy to save costs and stabilize the grid. MIMs with a digital twin model, a smart home controller and cloud data from NOVASOL, including booking schedules and weather forecasts, are used to overheat the pools when there is excess wind energy so that the pools are optimally heated when guests arrive at the holiday homes, while providing voltage and temperature control for the DSOs.

Another example is a project in an industrial cooling house, where cooling is shifted to times when electricity is cheaper using real-time data and flexibility functions. This approach saves up to 30% electricity cost for the industry and supports the grid. To ensure full cooling functionality while capitalizing on price advantages, sensors were installed in the cooling house and new measurement techniques were developed.

A final case study is a solution for wastewater treatment plant, which is joint work with the French company Veolia. By using the flexibility functionality as predictive control of the water resource recovery facility, where the first priority is to avoid overflow in the street the second to maintain the active bacteria in the plant and third to save costs.

All of Data Center Denmark's models are open source, open standard and open solutions, which are intended to empower the end user and the partners so that they can provide this flexibility without being subject to disproportionate, too many technical requirements, administrative requirements, procedures, agreements and fees.

To fully utilize the potential of the SE-OS framework and the flexibility function, data hubs with real-time or near real-time data on all energy vectors are needed. This enables the connection of the conventional power market to end-users via price signals or different energy vectors with each other. Currently, most European data hubs, like Denmark's ENERGINET, only provide historical electricity data. Once real-time data is available across Europe, the options to activate **demand-side flexibility** will be vast, potentially saving up to 80% of electricity costs and enhancing the flexibility, stability, and efficiency of the energy system. An overview of current European data hubs is provided in the annex.

3.5 Innovative Solutions by Pratexo: AI-enabled edge-to-cloud management and orchestration platform

Pratexo is a private company founded in 2019 that provides **AI-enabled edge-to-cloud management and orchestration platform** solutions, primarily for the energy sector.

For a flexible, stable, and efficient energy system, edge computing is essential to manage distributed and decentralized operations, offering benefits in latency, cost, and system resiliency. Pratexo's solutions meet key requirements: edge-to-cloud integration, reliability, scalability, security, real-time low latency, offline functionality, and breaking down silos. They offer pre-built, but also highly **customizable solution frameworks** that connect on-premise calculations with an open stack cloud and potentially major hyperscaler clouds for various electrification market use cases. Herin Pratextos approach acknowledges the fact that is not always possible, necessary or wanted as well as expensive to send data or unprocessed data to a cloud. For example sensor data from DSOs is in many cases very big as well as security sensitive and it can be beneficial to process the data on the edge or near the edge and communicate only the necessary fraction of processed data to higher levels.

Built on a large stack of open-source components like Kubernetes, Pratexo's platform allows architects and solution developers to integrate and deploy a **wide range of open-source tools**, as well as proprietary systems, analytics, and scripts. Additionally, the platform supports various core architecture designs, enabling the **creation of digital twins of devices**. This feature allows for simulation and testing of applications and architectures before any physical deployment, significantly speeding up and reducing the risk of these deployments.

Pratexo is developing solution frameworks for a variety of companies. For instance, ABB invested in Pratexo in 2023, integrating Pratexo's software as a core part of its software stack. This software is wrapped around ABB's electrification hardware, such as switchgear or transformers, to increase machine uptime and efficiency. As a result, ABB can offer enhanced service capabilities to their customers.

Another example is Hallingdal Kraftnett (HKN), which is running Pratexo software in the Norwegian power grid. By Norwegian law, transformers emit data, and backup sensors collect the same data for redundancy, neither of which can be transmitted over the public internet. However, due to low connectivity and high data volumes, this data was previously underutilised. Now, first-level processing and analytics are performed on-site using. Furthermore Pratexo is also implementing advanced use cases, such as using cameras to detect people or animals near the stations and microphones to listen for partial discharges. To improve connectivity Pratexo is partnering with the telecommunications company Telenor by connecting more transformer stations with 5G,

improving data visibility and operational efficiency of the Norwegian power grid. In areas with higher connectivity, Pratexos software then groups individual compute nodes running at these substations into a 'micro-cloud', enabling high-performance, resilient and scalable applications across multiple substations. This comprehensive approach demonstrates Pratexo's ability to enhance operational efficiency, data utilization, and service capabilities (see Figure 6).

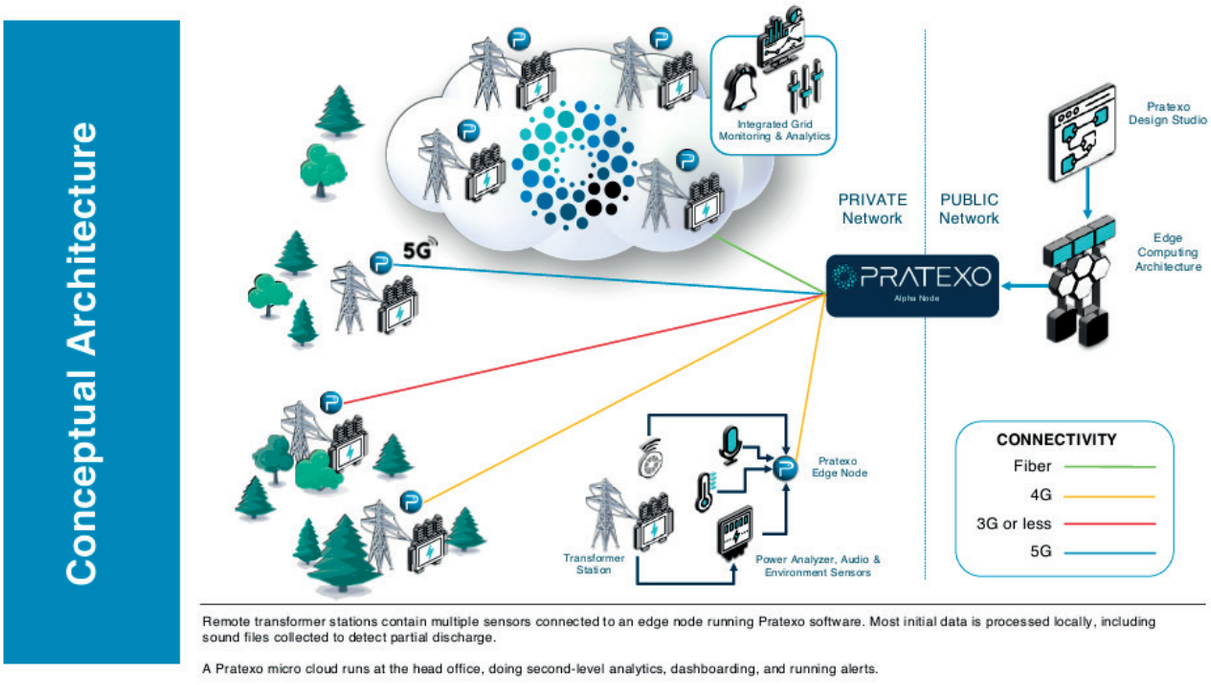

Figure 7: Conceptual Architecture of edge-to-cloud management and orchestration platform in TSO - Source: Blaine Mathieu

Pratexo's new generative AI-enabled system revolutionises understanding and predicting complex machine failures, significantly reducing the effort typically required. After developing a basic root cause analysis framework with ABB, Pratexo leveraged generative AI to enhance system design and deployment capabilities, simplifying the creation of effective predictive maintenance solutions.

The system enables for example machine experts to create fault cause graphs for specific machine types, with generative AI automatically generating prediction algorithms in Python. This allows for proactive measures to be taken, and the entire system is deployed using Pratexo's Edge Management and Orchestration platform. Within about an hour, a functional edge application can be developed to detect overheating and oil leaks using various sensors. This application can trigger specific actions, such as sending messages via MQTT stream or SMS. Enabled by AI, the system enhances grid edge resiliency and integrates AI for efficient and rapid responses.

4 Conclusions and observations

Multiple CEI companies are active in the European Energy Sector, with big players like AWS, Microsoft, IBM, and Bosch IoT dominating cloud-centered services, leaving limited room for European companies. Nevertheless, there's an opening at the edge for European companies to step in and provide more tailored edge computing services. Additionally, we explored leveraging open-source solutions at the edge to avoid vendor lock-in. However, these solutions typically need to be adaptable for the international market, as scalability is essential for software solutions. The following innovative solutions contribute to the energy transformation by enabling flexibility, stability and efficiency in smart energy system:

Tibber: Flexible electricity tariff and smart Energy Management for end-users

- **Added benefit:** minimises customers energy use & cost, shifting consumption to periods of low energy prices, thereby supporting grid stability.
- **Real-time data missing**: if real-time data were available in EU, Tibber could sell their customers flexibility to DSOs/TSOs to stabilise the grid instantly.
- **Risk:** High dependency on hyperscalers.

Technolution: Edge hardware and horizontal architectures

- **Added benefit:** enhances operational efficiency, stability and flexibility options for energy systems through edge hardware & processing of large volumes of sensitive data, ensuring compliance with privacy and security requirements via measures such as one-way data flow.
- **Risk:** In the smart meter use case, there is no adoption of DSOs due to security concerns and traditional approaches to data management.

EVerest/Pionix: Open-source software at the edge for EV charging stations

- **Added benefit:** simplifies the software for charging station and thereby minimises errors in the electrification of mobility; no vendor lock-in; easy adoption of new standards and protocols e.g if DSOs/TSOs would communicate status, measures to stabilise the grid could easily be integrated.
- **Risk:** needs to be widely adapted by manufacturers, needs engaged open-source community.

Center Denmark: Digital infrastructure for sector coupling and activating energy demand-side flexibility

- **Added benefit:** Powerful mathematical framework that can enable flexibility, stability and efficiency on all levels.
- **Real-time data & orchestration platforms/institutions missing**: Real-time data and orchestration platforms for coupling energy vectors (e.g. electricity & heat) with demand-side flexibility would solve many of the challenges of energy transformation. A cross-sector communication infrastructure for price signals is lacking.
- **Risk**: fears of data security and new ways of data management of price signals are needed. Conservative attitude towards cross-sectoral data sharing, high complexity of data-driven value chains and understanding of the ways how to participate in the energy markets.

Pratexo: AI-enabled edge-to-cloud management and orchestration platform

- **Added benefit:** Optimises energy system efficiency and stability by integrating edge-to-cloud

operations, reducing latency and costs associated with unnecessary data transmission, offers easy and flexible digitalization options for all sorts of players; built on open-source.

- **Risk: US-based player.** At present, Pratexo has positioned itself internationally with Swiss-based ABB as the main investor. However, it remains to be seen how this company will develop and who will be responsible for strategic partnerships.

These examples show that a range of viable solutions to enhance flexibility, stability, and efficiency in the energy system are already on the market or demonstrated in various projects. However, many innovative solutions would need real-time energy - data to unlock their full potential to facilitate the seamless integration of renewable energy sources, efficient grid operations, and the transition to smart grids. However despite the establishment of national energy data hubs or platforms in several European countries (see 5 Annex), the collected data currently lacks standardisation, primarily consisting of historical data and often focusing solely on electricity, while other energy system vectors such as gas, district heating, and wastewater treatment remain mostly neglected. With more advanced distributed data management in the energy sector in Europe the presented solutions promise to meet the challenges of the energy transition in very effective ways.

5 Annex: Overview of the European data hubs

Several European countries have established national data hubs or platforms to facilitate data exchange and communication within the energy sector. These platforms could play a crucial role in enabling the integration of renewable energy sources, managing grid operations, and supporting the transition to smart grids.

The entities responsible for national platform operations vary, ranging from national authorities to Transmission System Operators (TSOs) in other countries. Moreover, the collected data lacks standardisation, predominantly comprises historical data and usually only considers electricity while other energy system vectors like gas, district heating, and wastewater treatment are neglected.

- ENTSO-E Transparency Platform (European Union): The European Network of Transmission System Operators for Electricity (ENTSO-E) operates a transparency platform that provides access to electricity market data, including generation, consumption, and grid information across the EU.
- Energinet (Denmark): Energinet operates as Denmark's transmission system operator (TSO) and facilitates data exchange and communication in the Danish energy sector, including electricity and gas grid information.
- Energie Data Services Nederland (Netherlands): EDSN is responsible for data communication in the Dutch energy sector, managing data related to electricity and gas, supporting market processes, and ensuring data quality and security.
- Elexon (United Kingdom): Elexon operates as the Balancing and Settlement Code (BSC) Administrator for the electricity market in the United Kingdom. It manages data related to electricity generation, consumption, and settlement processes.
- RTE ECO2mix (France): RTE ECO2mix is a platform operated by Réseau de Transport d'Electricité (RTE) in France, providing real-time data on electricity production, consumption, and grid status.
- Terna (Italy): Terna operates an Energy Data Hub that collects and manages data related to Italy's electricity grid, including information on generation, consumption, and grid stability.
- E-Control (Austria): E-Control, the Austrian Regulatory Authority for electricity and gas markets, operates a data hub that provides access to energy market information.
- Statnett (Norway): Statnett operates a data platform that offers real-time data on electricity generation, consumption, and grid conditions in Norway.
- Terna (Spain): Terna, the Spanish Transmission System Operator, manages a platform that provides data on electricity generation, consumption, and grid operation in Spain.

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