Alliance for AI, IoT and Edge
Continuum Innovation

Webinar • 03.04.2025

Presentation of the paper AI in Energy

Opening and Welcome

Natalie Samovich, WG Energy Chair (Enercoutim)

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3C’s: Collaborative environments, advanced Connectivity and Computing the advanced digital network infrastructures and services will become key enablers for transformative digital technologies and services such as AI, Virtual Worlds and the Web 4.0 while addressing societal challenges

Agenda

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15.00	**Opening and Welcome (5 min)**
	Natalie Samovich, AIOTI WG Energy Chair, Enercoutim
15.05	**Presentation of the paper (10 min)**
	Rute Sofia, AIOTI WG Energy Co-Chair, fortiss
15.15	**Discussion (45 min)**
	Stavros Stamatoukos, European Commission, DG Energy
	Natalie Samovich, AIOTI WG Energy Chair
	Rute Sofia, AIOTI WG Energy Co-Chair
	Mays Al-Naday, University of Essex
16.00	**Interactive SWOT and Q&A (15 min)**
16.15	**Wrap up and end of Webinar**
	Natalie Samovich, AIOTI WG Energy Chair, Enercoutim

About AIOTI WG Energy

AIOTI WG Energy

Natalie Samovich
Chair
Enercoutim

Rute Sofia
Co-Chair
fortiss

Deliverables	Collaborations	Events
▪ AI in Energy paper ▪ Facilitating the creation of consortia for collaborative research projects	▪ EC TF Smart Energy Expert Groups ▪ HLF on European Standardisation providing contributions	▪ AIOTI Days 2024 ▪ Presentations on EC workshops ▪ Webinar promoting deliverables

Group deliverables: https://aioti.eu/resources-energy/

AIOTI

Presentation of the AI in Energy paper

Rute C. Sofia, WG Energy Co-Chair (Head of IIoT, fortiss GmbH)

AI in the Energy Sector (2024)

Focus:

How Artificial Intelligence (AI) can be leveraged to transform and optimise the energy sector - from generation and distribution to consumption while ensuring sustainability, resilience, and efficiency

Builds on:

- AIOTI Edge driven Digital Twins in distributed energy systems paper
- AIOTI 2023 Strategic Research and Innovation Agenda (SRIA)
- AIOTI Paper on Edge IoT Industrial Immersive Technologies and Spatial Computing Continuum R1
- View from EU and national initiatives/projects
- View from Experts involved in the AIOTI WG Energy

AIOTI

AI in Energy: Structure

1. Continuity from AIOTI Digital Twins Paper
2. References to AIOTI SRIA
3. EU & National Funded Projects
4. AI in Various Energy Sectors
5. AI for Marketplaces
6. Distributed Data Management for AI
7. Edge AI
8. Sustainable AI
9. Evolving Ecosystems & Initiatives
10. Virtual Worlds, Digital Twins & AI
11. Testing Facilities & Infrastructure
12. AI & Energy Poverty
13. Policy & Standardisation Aspects
14. AI + 6G for Energy Innovations
15. Conclusions & Recommendations

Emerging Technologies and Trends

Edge Computing: Enables data processing closer to the source, reducing latency and improving response times in energy systems.

Digital Twins: Virtual replicas of physical assets allow for simulation and analysis, enhancing decision-making and predictive maintenance.

Integration with IoT: Combining AI with Internet of Things devices facilitates advanced monitoring and control of energy consumption and distribution.

Distributed AI: beyond federated learning

Challenges and Considerations:

Data Availability and Interoperability:

Vast amounts of data, but **access is often limited**, fragmented, or siloed.

Standardized data formats and interfaces to enable seamless integration and effective AI training.

Trust, Ethics, and Transparency:

Critical decisions in energy distribution or pricing require explainable, fair, transparent AI systems.

Ensuring **ethical use** and addressing **bias** in algorithms is a core concern.

Cybersecurity and Privacy Risks:

Large-scale, often personal or sensitive data, protecting it from breaches and misuse is crucial.

Privacy preservation is crucial in decentralised/distributed AI systems for energy.

Lack of Standardisation and Regulation:

There is a **regulatory gap** in AI deployment for energy applications.

Clear **guidelines, legal frameworks,** and **interoperable standards** are needed to ensure safe and coordinated rollouts.

Expected Benefits, AI-Energy Sector

Increased energy efficiency and resilience

AI enables real-time monitoring, predictive maintenance, and optimization of energy systems—leading to reduced downtime and operational costs.

Better integration of renewable energy assets

AI helps manage the variability of renewable sources by forecasting supply and demand, balancing grids, and optimizing storage and distribution.

Empowered consumers and prosumers

Through smart meters, dynamic pricing, and automation, AI gives consumers more control and allows prosumers to actively participate in energy markets.

Smarter decentralised energy systems

AI supports distributed energy resources and enables flexible, localized solutions such as peer-to-peer energy trading and microgrids.

Conclusions and Recommendations

AI is a strategic enabler for the Energy Transition

Assists renewable integration, enhances grid resilience, supports smarter, decentralised energy systems

Trustworthy, explainable AI is essential

Effective AI must be transparent, privacy-preserving, ethical

Needs common data spaces, standards, regulations

Cross-sector collaboration is a must

AI developers, energy sector stakeholders, policy makers, citizens

Investment in R&D, skills, testing infrastructures

Discussion

Moderator: Natalie Samovich, WG Energy Chair (Enercoutim)

Discussion

Moderator:

Natalie Samovich, AIOTI WG Energy Chair

Participants:

Stavros Stamatoukos, European Commission, DG Energy

Rute C. Sofia, AIOTI WG Energy Co-Chair, fortiss

Mays Al-Naday, University of Essex

Discussion: Topics

- AI use cases are widespread in energy systems. Many use cases and solutions are being discussed, but as these experiences show - old problems related to interoperability and data sharing are still lingering (ETIP SNET webinars on AI). Along with these issues additional risks are surfacing up along with opportunities, such as Foundation models for energy, for example.

Discussion questions for the participants:

1. Role of cloud edge continuum in scaling up AI in energy - expected impact and progress
2. Impact of competitiveness and scaling up challenges for AI in energy - expected impact and progress
3. Data spaces as AI enabler
4. Connectivity: 6G aspects in AI enablement
5. AI at the edge

Interactive SWOT and Q&A

Moderated by: Natalie Samovich, WG Energy Chair (Enercoutim)

Interactive SWOT AI, Edge Computing, 6G and Sustainability in Energy

Join at
slido.com
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Goal: Explore the intersection of AI, Edge computing, 6G and sustainability topics in energy systems.

Format: SWOT-based discussion with Slido audience participation.

Let’s create AI in energy SWOT towards future energy systems – together.

Technology focus

Interactive SWOT AI, Edge Computing, 6G and Sustainability in Energy

Join at
slido.com
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Adaptation barrier:

STRENGTHS – What's working, what is expected to have biggest impact?

WEAKNESSES – What's not working?

OPPORTUNITIES – What should we be doing more of?

THREATS – What could go wrong?

Interactive SWOT AI, Edge Computing, 6G and Sustainability in Energy

Join at
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STRENGTHS – What's working, what is expected to have biggest impact?

WEAKNESSES – What's not working?

OPPORTUNITIES – What should we be doing more of?

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AIOTI

Interactive SWOT AI, Edge Computing, 6G and Sustainability in Energy: VISION

Join at

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Wrap up and end of the Webinar

Natalie Samovich, WG Energy Chair (Enercoutim)

Backup slides

AI in Energy

- The rapid integration of Artificial Intelligence (AI), 5G, and upcoming 6G technologies into the energy sector signifies a transformative and long-term transitional shift towards a more sustainable and efficient future enabled by myriads of digital technologies

- Through comprehensive and dynamically evolving digital infrastructures the advanced data analytics, real-time monitoring, and predictive modelling, AI enhances the flexibility, reliability, and efficiency of energy systems

- The convergence of AI and 6G technologies is particularly critical in optimising the performance of renewable energy sources, rolling out smart grid solutions to ensure grid stability, and fostering a resilient energy ecosystem

AI-driven energy innovation

- 3C’s: **colla**borativ**e connectivity** and **computing** as mentioned in the European Commission White Paper "How to master Europe's digital infrastructure needs?" the advanced digital network infrastructures and services that will become a key enabler for transformative digital technologies and services such as **AI, Virtual Worlds and the Web 4.0**, and for addressing societal challenges
- This represents **an opportunity for new pilots** closing demand and supply side, i.e. strengthen industrial demand side and deliver an enablement for the path towards sustainability of key sectors. **It can enable new innovations and services** for European digital supply industry while strengthening the industrial ecosystems in areas like mobility, energy, health, smart communities, logistics and manufacturing, drawing on our experiences from the IoT Pilot projects funded by the EU.
- **Continuity from Edge driven Digital Twins in distributed energy systems**
- **Ethical and cybersecurity considerations**

AI in various energy sectors

- **Optimise the integration of intermittent renewable energy sources**
- **Optimise the charging and discharging of energy storage systems**
- **Demand and supply forecasts**
- **Demand response management**

controlling, monitoring and adjusting consumers' energy consumption

- **Predictive maintenance**

AI is used to predict when equipment that is part of the energy system will fail, enabling preventive maintenance

- **Energy trading**

AI algorithms are used in energy trading platforms to analyse market data connected to supply and demand dynamics, energy prices, policy instruments and regulatory constraints, to make trading decisions in the energy markets

AI for Energy Marketplaces

AI agents

- An AI agent can be described as a digital entity that continually evaluates its surroundings, learns from interactions, and makes decisions to accomplish specific goals. This encapsulates the essence of an AI agent, functioning akin to a digital assistant that carries out tasks, comprehends context, adapts strategies, and even devises new approaches to achieve its objectives. The spectrum of AI agents varies from simple programs designed for singular tasks to intricate systems overseeing complex processes.

Shared Algorithms

- The concept of shared AI algorithms signifies a groundbreaking vision in the realm of artificial intelligence. This vision heralds a future where numerous individual AI units have the capacity to independently learn over their lifetimes and share their accumulated knowledge with each other. The fusion of lifelong learning and knowledge sharing holds the promise of establishing a community of AI systems, wherein each unit contributes to and gains from the collective intelligence.

BD4NRG Toolbox

- BD4NRG Open modular Energy Analytics Toolbox combines and makes available to end-users the advanced user-friendly graphical working environment capabilities to support custom selection of local and/or third-party assets. It includes:
- discovery of heterogeneous data sources formats
- variety of analytics techniques via an AI-based machine learning algorithms/models

Distributed data management for AI

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:

- 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.
- Datahub (Finland): Fingrid, the Finnish Transmission System Operator administers centralised data exchange system for the electricity retail market.

Edge AI and Sustainable AI

Edge AI

- Edge AI refers to the engineering of AI algorithms towards edge devices, brings immediate advantages when compared with Cloud-based AI solutions. By reducing the volume of data required to be transmitted to the Cloud, it intuitively brings advantages in terms of overall energy consumption and data security/sovereignty

Sustainable AI

- AI services are not only CPU intensive but more so data Input/Output (I/O) intensive, and reliant on consuming large data assets (datasets). This implies novel dependencies between functional and data assets, which impacts the sustainability of running AI in terms of: energy consumption, green ratio of consumed energy a.o. CO_2 footprint, economic cost, performance, privacy and cybersecurity.
- From an infrastructure perspective, the energy profile of an AI workflow can be broken down to the combination of sub-profiles of:
- functional components of a workflow (e.g. data I/O, data preprocessing and model training);
- storage components of datasets feeding to a workflow; and,
- data-function mapping in a workflow, which implies data transmission that can be instigated over the network

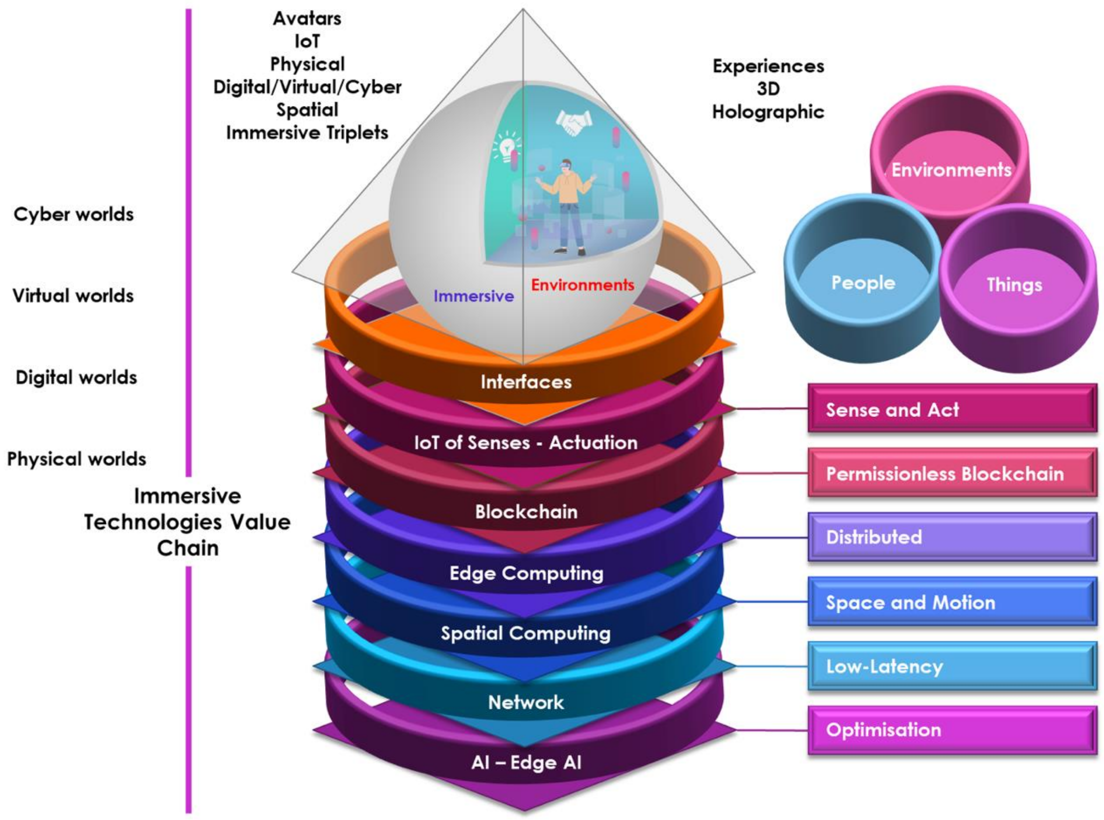
Virtual Worlds, DT and AI in Energy

- AIOTI has published in April 2024 the paper on **Edge IoT Industrial Immersive Technologies and Spatial Computing Continuum**.

- The paper aims to provide the vision of the convergence of edge IoT, artificial intelligence (AI), digital twins (DT), immersive triplets (IMT), intelligent mesh connectivity, IoT of senses (IoTS), software-defined automation (SDA) and spatial computing technologies to create an industrial real-digital-virtual continuum. Such continuum is made of immersive environments, which are computer-generated virtual worlds where users can sense as if they were physically embodied in that generated perception context.

- The convergence of these technologies into industrial immersive solutions advances the integration and application of edge intelligent immersive technologies combining augmented reality (AR), virtual reality (VR), mixed reality (MR), and extended reality (XR) with concepts like metaverses, omniverse, multiverses, next generation spatial web, Web 4.0 as part of future virtual worlds.

- Such convergence of industrial immersive technologies at the edge can improve efficiency, reduce downtime, enhance safety, and better decision-making in industrial settings. However, to be effectively deployed, it both requires a strong interdisciplinary collaboration and presents challenges like robust hardware (HW) design and cost-effective availability, data security and privacy preserving methods, and effective industrial workflow integration. As technology advances, the adoption of such convergence in industry is expected to grow, offering transformative benefits across various sectors and vertical markets, including industrial manufacturing, product operations, design and maintenance, training and collaboration, data visualisation, mobility and logistic, energy, automotive, aerospace, and healthcare



Edge immersive technologies convergence across the value chain

Contributions towards recommendations (sample)

Enhanced data sharing and privacy

OMEGA-X and Data Cellar

Integration of AI in energy management

ODEON and iFLEX, BD4NRG

Support for sustainable energy solutions

Initiatives like PEDVOLUTION and Smart Grid 2.0 are dedicated to developing sustainable energy solutions, such as Positive Energy Districts and resilient electricity grids.

Regulatory frameworks and policy support

GECKO project

Innovation in energy services

BD4OPEM, BD4NRG and SYNERGIES

AI in cybersecurity for energy systems

The NATWORK project explores the intersection of AI, 6G technology, and cybersecurity, aiming to develop energy-efficient AI cybersecurity solutions. This initiative seeks to protect AI-enabled 6G services from energy-oriented sustainability attacks, ensuring the resilience and security of future energy systems.

Collaboration and market integration

Projects such as OneNet and Enershare are enabling extended ecosystems of stakeholders, use cases and digital solutions enabled governance tools where the importance of collaboration among energy actors to create an integrated and efficient electricity network across Europe is strategic core. These projects are already fostering an open and fair energy market approach, interoperable services, and forming "digital spine" to enable AI services, while supporting the broader goal of a sustainable and interconnected energy system. Interconnectors, digital governance mechanisms, energy data spaces focusing on main use cases are at the core.

Continuity from Edge driven Digital Twins in distributed energy systems

- Digital twins, which are virtual replicas of physical systems, depend on robust data infrastructure to ensure accuracy
- AI plays a crucial role in maximising the potential of digital twins by enabling sophisticated data analysis, predictive capabilities, and real-time decision-making
- The integration of AI significantly enhances digital twins through efficient data collection, secure storage, and advanced management systems
- In energy optimisation, AI-driven digital twins offer detailed models of energy systems.
- AI also forecasts demand and supply fluctuations, allowing for proactive adjustments that optimise energy usage.
- Predictive maintenance reaps significant benefits from AI integration
- Another area where AI excels is process optimisation
- AI-driven digital twins also play a pivotal role in improving environmental sustainability by optimising resource use and managing renewable energy sources efficiently, thereby reducing reliance on fossil fuels and lowering carbon footprints
- AI integration transforms digital twins, enhancing accuracy, efficiency, and predictive capabilities
- This strategic investment enables unprecedented levels of efficiency, sustainability, and reliability, positioning organisations at the forefront of technological innovation

Contributions towards recommendations

Enhanced data sharing and privacy

Projects like OMEGA-X and Data Cellar focus on creating federated energy data spaces that facilitate data sharing among stakeholders while ensuring privacy, security, and data sovereignty. This approach aims to boost innovation, particularly for SMEs and startups, by providing accessible and secure data environments that can facilitate AI driven services enablement in line with EU AI Act.

Integration of AI in energy management

Several projects, such as ODEON and iFLEX, BD4NRG highlight the critical role of AI in managing energy systems. These projects aim to develop AI-driven tools for data processing, demand response management, and the optimization of energy consumption, enhancing overall energy efficiency and consumer engagement.

Support for sustainable energy solutions

- Initiatives like PEDVOLUTION and Smart Grid 2.0 are dedicated to developing sustainable energy solutions, such as Positive Energy Districts and resilient electricity grids. These projects focus on enhancing energy efficiency, integrating renewable energy sources, and ensuring grid stability amidst the transition to decarbonized energy systems that can be enhanced with data continuum.

Regulatory frameworks and policy support

- The GECKO project addresses the need for adaptable regulatory frameworks to accommodate emerging technologies in transportation and energy sectors, including AI. Project provides guidance and recommendations to ensure the sustainable and competitive development of new business models and technologies. AI driven business models need to evolve.

Innovation in energy services

- Projects like BD4OPEM, BD4NRG and SYNERGIES focus on leveraging big data and AI to create innovative energy services. These projects aim to enhance grid monitoring, operation, and maintenance, as well as develop new business models and services that drive the energy market towards efficiency and sustainability adressing many use cases.

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Recommendations (2)

Role of IIoT and edge technologies

- Advancing the EU energy sector through AI services and solutions, IIoT and edge technologies can go hand in hand with focus on sustainability, efficiency, and the integration of new business models and advancements of regulatory frameworks. Dynamic policy feedback is essential for this rapidly evolving field of innovation.
- The discussion covers several key impacts of AI on edge and IoT systems, focusing on efficiency, data management, security, and energy consumption.

Efficiency and scalability

- IoT devices often have limited bandwidth which can constrain scalability. However, IoT edge mesh architectures resolve this by distributing data across multiple edge devices, which can share and offload computational tasks. this results in faster processing times, better response times, reduced make span, and higher throughput. additionally, if a device fails, other devices can take over its load, enhancing system robustness.
- AI/ML techniques tailored to decentralisation, such as hierarchical federated learning, swarm learning, or MARL, play a crucial role in the context of providing energy-efficiency, and improving scalabilities.

Data management and security, Edge AI

- Impact of processing data at the edge rather than sending it to the cloud is more efficient and secure, especially for large and sensitive datasets. Edge AI driven approach, known as edge management and orchestration, reduces the volume of data that needs to be transmitted, which in turn lowers energy consumption and enhances data sovereignty and security.

Energy efficiency

- the integration of ai methods with IoT/edge computing supports the development of sustainable, optimised and energy efficient systems, helping to optimise energy consumption across the entire value chain of stakeholders through grid operations. As more and more transactions will be taking place at the grid edge, the related solutions and large data management will need to be enhanced and optimised.

Technological integration

- The heterogeneity of IIoT energy networks systems, which include various devices and technologies, already requires AI based algorithms that are portable across different environments as demonstrated in a number of projects. This includes the need for lightweight communication protocols and standard interfaces for effective integration and interoperability.
- Research is needed to further develop distributed learning algorithms, the enabling platforms and necessary infrastructures that maximise system reliability and availability.

Future research directions

- Further research is necessary to enhance federated learning and ai for edge IoT systems. this includes developing architectures and frameworks that support these technologies, improving hardware platforms, and ensuring scalability and efficiency while focusing on security by design and advanced connectivity.
- In summary, AI significantly enhances edge and IoT driven systems across energy sector and network topologies by improving efficiency, scalability, and energy consumption while ensuring better data management and security.
- The integration of AI at the edge enables faster and more secure data processing, which is essential for the dynamic and heterogeneous nature of IIoT environments.

Thank you for listening

Any questions?

You can email us at sg@aioti.eu