CENELEC WORKSHOP AGREEMENT

CWA 50784

July 2026

ICS 27.015, 29.240, 29.240.20

English version

Impact of P2P trading at distribution grid level

This CENELEC Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties, the constitution of which is indicated in the foreword of this Workshop Agreement.

The formal process followed by the Workshop in the development of this Workshop Agreement has been endorsed by the National Committees of CENELEC but neither the National Committees of CENELEC nor the CEN-CENELEC Management Centre can be held accountable for the technical content of this CENELEC Workshop Agreement or possible conflicts with standards or legislation.

This CENELEC Workshop Agreement can in no way be held as being an official standard developed by CENELEC and its Members.

This CENELEC Workshop Agreement is publicly available as a reference document from the CENELEC National Committees.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and United Kingdom.

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No.:CWA 50784:2026 E

Contents

Page

Foreword

This CENELEC Workshop Agreement (CWA 50784:2026) has been developed in accordance with the CEN-CENELEC Guide 29 “CEN/CENELEC Workshop Agreements – A rapid way to standardization” and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by the Workshop CENELEC “Impact of P2P trading at distribution grid level”, the secretariat of which is held by “UNE” consisting of representatives of interested parties on 2026-05-15, the constitution of which was supported by CENELEC following the public call for participation made on 2025-08-18. However, this CENELEC Workshop Agreement does not necessarily include all relevant stakeholders.

The final text of this CENELEC Workshop Agreement was provided to CENELEC for publication on 2026-07-16.

Results incorporated in this CWA received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101096333 and No 101075660.

The following organizations and individuals developed and approved this CENELEC Workshop Agreement:

— Iker Iñigo Ochandorena (UNE), Secretary

— Álvaro Nofuentes Prieto (ETRA I+D), Chair

— Zia Lennard (R2M Solution SAS), Vice-Chair

— Gorka Naveran Lanz (VEOLIA)

— Estíbaliz Castrillejo (VEOLIA)

— José Antonio González (VEOLIA)

— Edorta Ibarra (VEOLIA)

— Andrew Peacock (Heriot-Watt University)

— Ana Trbovich (Grid Singularity GmbH)

— Spyridon Tzavikas (Grid Singularity GmbH)

— Quentin Donnette (Smart Energy Europe)

— Valeria Ghiotto (Smart Energy Europe)

— Iván Pasarín (Energy Web AG)

— Benjamin Grellier (Joanneum Research)

— Andreas Tuerk (Joanneum Research)

— Federico Giani (Azienda Elettrica di Massagno (AEM) SA)

Attention is drawn to the possibility that some elements of this document may be subject to patent rights. CEN-CENELEC policy on patent rights is described in CEN-CENELEC Guide 8 “Guidelines for Implementation of the Common IPR Policy on Patent”. CENELEC shall not be held responsible for identifying any or all such patent rights.

Although the Workshop parties have made every effort to ensure the reliability and accuracy of technical and non-technical descriptions, the Workshop is not able to guarantee, explicitly or implicitly, the correctness of this document. Anyone who applies this CENELEC Workshop Agreement shall be aware that neither the Workshop, nor CENELEC,

Introduction

The P2P trading of energy communities (between members and/or between communities) may impact in the Distribution Grid by relieving or increasing congestion due to bidirectional electricity flows.

In order to assess and quantify this impact, it is necessary to be able to predict when the distributed renewable energy resources will feed the grid (24 hours in advance would be required). Then the impact of this bidirectional flow in the grid needs to be calculated, both to study the voltage variations in the affected power lines in the transient state, and to leverage the local flexibility as a resource for improved congestion management.

It is also possible to assess the energy import and export levels and how they are affected by the implementation of P2P energy and flexibility trading and any related dynamic tariffs.

This document stems from the collaboration of two Horizon Europe projects (OPENTUNITY and FEDECOM), and the outcomes of these projects.

While FEDECOM tackles the P2P within and between energy communities, OPENTUNITY addresses its impact in the grid during the transient state.

1 Scope

This document describes use cases, data exchange and interoperability requirements, demonstration and KPI-based validation approaches, and grid observability considerations related to the implementation of peer-to-peer (P2P) energy trading and the assessment of its impact at distribution grid level. The document draws on the implementation experience of the Horizon Europe projects FEDECOM and OPENTUNITY. It provides implementation guidance for distribution system operators (DSOs), energy community coordinators, solution providers (including aggregators, IT integrators, and technology vendors), and public authorities involved in the deployment or assessment of decentralised energy trading schemes.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp/

— IEC Electropedia: available at http://www.electropedia.org/

3.1
peer-to-peer energy and flexibility trading
P2P trading
decentralized model where producers/prosumers (generation assets or higher-level market participants such as households or businesses who both produce and consume) and consumers (consuming assets or higher-level market participants) directly buy and sell renewable energy, with support of digital, often blockchain-powered platforms

Note 1 to entry: P2P trading can occur at any market level, within and among communities, but its application is dependent on local legislation. In practice P2P trading is frequently misused to represent peer-to-pool trading, including simple coefficient-allocation schemes, but this is not the correct meaning of the term and here it is used as intended.

3.2
peer-to-pool trading
trading arrangement in which the energy or flexibility offered by individual participants is aggregated in a common pool and allocated, matched or settled through a central platform, coordinator or predefined allocation rules, rather than through direct bilateral transactions between identified peers

Note 1 to entry: Peer-to-pool trading can include coefficient-based allocation schemes for shared generation or storage.

3.3
distributed energy resources
DER
generators (with their auxiliary, protection and connection equipment), including loads supporting generation mode (such as electrical energy storage systems), connected to a low-voltage or a medium-voltage network

[SOURCE: IEC 60050, 617-04-20]

3.4
flexibility
capability of a generation unit, load, storage system or other grid-connected resource to modify its active power and/or reactive power injection, withdrawal or timing in response to an external signal, in order to support the efficient operation of the energy system

Note 1 to entry: Flexibility can be used for congestion management, voltage support, balancing, peak shaving, self-consumption optimisation or other system services.

3.5
flexibility asset
physical or virtual resource, or aggregation of resources, that is technically capable of providing flexibility

Note 1 to entry: Flexibility assets can include controllable demand, distributed generation, battery storage, electric vehicles, heat pumps and other controllable energy resources.

3.6
flexibility service
service provided to a system operator, market participant, energy community or other authorised actor through the activation of flexibility assets in order to achieve a defined technical, economic or operational objective

Note 1 to entry: Flexibility services can be used for congestion management, peak shaving, balancing support, voltage control, self-consumption optimisation or local market participation.

3.7
aggregator
party who contracts with a number of other network users (e.g. energy consumers) in order to combine the effect of smaller loads or distributed energy resources for actions such as demand response or for ancillary services

[SOURCE: IEC 60050, 617-02-18]

3.8
energy community
legal entity or organised group of participants carrying out collective energy-related activities for the benefit of its members, shareholders or the local area, rather than primarily for financial profit

Note 1 to entry: In this document, “energy community” is used as an umbrella term that can include citizen energy communities and renewable energy communities, depending on the applicable legal framework.

3.9
intra-community trading
trading of energy or flexibility between members, participants or assets belonging to the same energy community

Note 1 to entry: Intra-community trading can be implemented as peer-to-peer trading or through a community-level coordination or pooling mechanism

3.10
inter-community trading
trading of energy or flexibility between two or more distinct energy communities, either directly or through an intermediary market, federation or platform

Note 1 to entry: Inter-community trading can involve aggregation of community positions before market matching and settlement.

3.11
observability
temporal, geospatial, and topological awareness of all grid variables and assets

[SOURCE: EDSO The Road Map on Go4Flex - Grid observability for Flexibility]

3.12
topology
representation of all the major objects in an electric utility enterprise typically involved in utility operations

[SOURCE: https://interoperable-europe.ec.europa.eu/collection/ict-standards-procurement/solution/en-61970-3012017-energy-management-system-application-program-interface-ems-api-part-301-common]

3.13
distribution system operator
DSO
party operating a distribution system

[SOURCE: IEC 60050, 617-02-10]

3.14
advanced distribution management system
ADMS
platform for optimized distribution system operational management

[SOURCE: Agalgaonkar Y.P., M.C. Marinovici, S.V. Vadari, K.P. Schneider, and R.B. Melton. 2016. ADMS State of the Industry and Gap Analysis Richland, WA: Pacific Northwest National Laboratory.]

3.15
state estimation
signal processing effort that transforms noisy metering measurements and pseudo-measurements into an estimate of a power system's static-state, which includes the steady-state vector of phase angles and magnitudes of voltages at all network buses

[SOURCE: S. Golestan, M.R. Habibi, S.Y. Mousazadeh Mousavi, J.M. Guerrero, J.C. Vasquez, Quantum computation in power systems: An overview of recent advances, Energy Reports, Volume 9, 2023.]

4 Use cases

Both FEDECOM and OPENTUNITY present a series of use cases mapping and validate different scenarios.

FEDECOM implements six use cases (UC1–UC6) in three pilot sites **to validate decentralised energy and flexibility trading within and between energy communities**. The project demonstrates the intra-community peer-to-peer (P2P) trading scheme, where participants exchange energy directly within the community, and inter-community P2P trading scheme, where communities aggregate energy and trade with each other and/or enable trading in higher flexibility and wholesale markets.

In Switzerland, the following Use Case is implemented:

- UC5 focuses on P2P trading within a solar and battery-equipped residential community using a blockchain-based local energy exchange whereby matching is based on forecasted demand and supply (demanded consumption and available generation, calculated in 15-minute time intervals based on forecasts) with ensuing execution based on actual measurements, and accounting for network fees and all other charges.

In Belgium:

- UC6 implements P2P trading within and among three solar and battery-equipped residential communities located in different provinces, as above, and this time accounting for applicable pricing in three different network zones. In both cases P2P trading will be applied live within a virtual canary test network and the impact of dynamic tariffs is also to be assessed.

OPENTUNITY use cases have a clear focus on promoting the ones that enhance Distribution Grids performance via new software technologies and flexibility markets. **Considering the use cases of FEDECOM**, there are two types of problems that DSOs may face when DERs are deployed at the low voltage (LV) networks and function P2P and peer-to-pool schemas: capacity problems and voltage problems. **Both of them are included in OPENTUNITY approach:**

To tackle **capacity problems**, OPENTUNITY focuses on enhanced forecasting models that will identify problems in the network during peak distribution generation periods. The idea is to identify these problems beforehand by running state estimation techniques using short term distributed energy resource (DER) generation forecasting (on PVs).

Whilst capacity problems can be observed in the power flows at steady estate, **voltage problems** normally affect the transient state while the system is not yet stabilized. The variations of the injected active energy produces temporal oscillations in the current and the voltage at the supply point. This might lead to problems in nearby grid devices and could lead to outages.

The core of the **capacity problem detection (UC 1.3)** process is based on the calculation of power flows. In this case, the demand and generation forecasts are calculated leveraging machine learning (ML) models of the loads and DERs. The ML models correlate energy demand and generation with weather information (solar irradiation in this case), thus including the forecasted local weather in the prediction calculation.

With these estimations, power flow will be calculated every hour for the next 24 hours. If the steady estate calculation detects grid congestion (capacity problems), the information is presented to the operator to take appropriate actions to solve the problem.

The **voltage problems detection process of OPENTUNITY (UC 1.1)** goes a step ahead of the steady estate power flow calculation by making use of dynamic models for the elements in the grid. These models try to mimic the electrical behaviour of the power electronics of the energy grid assets.

5 Data exchange & interoperability requirements

FEDECOM enables secure, decentralised data exchange to support energy and flexibility trading within and across energy communities. The exchanged data includes asset telemetry, flexibility offers, consumption and generation forecasts, market signals, and measurement data. These flows occur between DER operators, community coordinators, DSOs, and federation-level services. The architecture of the FEDECOM Platform connects local pilot platforms to shared federation services, including the Grid Singularity Decentralised Exchange (GSY DEX), a blockchain-based engine for market clearing, trade execution, settlement and remuneration. Communication is based on structured REST APIs and JSON messages, with on-chain logic executed via a Substrate-based runtime. In this project, data access control is supported through the project partner cloud-based databases, but the project includes preparedness for future integration with the Decentralised Identifier (DID) Registry toolstack developed by Energy Web, aligned with self-sovereign identity principles defined by the World Wide Web Consortium (W3C), including specifications such as DIDs v1.1 and the Verifiable Credentials Data Model v2.0. Each pilot platform exchanges data with the FEDECOM federation layer via standardised APIs and a canonical data model, enabling interoperability across heterogeneous systems. Semantic interoperability is achieved using domain-aligned ontologies, including SAREF (Smart Appliances REFerence, as specified in ETSI/TS 103 264), together with the W3C SOSA (Sensor, Observation, Sample, and Actuator), and SSN (Semantic Sensor Network) ontologies, enabling standardised representation of device, measurement, and control data. The architecture aligns with the Gaia-X framework for federated cloud infrastructure and the International Data Spaces Association (IDSA) Reference Architectural Model for trusted data sharing. It is also compatible with emerging dataspace interoperability specifications such as the Dataspace Protocol. Finally, the project will also implement an immutable registry for renewable energy Guarantees of Origin (GoO) and for activated flexibility resources using distributed ledger (blockchain) technology, aligned with the European Energy Certificate System (EECS). Thus, the RES producers across communities will be able to issue the green certificates in a confinable manner and manage GoO transactions through the energy certificate markets.

While the data exchange from LV prosumers to the rest of the actors is well covered with the FEDECOM approach, **DSOs are still missing a common topology format to integrate the topology of the grid with the required information** (DER location, line characteristics etc.) **for performing the abovementioned grid analysis.** This is due to the fact that there are inherent problems linked to the IEC Common Information Model (CIM) grid modelling that might compromise its wide adoption by DSOs. As an answer to these problems, **OPENTUNITY proposes a methodology and a set of tools to facilitate the interoperability of topological models between different software components used by different utility operators, with a focus on the DSO utilities**, that lack a version of CIM that cover its specific topological modelling requirements.

The availability of importers and exporters of CIM/CGMES (which are a collection of profiles defined within the EN/IEC 61970 series but also supports market-related use cases – EN/IEC 62325 series - and utility integration related use cases – EN/IEC 61968 series -) is very limited in the software components normally used by DSOs. **Thus, in the OPENTUNITY methodology a more realistic approach has been chosen, that does not restrict to software components natively supporting CIM/Common Grid Model Exchange Specification (CGMES) but also supports other alternatives.** OPENTUNITY methodology is Open-Source and supports conversion and implementation of CIM, PowSyBl, Pandapower, Excel, etc.

With this approach, it is ensured that the lack of standard DSO topology format does not avoid the provision of advanced functionality to DSOs (especially considering medium and small ones) and the integration of more DER and the execution of P2P schemas.

6 Demonstration and KPI-based validation

FEDECOM validates community-scale energy and flexibility trading through simulation and forecasting-based performance indicators. Dispa-SET (a unit commitment model extended to support decentralised coordination and tariff-based dispatch) simulates system behaviour under varied grid and market conditions, generating outputs such as voltage deviation, import/export imbalance, and curtailment. Probabilistic forecasts of electricity demand, thermal load, and PV generation feed both Dispa-SET and the GSY DEX Matching and Analytics Engines, which compares realised and expected performance at 15-minute intervals using data from InfluxDB and the GSY DEX off-chain storage. Forecast accuracy is assessed using skill scores and normalised error metrics derived from pilot data. Key performance indicators (KPIs) are derived from both metered pilot data and simulation outputs. Grid-related KPIs include peak load shaving, average peak load reduction at MV/LV transformers, and reduction in grid electricity usage—enabling direct evaluation of demand-side flexibility. Observability is assessed through forecasting offset metrics and state estimation error, benchmarked by normalised scoring functions. Voltage variability is also monitored as a key impact metric, aligned with the ±10% (during 95% of the time) threshold defined by EN 50160. Additional KPIs track flexibility availability at community level, variability in flexibility activation, and the degree of self-sufficiency and self-consumption achieved through local coordination. Economic indicators include cost savings, load shifting, and price signal responsiveness; environmental indicators include avoided emissions. Most KPIs follow standardised definitions compatible with the International Performance Measurement and Verification Protocol (IPMVP), ensuring replicability and comparability across use cases. For use cases requiring baseline estimation, calibrated simulations and backcasting are applied with normalised external inputs, following ISO 17741. Forecasting models, APIs, and measurement and verification (M&V) routines are stress-tested under edge cases and partial data loss. These KPIs feed directly into remuneration procedures, enabling consistent, auditable settlement and supporting cross-project comparability.

For OPENTUNITY, the main aim of this topic is to study the voltage variations due to DER fluctuations that might impact the stability of the grid by causing congestion or affecting the protection schemes. OPENTUNITY demonstration (with data - P, Q, V, I -coming from the SCADA -from the nodes- and the smart meters) analyses the precision of the voltage variation forecast performed in ÉTER and also checks if the voltage variations are within the thresholds defined by the DSO. Thus, the main KPI to validate within this topic is the “Variability of the voltage”. ± 10 % is the maximum voltage variation allowed (during 95 % of the time) according to previously mentioned EN 50160, and this figure serves as a reference value for this KPI. It serves as a baseline value, ensuring that within the tests of the Analysis of the impact of DER in the Distribution grid, this value is respected in the analysed nodes more than 95 % of the time.

7 Grid observability and impact assessment

In both FEDECOM and OPENTUNITY, observability of distributed assets is technically feasible but constrained by the latency and resolution of metering and communication infrastructures. While 1–2 minutes data granularity would be ideal for near real-time impact assessment, most pilot sites experience longer delays due to device polling intervals, backend processing, and data synchronisation limits. As a result, the system cannot support real-time control or high-frequency event detection but enables retrospective analysis of asset behaviour, import/export variations, and trading-induced flow shifts. Time-series data captured by pilot-level acquisition systems and stored via off-chain infrastructure is used to reconstruct load profiles, validate flexibility activation, and evaluate local grid impacts, including voltage variation and congestion risk. Where real-time visibility is lacking or data gaps occur, forecast-based backfilling and simulation outputs are used to reconstruct asset-level and grid behaviour for KPI tracking and impact validation.

8 Implementation guidance for different actors

A series of guidelines can be drawn from both projects for different roles:

FEDECOM defines implementation pathways for four key actor categories: DSOs, energy community coordinators, solution providers (including aggregators, IT integrators, and technology vendors), and public authorities.

- DSOs interact with decentralised trading mechanisms through tariff signals and observability endpoints, enabling non-intrusive monitoring of local import/export dynamics without requiring direct inverter control. FEDECOM’s architecture integrates with grid management systems via canonical data models and standardised APIs, allowing KPI outputs to inform grid planning and validation. More importantly, it allows DSOs to source local flexibility when needed.

- Energy community coordinators (e.g., municipalities, cooperatives, citizen-led initiatives) can deploy local or cross-community trading by interfacing their platforms with the federation layer services, configuring asset registration, forecasting, and remuneration workflows in compliance with DSO requirements.

- Solution providers implement forecasting algorithms, DER onboarding, trading logic, and local control strategies that align with local and/or federation-level validation protocols.

- Public authorities may use FEDECOM components to design regulatory sandboxes or pre-commercial support schemes, drawing on interoperable M&V frameworks and harmonised KPIs to evaluate decentralised coordination models, especially for inter-community trading which still has not been permitted in practice in any EU member state.

Complementary, regarding this topic, OPENTUNITY has its main focus on the DSOs and provides them the required documentation and software access to the ADMS (called ÉTER) in which the DER impact analysis is included. However, as usual in this type of solutions, a great integration process is required. To facilitate this integration process was one of the reasons to develop the Topology converter methodology proposed in OPENTUNITY (previously explained) and it is composed by the following elements that facilitates its implementation:

- A **software component that allows converting among different topological data models**. This software component has been provided as an open-source component available to the broad audience. The component integrates different open-source available converters and facilitates its usage within the tool.

- **A new tabular/excel data model** that allows easily defining the topology that has been defined. This is particularly well suited for small distribution networks and is an alternative to other specific and proprietary topology editors.

- **An on-line topology visualization tool** that allows representation of the grid topology in a graphical way. It does not require any previous knowledge on any specific software component, nor require any software license.

9 Recommendations

Drawing from implementation progress and preliminary outcomes across five Member States in FEDECOM and OPENTUNITY, this document recommends that standardization bodies and policymakers align across four domains: interoperability, market design, data governance, and regulatory harmonisation.

- Semantic interoperability should be supported through canonical data models and standard ontologies (e.g., SAREF, SOSA, and SSN), combined with machine-readable APIs and schema validation. To ensure compatibility with emerging EU data frameworks, federated architecture principles should be adopted, drawing from initiatives like Gaia-X and the IDSA to address identity, access control, and trust services.

  In this line, it is also relevant to facilitate the interoperability of topological models between different software components used by different utility operators, with a focus on the DSOs, that lack a version of CIM that covers their specific topological modelling requirements. Topology is the basis for most of the smart functionalities addressed to DSOs that are being developed in R&D projects.

- Regulatory frameworks should evolve to support decentralised coordination models. This includes enabling dynamic trading coefficients, ex-ante and ex-post trading rules, and overall intra-/inter-community trading under differentiated, market-based pricing structures. These changes require formal roles, procedures, and remuneration logic to be defined within DSO settlement processes, particularly for distributed flexibility integration. The regulatory explicit promotion of having ADMS to small and medium DSOs in order to improve grid digitalization and operational observability or to support advanced distribution grid management would be also valuable.

- Observability and data access management requirements should include minimum thresholds for data granularity, latency, and time synchronisation (especially for flexibility activation, forecasting, and performance optimisation and verification). National and EU regulatory sandboxes should also be leveraged to test these configurations within specific legal and market contexts. To that end, to complete the smart meter deployment is of utmost importance. A key enabler in this domain would be a decentralised flexibility registry, ideally at EU-level and at a minimum at EU member-state level to enable secure access to data by grid operators, utilities as well as solution providers such as demand response and P2P trading services, while also ensuring citizen privacy and data access management.

- Currently, the legal basis for peer-to-peer and peer-to-pool trading is not mandated or explicitly enabled in national legislation in terms of harmonised roles, data access protocols, and settlement procedures.

NOTE Attention is drawn to the Electricity Directive (EU) 2019/944 (including the extension and harmonization of the radius in which PV energy can be shared).

Bibliography

[1] EN 50160, *Voltage characteristics of electricity supplied by public electricity networks*

[2] EN-IEC 61968 (series), *Application integration at electric utilities - System interfaces for distribution management*

[3] EN-IEC 61970 (series), *Energy management system application program interface (EMS-API)*

[4] EN-IEC 62325 (series), *Framework for energy market communications*

[5] ETSI/TS 103 264 V4.1.1 (2025-03), *SmartM2M; Smart Applications; Reference Ontology and oneM2M Mapping*

[6] ISO 17741, *General technical rules for measurement, calculation and verification of energy savings of projects*

[7] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast)

[8] OPENTUNITY. https://opentunityproject.eu/

[9] FEDECOM. https://fedecom-project.eu/

[10] GAIA X. https://gaia-x.eu/

[11] Singularity G. *Grid Singularity Decentralised Energy Exchange (GSY DEX)*, published under the GPL v.3 open source license, https://github.com/gridsingularity/gsy-decentralized-exchange

[12] Decentralized Identifiers (DIDs) v1.1 Core architecture, data model, and representations. W3C Candidate Recommendation Snapshot 05 March 2026

[13] Verifiable Credentials Data Model v2.0. W3C Recommendation 15 May 2025

[14] W3C, Decentralized Identifiers (DIDs) v1.1 – Core architecture, data model, and representations, W3C Candidate Recommendation Snapshot, 5 March 2026.

[15] W3C, Verifiable Credentials Data Model v2.0, W3C Recommendation, 15 May 2025.

[16] W3C Recommendation: Semantic Sensor Network Ontology, 19 October 2017.

[17] Dataspace Protocol Specification (DSP) 2024-1, International Data Spaces Association / Eclipse Dataspace Working Group.

[18] EDSO The Road Map on Go4Flex - Grid observability for Flexibility

[19] Agalgaonkar Y.P., Marinovici M.C., Vadari S.V., Schneider K.P., Melton R.B. *ADMS State of the Industry and Gap Analysis Richland*. Pacific Northwest National Laboratory, WA, 2016

[20] S. Golestan, M.R. Habibi, S.Y. Mousazadeh Mousavi, J.M. Guerrero, J.C. Vasquez, Quantum computation in power systems: An overview of recent advances, Energy Reports, Volume 9, 2023.