USE-CASES - INTEGRATED DIGITAL SOLUTIONS FOR THE ENERGY SECTOR

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1. INTRODUCTION

This document outlines the use cases to be incorporated into the "*Integrated Digital Solutions for the Energy Sector*" thematic call for proposals.

The use cases presented have been developed through collaboration between the European Space Agency (ESA) and key stakeholders in the energy and utilities sector, including members of the "Task Force for Innovation in Energy Through Space" (Energy Task Force).

The initiative aims to foster the development of sustainable services that leverage space assets and technology to address critical challenges and unlock opportunities for operational solutions.

When preparing the initial proposal (APQ/Outline proposal), applicants must clearly specify which use-case(s) their proposed solution intends to address.

2. USE CASES

ESA and the aforementioned key stakeholders have identified the following focus areas and use cases where space-enabled solutions can add value. Prospective bidders to this thematic call for proposals are invited to submit proposals addressing the use cases outlined below or to propose alternative ideas based on their own research and expertise.

2.1. EPRI

The Electric Power Research Institute (EPRI) is a leading independent, non-profit organisation that conducts research and development to advance the generation, delivery, and use of electricity for the benefit of the public. Headquartered in the United States, EPRI collaborates globally with utilities, government agencies, and other stakeholders to drive innovation across the energy sector.

Their work spans a wide range of topics, including renewable energy integration, grid modernisation, energy efficiency, and decarbonisation strategies. By delivering cutting-edge research and practical solutions, EPRI supports the transition to a more sustainable, resilient, and low-carbon energy future.

2.1.1. Use-case #1: Grid management and optimisation

- **Wildfire Detection and Response:** Utilising AI to improve wildfire risk evaluation and early-stage detection, thereby enhancing grid resilience and safety.
- **Congestion Management:** Applying AI to manage grid congestion, ensuring efficient energy distribution and preventing bottlenecks.

2.1.2. Use-case #2: Predictive maintenance and asset management

- **Equipment Failure Prediction:** Implementing AI to predict equipment failures, allowing for proactive maintenance and reducing downtime.
- **Asset Performance Optimisation:** Using AI to monitor and optimise the performance of energy assets, extending their operational life and efficiency.

2.1.3. Use-case #3: Energy efficiency and demand response

- **Energy Consumption Forecasting:** Employing AI to predict energy consumption patterns, facilitating better demand response strategies and energy efficiency measures.
- **Optimising Energy Generation and Demand:** Utilising AI to balance energy generation with demand, improving overall system efficiency.

2.1.4. Use-case #4: Integration of renewable energy sources

- **Renewable Energy Forecasting:** Applying AI to forecast the availability of renewable energy sources, aiding in their integration into the grid.
- **Distributed Energy Resources (DER) Integration:** Using AI to manage and integrate DERs, enhancing grid flexibility and reliability.

2.1.5. Use-case #5: Cybersecurity

- **Threat Detection and Response:** Implementing AI to detect and respond to cybersecurity threats, safeguarding critical energy infrastructure.

2.1.6. Use-case #6: Customer engagement and service

- **Improving Customer Service:** Utilising AI to enhance customer service interactions, providing more efficient and personalised experiences

2.2. ENEL Group

Enel is a multinational energy company and one of the world's leading integrated electricity and gas operators. Headquartered in Italy, Enel operates across a wide range of markets, providing electricity and gas generation, distribution, and supply services. With a strong focus on renewable energy, Enel is a global leader in driving the energy transition, investing heavily in wind, solar, hydro, and geothermal power.

The company is committed to sustainability, innovation, and digitalisation, aiming to create a smarter, greener energy network. Enel's initiatives contribute significantly to decarbonisation, electrification, and the advancement of a circular economy within the global energy sector.

2.2.1. Use-case #1: Water leak detection

Context Information:

Open canals in hydroelectric plants often develop subsurface cracks, leading to water leaks that are extremely challenging to detect before causing significant damage to surrounding areas. Advanced satellite image analysis offers the potential for early leak detection, enabling targeted and more efficient maintenance efforts.

How does the process work today?

In practice, canals can stretch tens or even hundreds of kilometres in length. Manual inspections are time-consuming, often taking weeks, and rarely provide a comprehensive assessment of leaks. The challenge is compounded by the fact that most cracks form underwater, making them impossible to observe without draining the canals, which is both costly and disruptive.

How can the process be improved?

By utilising satellite imagery and other remote sensing data—such as ground surface temperature, vegetation water stress, and soil moisture information—it is possible to develop deep learning algorithms capable of identifying abnormal areas along canals. These algorithms compare conditions to baseline ‘normal’ patterns, helping to pinpoint potential issues with greater accuracy and efficiency.

What is the target process?

The main objectives are to:

- Verify the availability of satellite data for monitoring ground conditions near canals.
- Determine the frequency at which this analysis can be performed.
- Train deep learning algorithms using data from known cases of canal leaks.
- Validate the methodology by applying it to a selection of representative canals.

Requirements:

- Maximum temporal acquisition frequency: Weekly.
- Satellite imagery in visible, near-infrared, and radar bands.
- Infographic representation integrated with GIS systems.

Cost efficiency is a key driver to ensure accessibility for utilities. This includes leveraging low-cost or free satellite data, minimising data transfer requirements to ground systems, and optimising operational costs.

2.3. DENA

The German Energy Agency (DENA) is Germany’s centre of expertise for energy transition and climate protection. Based in Berlin, DENA works to promote sustainable energy systems by focusing on energy efficiency, renewable energy integration, and innovative technologies. As a driving force behind Germany's energy transition, DENA supports stakeholders across industries, politics and society by developing strategies, implementing pilot projects, and providing policy recommendations. Its initiatives aim to foster decarbonisation, ensure energy security, and accelerate the transformation towards a climate-neutral economy.

2.3.1. Use-case #1: Artificial Intelligence/ Machine Learning/ Grids

- **Data Analysis and Artificial Intelligence in the Electricity Distribution Grid:** Exploring opportunities for the future of electricity grids through collaboration between distribution system operators and start-ups.

- **AI in Power Grids:** Industry processes for the digitalisation of grid operators.

2.3.2. Use-case #2: Efficiency

- **Energy-Efficient AI:** Enhancing energy efficiency in AI applications.
- **Rethinking Blockchain's Electricity Consumption:** Exploring strategies to reduce the energy demands of blockchain technology.
- **Green Coding:** Developing energy-efficient software solutions.

2.3.3. Use-case #3: Decarbonisation of heat

- **AI in District Heating:** Utilising AI to optimise district heating systems.
- **Machine Learning in District Heating:** Applying machine learning techniques to improve efficiency and sustainability in district heating.

2.3.4. Use-case #4: IoT/ Communication

- **EnerComputing:** Leveraging cloud and edge technologies to support a decentralised energy system.

2.3.5. Use-case #5: Earth Observation/ Climate action

- **Digital Climate Communities ("Klimakommune.digital"):**
    - Creation of digital infrastructure, such as municipal data platforms, to promote data exchange and support climate initiatives.
    - Optimisation of environmental and CO2 emission data recording at a local level.
    - Development of measures to reduce CO2 emissions using digitally collected data.
- **CO2 Data Demonstrator (CO2-Datendemonstrator):**
    - Tools for recording and visualising municipal CO2 emission data to aid climate protection.
    - Optimisation of the procurement and provision of municipal CO2 emission data.
    - Development of a CO2 emissions model for the German power grid to minimise curtailment of renewable energy and address regional grid bottlenecks.

    - Analysis of temporal and spatial energy load shifts using local CO2 emissions data.
- **ECO Zone Project:**
    - Creation of zonal analyses for energy control and emission reduction.
    - Defining specific zones within the grid to account for regional differences in energy production, demand, and distribution bottlenecks.

2.3.6. Use-case #6: Data exchange / Digitalisation

- **Data Spaces in the Energy Industry:** Exploring the fundamentals and importance of data spaces (dena-ENDA and Data Institute).
- **Digital Machine Identities:** Implementing machine identities as a foundation for an automated energy system.
- **Blockchain Machine Identity Ledger:** Using blockchain for managing digital identities.
- **Smart Contract Register:** Developing a register to automate and streamline energy system operations.

2.4. E.DSO

E.DSO (European Distribution System Operators) represents the leading electricity distribution system operators across Europe, promoting the modernisation of power grids and supporting EU energy policy. It plays a key role in facilitating the transition to a sustainable, digitalised, and decentralised energy system.
Working closely with European institutions, industry stakeholders, and regulators, E.DSO helps shape policies that enhance grid resilience, efficiency, and the integration of renewable energy sources. It fosters innovation in smart grids, digitalisation, and cybersecurity while advocating for the vital role of DSOs in achieving Europe's energy transition goals.

2.4.1 Use-case #1: Generation and demand forecast

AI, advanced analytics models and digital twins combined with classical solutions offer the potential to improve the quality of forecasts for consumption, generations and losses of power networks for the overall optimisation of the power system.

2.4.2 Use-case #2: Congestion management and flexibility from DERs

AI enhances the prediction of transformer and substation load, and the assessment of future flexibility needs to solve congestion issues in the grid, especially when the increasing integration of distributed energy resources results in increasing network control complexity. This support ranges from risk assessment to short-term control and monitoring. On the other hand, 5G facilitates DER (Distributed Energy Resources) management solutions for the activation of flexibility from assets connected to all voltage levels.

2.4.3 Use-case #3: Network development studies

AI supports the completion of network development studies accounting for technical constraints in grids and for different technological and sociological scenarios. In combination with satellite imagery and the development of digital twins, AI-enhanced assessment of different grid designs supports the identification of optimal locations for substations and other grid assets. Several scenarios can be assessed to determine available grid hosting capacity and the impact of electrified load on the system and support the identification of the most cost-effective solutions for the integration of new (flexible) assets.

2.4.4 Use-case #4: Asset management

Advanced analytics and AI-powered image processing enable automatic diagnosis to enhance programmed maintenance and renovation, anticipating failures. These applications can be further enhanced with the use of drones and satellite imagery, while the integration of both IoT and 5G-connected sensors can support monitoring and diagnosis of network assets.

2.4.5 Use-case #5: Network buildout

AI models support the planning of new construction and maintenance, for instance, by estimating the risk of network damage due to excavations in areas where underground cables are laid.

2.4.5 Use-case #6: Network control and outage prediction

AI can augment the capabilities of control rooms in terms of fault location, enabling more precise control of (low voltage) grids. The combination of AI models with meteorological data can support the prediction of outages and disruptions during (extreme) weather events supporting crisis preparation and restoration. The use of both IoT and 5G-connected sensors can further enhance advanced automation and control functions such as fault location isolation and service restoration.

2.4.7 Use-case #7: Training and remote assistance

The use of virtual/augmented reality and digital twins in procedural training allows for exposing trainees to specific system situations/conditions without exposing them to the associated risks. Likewise, VR/AR tools in combination with digital twins of the grid allow for providing first assistance and assessment of faults/disruptions and potential risks of a field intervention.

2.5. EirGrid

EirGrid is the electricity transmission system operator (TSO) for Ireland, responsible for managing and developing the national grid to ensure a secure and reliable electricity supply. Headquartered in Dublin, EirGrid operates the transmission network and oversees the flow of electricity from generators to distribution networks and large energy users.
EirGrid plays a key role in Ireland's energy transition by enabling the integration of renewable energy sources, enhancing grid flexibility, and supporting cross-border interconnection with the UK and Northern Ireland. Through innovation, infrastructure investment, and advanced grid management solutions, EirGrid is driving the transformation towards a sustainable, decarbonised electricity system while maintaining grid stability and security.

2.5.1. Use-cases for Operations

Situational awareness & lookahead forecasting

- Leveraging satellite-based Earth observation, AI-driven analytics, and advanced weather forecasting to anticipate system conditions.
- Enabling real-time visibility and predictive insights for grid operators to manage fluctuations in renewable generation.

Artificial intelligence for forecast accuracy assessment

- AI-powered models to evaluate and improve the accuracy of renewable generation forecasts, integrating multiple data sources such as satellite imagery, IoT sensors, and historical grid data.

Control room of the future - Decision support systems

- Digital twin technology and AI-driven decision support tools to simulate real-time grid scenarios.
- Providing actionable insights on grid stability, risk mitigation, and economic impact assessments of different operational decisions.

Outage coordination & grid resilience

- AI-enhanced tools for automated outage planning, approval workflows, and recall strategies.
- Integration of space-based data for early detection of potential threats (e.g., extreme weather events, asset failures).

Network capability & system limits management

- Digital platforms for real-time assessment of system limits, dynamic ratings, and control scheme optimisation.
- Enhanced grid stability through AI-enabled forecasting of transmission constraints and power flow optimisations.

2.5.2. Use-cases for Planning

Network model management for future grid development

- Creation of a comprehensive digital library of network models (2025-2050) to simulate future grid expansion, demand scenarios, and infrastructure upgrades.
- Integration of geospatial intelligence and AI-powered scenario analysis to support long-term planning.

System condition forecasting & predictive analytics

- Incorporating SCADA (Supervisory Control and Data Acquisition), dispatch data, and contingency models to create advanced lookahead system conditions.
- Using space-based observation and digital twin technologies to run predictive simulations and assess the impact of different grid management strategies.