Energy Data Governance Fragmentation in Europe: Challenges, Models, and Pathways to Integration

Shievam Kashyap*, Wieland Schwinger⊥, Stefan Grünberger*, Christoph Schaffer*, Georg Hartner*

Department of Smart and Interconnected Living, *University of Applied Sciences Upper Austria*, Hagenberg, Austria*
Institute of Telecooperation, *Johannes Kepler University*, Linz, Austria⊥

***Abstract*—The shift to a decentralized and digitalized energy market in Europe requires efficient and standardized energy data exchange. Diverse national data governance rules create interoperability problems, hindering market efficiency and cross-border integration. This paper analyzes the diversity in energy data-sharing mechanisms among European nations, categorizing them into centralized, decentralized, and hybrid frameworks. The publication synthesizes conclusions gathered from several knowledge-sharing round-tables with experts from regional representatives into a taxonomy that delineates the current roles and duties across various European member states. Furthermore, the research suggests a potential solution by presenting critical modules for connecting heterogeneous member states by acting as a mediator layer.**

***Index Terms*—Energy Data Governance, Energy Sharing, Policy, Energy Market Design, Taxonomy**

I. Introduction

Democratization of energy landscape, shift towards decentralized energy systems, increasing renewable penetration, and enhanced consumer participation have underlined the significance of efficient energy data exchange [1]. However, heterogeneity in national data access frameworks poses significant hurdles to the realization of a unified European energy market [2]. This leads to challenges in achieving economies of scale across European energy markets due to high costs of adhering to heterogeneous national practices, as mentioned by [3].

Aimed at ensuring standardized, secure, and non-discriminatory access to energy data, the European Union has introduced several regulatory measures to address these challenges such as the Clean Energy for All Europeans Package and the Electricity Market Directive, as detailed in section II. Despite these efforts, inconsistencies persist in the implementation of these regulations across member states, as elaborated in section III.

This paper explores the existing landscape of energy data-sharing arrangements in Europe, examining the technical, legislative, and administrative challenges to achieving a harmonized market. It analyzes country-specific implementations in various member states of EU through several rounds of consulting and interviewing the regional representatives. Additionally, it discusses plausible solutions, including the role of interoperability standards and mediation layers, in bridging the gap between fragmented data governance structures.

II. European Regulatory Framework for Energy Data Sharing

As discussed earlier, with the energy sector transition towards greater decentralization, renewable integration, and consumer participation, the ability to access and share energy data efficiently has become a key enabler of market competitiveness and system flexibility [4]. The value added services can only be offered with explicit authorization by the users to share their energy data with third-party service providers [5], the process of which differs from one region to another.

Recognizing such issues, the European Union has systematically established regulatory measures to ensure the accessibility, standardization, and security of energy data. An important step in this direction was the adoption of the Clean Energy for All Europeans Package [6], which aimed to redefine the relationship between consumers and the energy providers. Essentially, this package reaffirmed the notion that the consumers should have transparent and non-discriminatory access to their energy consumption data, thereby empowering them to make informed decisions, seamlessly switch providers, and benefit from innovative digital energy services. The Electricity Market Directive [7], as a key element of this package, established a legal basis for standardized data access while outlining the obligations of market participants such as Distribution System Operators (DSOs), Transmission System Operators (TSOs), and energy service providers. Although the directive provided comprehensive principles, its implementation across member states remained inconsistent, leading to substantial disparities in how energy data is stored, accessed, and shared. In accordance with the principle of subsidiarity, article 23 of the directive [7] permits the member states to designate which parties (e.g., DSOs, independent data hubs, or third parties) take on data management roles. Some of the key roles, as delineated in the Harmonized Electricity Market Role Model (HEMRM) [8], are succinctly explained here and referenced in the subsequent sections. As the roles embodied by HEMRM, the energy data from smart meters is retrieved by Metered Data Collector (MDC), a party responsible for meter reading and quality control of the reading. Meter Data Responsible (MDR) then establishes and validates measured data based on the collected data received from the MDC. MDR transmits the validated data to Meter Data Administrator (MDA) who in turn is responsible for storing and distributing validated

measured data through a Data Access Provider (DAP). Consent Administrator, also known as Permission Administrator (PA), facilitates authorized data sharing based on user consent. The autonomy of the member states to choose the pertinent players has created heterogeneity where different roles of the data-sharing infrastructure are prerogative of varying market players, as detailed in section III-B.

In order to rectify these inconsistencies, the European Commission introduced Implementing Regulation [9], which laid down specific requirements for data interoperability. It aimed to bridge the technical divide between nations with established centralized data centers and those with fragmented or DSO-managed systems by requiring the use of common data models and standardized digital interfaces. Under this framework, energy data must be made available in machine-readable formats, assuring that suppliers, aggregators, and third-party innovators can access the same level of information regardless of national boundaries. Nevertheless, significant hurdles persist in harmonizing legacy IT infrastructures and reconciling different national interpretations of data governance protocols.

Additional substantial concerns emerge pertaining to customer privacy and security. The proliferation of smart metering infrastructure and digital platforms generates unparalleled volumes of personal consumption data [10], necessitating robust governance frameworks. The General Data Protection Regulation (GDPR) [11] establishes fundamental legal principles for personal data management, encompassing access, rectification, and deletion rights. However, the actual enforcement of these rights has not been consistent across member states [12]. While some countries have implemented centralized consent management platforms that simplify consumer authorization, others require ratification with respective DSOs, creating barriers to seamless data portability.

Technical standardization deficiencies present additional barriers to market harmonization [1], [13]. Different national regulators have adopted proprietary communication protocols and fragmented IT infrastructures, making it difficult for energy service providers to operate across multiple jurisdictions without costly adaptations. To mitigate this issue, the EU has introduced a series of Network Codes and Guidelines that define common technical frameworks for data exchange, ensuring that grid operators, demand response aggregators, and market participants can communicate efficiently. The Electricity Balancing Guideline (EBGL) [14] and the Network Code on Demand Response [15] exemplify such efforts, providing structured communication protocols that facilitate real-time grid coordination and demand-side participation.

Notwithstanding these statutory measures, substantial governance deficiencies persist in data ownership and accessibility frameworks. The European Data Act [16] represents a strategic initiative to streamline cross-sector data-sharing policies, emphasizing enhanced data portability to facilitate service provider transitions and foster market competition. This regulatory evolution enables innovative business models, particularly in peer-to-peer trading and AI-driven efficiency optimization, predicated on high-quality, real-time data access.

III. Heterogeneity in Energy Data Sharing Models across Europe

The administration of energy data governance across European countries poses intricate challenges owing to diverse legislative frameworks and market structures. The Clean Energy Package (Directive (EU) 2019/944) and Commission Implementing Regulation 2023/1162 delineate essential concepts for data governance, encompassing criteria for accessibility and interoperability; nonetheless, their practical application, including processes, formats, and schemas, differ among member states [17], [18]. This diversity is evident in various data-sharing paradigms, which can be classified into centralized, decentralized, and hybrid architectural models.

A. Classification of Models adopted by Member States

1) Centralized Models - National Data Hubs: The centralized data management approach embodies a hierarchical structure wherein DSOs consolidate metering data from consumers prior to its transfer to a national data hub. This centralized repository typically operates under the governance of either a TSO, regulatory authority, or designated independent entity. The architecture's primary strength lies in its standardization of data exchange protocols, enabling streamlined market operations and uniform access mechanisms for diverse stakeholders. Centralized architecture offers advantages in regulatory oversight efficiency, reduced administrative complexity, lower operational costs, and curtailing complexity of data exchange [19]. However, it simultaneously introduces critical challenges regarding data security vulnerabilities, potential monopolistic control over data access, and constraints on competition in data-driven energy services.

2) Decentralized Models - DSO-led Data Management: Decentralized data management architectures present a significant departure from centralized frameworks, fundamentally altering the dynamics of metering data governance. Here, DSOs exercise autonomous control over their jurisdictional data, thereby minimizing the inherent vulnerabilities associated with consolidated repositories. This architectural paradigm, while mitigating cybersecurity risks and administrative constraints, introduces considerable challenges in cross-border data harmonization due to heterogeneous implementation protocols across DSO networks.

3) Hybrid Models - Combining Centralized and Decentralized Elements: Hybrid architectures in European energy data management merge selective aspects of centralized and decentralized frameworks, creating nuanced operational paradigms. These systems uphold decentralized metering data collection at the DSO level while establishing centralized interfaces for consent management and data access. This architectural innovation addresses the inherent tension between standardization requirements and localized data governance needs.

B. Country-Specific Approaches to Energy Data Sharing

1) Austria: Austria's implementation of energy data management demonstrates exemplifies a decentralized architectural

Country	Model	MDC & MDR	PA	MDA	DAP	No. of DSOs	Data range	Data granularity
Austria	Decentralized	DSO	DSO	DSO	DSO	124	Past: -36m Future: +36m	quarterly, daily
Denmark	Centralized	DSO	Eloverblik	Energinet	Energinet	38	Past: -48m Future: +12m	quarterly, hourly, daily, monthly, yearly
Estonia	Centralized	DSO	Elering's PARM	Estfeed Datahub	Estfeed Client Portal	32		
Finland	Centralized	DSO	Fingrid	Fingrid	Fingrid	77	Past: -72m Future: +24m	quarterly, hourly, daily, monthly, yearly
Netherlands	Hybrid	DSO	BAS/MFF	DSO	BAS/MFF	6	Past: -24m Future: +9999y	daily
Italy	Centralized	DSO	Acquirente Unico	DSO	Portale SII/ Portale Consumi	123		
Spain	Hybrid	DSO	Datadis	DSO	Datadis	333	Past: -24m Future: +24m	quarterly, hourly

TABLE I

A TAXONOMY REPRESENTING THE VARIATIONS IN VARIOUS MEMBER STATES WITHIN EUROPE BY LISTING THE MARKET-PLAYERS TAKING UP THE ROLES OF METER DATA COLLECTOR (MDC), METER DATA RESPONSIBLE (MDR), PERMISSION ADMINISTRATOR (PA), METER DATA ADMINISTRATOR (MDA), AND DATA ACCESS PROVIDE (DAP). ADDITIONALLY, THE VARIATION IN THE RANGE OF DATA THAT CAN BE REQUESTED FROM THE PAST AND THE DATA-SHARING PERMISSION FOR HOW LONG INTO THE FUTURE ARE OUTLINED. FURTHERMORE, THE GRANULARITY OF DATA THAT THE COUNTY'S INFRASTRUCTURE SUPPORTS.

approach, characterized by distributed responsibility across DSO networks. This framework assigns dual functionality to DSOs as Meter Data Administrators and Meter Data Responsible entities, maintaining data sovereignty at the collection source. Consumer data access protocols necessitate explicit authorization mechanisms directly through respective DSO interfaces.

While the framework ensures robust local control mechanisms, it introduces considerable challenges in cross-DSO data harmonization. Third-party service integration faces particular constraints due to the necessity of establishing multiple DSO interfaces, each governed by distinct procedural requirements. The establishment of Energiewirtschaftlicher Datenaustausch GmbH (EDA) [20] represents an attempt to address interoperability challenges while preserving the core decentralized architecture.

2) Denmark: Denmark employs a centralized approach through the Energinet DataHub [21], operated by the national TSO. The framework establishes a unified repository for consumer metering data, facilitating standardized access protocols for market participants across the energy value chain.

3) Estonia: Estonia adopted the centralized energy data governance that demonstrates an alternative architectural paradigm in utility digitalization. The Estfeed Datahub, administered by the national TSO Elering [22], establishes a hierarchical data management framework where DSOs maintain their collection functions while operating within a nationally standardized data submission protocol.

4) Finland: Finland has also embraced a centralized data-sharing model, where all energy metering data is collected and stored in a national repository managed by the TSO, Fingrid [23]. The Fingrid Datahub consolidates metering data from DSOs and provides a unified platform for accessing and managing energy consumption information.

5) Netherlands: Deploying a dual-layer framework that distinguishes storage and access management functions, the Netherlands exemplifies an innovative hybrid architecture. This approach maintains distributed data storage protocols at the DSO level while centralizing access management through the Market Facilitation Forum (MFF) and BAS infrastructure [24].

6) Italy: Italy has undertaken a centralized strategy through the implementation of a government-regulated infrastructure. The system architecture designates Acquirente Unico as the principal governance body, operating the Portale SII [25] as a unified data repository. This technical framework incorporates specialized consumer access mechanisms through the Portale Consumi platform, establishing validated protocols for historical data retrieval.

7) Spain: The energy data governance system in Spain exhibits a unique bifurcated architecture that delineates data management from consent processes. This hybrid infrastructure maintains decentralized data sovereignty at the DSO level while implementing centralized authentication mechanisms through the Datadis platform [26].

IV. CHALLENGES IN ACHIEVING A HARMONIZED EUROPEAN ENERGY DATA INFRASTRUCTURE

The heterogeneous landscape of European energy data governance frameworks reveals fundamental tensions between centralization and local autonomy in digital infrastructure design. This diversity manifests through varying architectural approaches to data management, consent protocols, and market facilitation mechanisms.

The observed architectural variation introduces complex implications for market development and system interoperability. Cross-border service provision faces substantial barriers due to heterogeneous data access protocols and divergent governance frameworks. However, this diversity also enables comparative analysis of different architectural approaches, facilitating evidence-based evaluation of governance models and technological implementations. The European Union's

regulatory harmonization initiatives provide mechanisms for leveraging these insights toward enhanced system integration.

The evolution of energy data governance frameworks necessitates innovative approaches to infrastructure design and market facilitation. Future developments must address the fundamental challenge of balancing standardization with flexibility, while ensuring robust data protection and market accessibility. This requires coordinated technological innovation and regulatory adaptation to establish interoperable communication protocols and harmonized governance frameworks across the European energy landscape. This chapter briefly summarizes the key hurdles in the energy data landscape.

A. Regulatory and Institutional Fragmentation

A significant obstacle to harmonization stems from the inconsistent transposition of EU directives at the national level. While the Clean Energy Package and Implementing Regulation 2023/1162 provide guidelines for data accessibility and interoperability, individual member states interpret and implement these rules differently. The divergence complicates cross-border energy trade, as market participants must traverse different regulatory landscapes, often necessitating distinct compliance measures for each jurisdiction in which they operate.

Moreover, national energy market structures influence the role of key stakeholders in data governance. In some cases, TSOs manage data hubs, ensuring consistency across the market, whereas in others, DSOs retain direct control over metering data. The lack of uniformity in market roles creates inefficiencies in the implementation of EU-wide data-sharing mechanisms.

B. Technological Barriers and Lack of Standardization

The lack of common technical standards for data exchange across member states is another considerable challenge. While some countries have developed automated data-sharing mechanisms with standardized APIs and structured communication protocols, others still rely on manual or semi-automated processes, compelling third-party service providers to adapt their systems to multiple data formats. The unavailability of a harmonized European market APIs and inconsistencies in adoption of common communication protocols [27] across member states poses a hindrance in this effort.

Furthermore, disparities in smart metering infrastructure complicate real-time data access. In countries where smart meters are fully integrated with centralized platforms, real-time data can be accessed with ease. However, in systems where smart meters require external adapters or proprietary interfaces, the retrieval of real-time data remains a hurdle. This inconsistency impedes the development of demand response services and other real-time energy management solutions, which rely on uniform high-quality data access.

Interoperability constraints also stem from the use of different encryption and cybersecurity standards, which can prevent seamless data exchange between platforms. Some national regulators impose strict data protection measures that create additional layers of complexity for cross-border integration, further hindering the existence of a cohesive European energy data infrastructure.

C. Administrative Complexity and Market Access Restrictions

Beyond regulatory and technical challenges, administrative impediments also play a role in inhibiting harmonization. The complexity of on-boarding third-party service providers varies widely across countries, with some markets requiring extensive approval processes, multiple agreements with DSOs, or lengthy certification procedures. In decentralized systems, where each DSO manages its own data-sharing rules, market entrants must negotiate individual agreements with multiple entities, therefore substantially elevating the effort and expense of participation.

The lack of standardized consent management frameworks exacerbates data access issues. While some countries have established centralized consent management platforms that allow consumers to authorize third-party access through a single interface, others require consumers to interact directly with their respective DSOs. This variation creates inconsistencies in consumer experience and delays in service activation for energy market participants operating in multiple jurisdictions.

Additionally, linguistic obstacles introduce an additional dimension of complexity. Many national data-sharing platforms provide documentation, user interfaces, and technical specifications solely in the local native language, complicating navigation of administrative requirements for international market participants. This issue particularly impacts smaller enterprises and innovative service providers seeking to expand their operations across multiple European markets.

D. Data Privacy and Compliance with GDPR

Although GDPR provides a uniform legal framework for data protection, the way in which individual countries implement consumer consent mechanisms varies, leading to discrepancies in enforcement. In certain cases, consumers can easily manage their data permissions through national data hubs or dedicated online portals, streamlining compliance. However, in decentralized markets, consumers must traverse multiple consent procedures, depending on the policies of their local DSO. This fragmentation increases the risk of non-compliance for market participants who must ensure they adhere to different interpretations of GDPR across member states.

Balancing data privacy with market efficiency is another challenge [28]. Though stringent data protection policies safeguard consumer rights, excessively restrictive frameworks may limit innovation in the development of data-driven energy services. The pursuit of finding an equilibrium between security, accessibility, and ease of authorization remains an ongoing issue as policymakers refine regulatory frameworks.

V. Proposed Solution

A viable and scalable approach to the problem of heterogeneous landscape of different national technical implementations, as being developed under project EDDIE [29], is

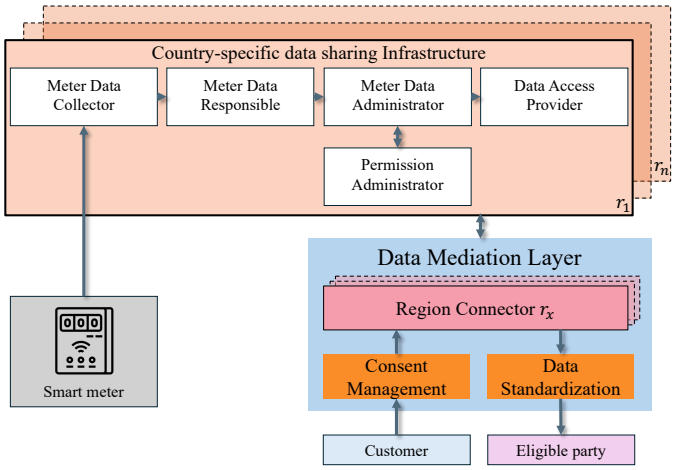

Fig. 1. Country-specific data sharing infrastructure, r_1 to r_n representing that these infrastructure changes from region to region where unique set of market participants play these roles. Designing of Data Mediation Layer could help where the 'Region Connector (r_x)' embodies the preconfigured set of parameters to make data accessible to Eligible Parties across different regions.

the implementation of a Mediation Layer. It is a dedicated interoperability framework that alleviates the necessity for individual users and market players to modify their systems for compatibility. The Mediation Layer acts as a dynamic intermediary, translating and standardizing interactions between two distinct and interdependent components of energy data exchange: users and data seekers (EP) on one side, and national energy data infrastructures on the other. Central to this solution is its capacity to abstract the complexities of regional data governance, acting as an intelligent intermediary that harmonizes disparate systems into a cohesive, interoperable framework.

The core functionality of mediation layer is epitomized by its Region Connector modules that are dedicated country-specific adapters engineered to interface with localized data infrastructures. Each module is designed to accommodate the unique characteristics of a given national energy data system, ensuring that data retrieval, access permissions, and compliance requirements align with the country's existing regulatory and technical frameworks. Each region connector, showcased as r_x where 'x' denotes the particular region, in Fig. 1, encapsulates the unique protocols, formats, and regulatory nuances of its respective region. For instance, in Austria, where decentralized DSO-managed systems dominate, the connector translates push-based XML/AS4 messaging into standardized schemas. Conversely, in the Netherlands the module automates the consent mechanism, which follows the standardized OAuth (Open Authentication) flow to authenticate third parties for data access. By developing dedicated region connectors to address the regional characteristics, the mediation layer enables users and eligible parties to interact with a unified interface, oblivious to the underlying heterogeneity.

Critical to this architecture is the Consent Management module, a centralized subsystem that orchestrates user permissions across jurisdictions. Rather than requiring consumers to navigate fragmented authorization workflows, the module takes care of redirecting the user to the appropriate permission administrator such as Austria's DSO-specific portals or Spain's Datadis platform. This eliminates the need for eligible parties to implement redundant authorization mechanisms, streamlining compliance and fostering trust.

Another key module is the layer's Data Standardization Engine, which transmutes region-bound data formats, such as Finland's Fingrid Datahub schemas or Italy's Portale SII structures, into a harmonized model to optimize interoperability [30]. Leveraging IEC-CIM standard [31], the engine ensures semantic consistency across data, temporal resolutions, and asset identifiers [32]. This allows, for instance, stakeholders to analyze Spanish consumption patterns alongside Belgian DER performance metrics without manual reconciliation, unlocking cross-border insights previously obscured by technical fragmentation.

The modularity of this system provides several key benefits. First, it ensures that national regulators and DSOs retain full control over data governance. Second, it eliminates the need for individual users and businesses to develop their own adaptations, significantly lowering barriers to market entry and cross-border operations. Finally, this approach enhances security and compliance by ensuring that each module is designed to adhere to the legal and technical standards of the respective country, while still aligning with overarching European regulations.

VI. Conclusion

The diversity of energy data governance among European member states yields persistent obstacles to market efficiency and interoperability. Existing regulatory frameworks provide a foundation, but variations in implementation continue to pose hurdles. This study demonstrates how varied national models effect data accessibility while highlighting major differences in regional approaches, as examples, through a taxonomy and suggests a Mediation Layer to ease cross-border integration. The indicated mediation layer design demonstrates that technical compatibility can be achieved while preserving national implementation sovereignty.

Acknowledgment

Co-funded by the European Union

This work was co-funded by the European Union's Horizon Innovation Actions under grant agreement No. 101069510. The authors would like to thank the project EDDIE consortium partner Energiewirtschaftlicher Datenaustausch GmbH, and in particular Leo Kammerdiener and Stefan Kienler, for organizing several expert round-tables involving representatives from each participating country.

REFERENCES

[1] S. Dekeyrel and M. Fessler, "Digitalisation: an enabler for the clean energy transition," *Journal of Energy & Natural Resources Law*, vol. 42, no. 2, pp. 185–209, 2024.

[2] V. Karagiannis, S. Kashyap, N. Zechner, O. Hödl, G. Hartner, M. Llorca, T. Jamasb, S. Grünberger, M. Kurz, C. Schaffer, and S. Schulte, "A framework for enabling cloud services to leverage energy data," in *2023 IEEE International Conference on Cloud Engineering (IC2E)*, 2023, pp. 43–50.

[3] European Commission, "The Future of European Competitiveness: A Competitiveness Strategy for Europe," https://commission.europa.eu/document/download/97e481fd-2dc3-412d-be4c-f152a8232961_en, January 2024, the Draghi report: A competitiveness strategy for Europe.

[4] S. Küfeoğlu, E. Açıkgöz, Y. E. Taşcı, T. Y. Arslan, J. Priesmann, and A. Praktiknjo, "Designing the business ecosystem of a decentralised energy datahub," *Energies*, vol. 15, no. 2, 2022. [Online]. Available: https://www.mdpi.com/1996-1073/15/2/650

[5] M. R. Asghar, G. Dán, D. Miorandi, and I. Chlamtac, "Smart meter data privacy: A survey," *IEEE Communications Surveys & Tutorials*, vol. 19, no. 4, pp. 2820–2835, 2017.

[6] European Commission, "Clean energy for all europeans package," https://energy.ec.europa.eu/topics/energy-strategy/clean-energy-all-europeans-package_en, 2019.

[7] European Union, "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," June 2019. [Online]. Available: http://data.europa.eu/eli/dir/2019/944/2024-07-16

[8] ENTSO-E, "Harmonised role model," January 2023. [Online]. Available: https://eepublicdownloads.entsoe.eu/clean-documents/EDI/Library/HRM/Harmonised_Role_Model_2023-01.pdf

[9] European Commission, "Commission Implementing Regulation (EU) 2023/1162 of 6 June 2023 on interoperability requirements and non-discriminatory and transparent procedures for access to metering and consumption data," June 2023. [Online]. Available: http://data.europa.eu/eli/reg_impl/2023/1162/oj

[10] S. Lavrijssen, B. Espinosa Apráez, and T. Ten Caten, "The legal complexities of processing and protecting personal data in the electricity sector," *Energies*, vol. 15, no. 3, p. 1088, 2022.

[11] European Union, "Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation)," https://eur-lex.europa.eu/eli/reg/2016/679/oj, 2016.

[12] K. Huhta, "Smartening up while keeping safe? advances in smart metering and data protection under eu law," *Journal of Energy & Natural Resources Law*, vol. 38, no. 1, pp. 5–22, 2020.

[13] D. V. Fernandes and C. S. Silva, "Open energy data — a regulatory framework proposal under the portuguese electric system context," *Energy Policy*, vol. 170, p. 113240, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0301421522004591

[14] European Union, "Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing," https://eur-lex.europa.eu/eli/reg/2017/2195/oj, 2017.

[15] ENTSO-E and EU DSO Entity, "Draft Network Code on Demand Response," https://consultations.entsoe.eu/markets/public-consultation-networkcode-demand-response/supporting_documents/Network%20Code%20Demand%20Response%20v1%20draft%20proposal.pdf.

[16] European Union, "Regulation (EU) 2023/2854 of the European Parliament and of the Council of 13 December 2023 on harmonised rules on fair access to and use of data and amending Regulation (EU) 2017/2394 and Directive (EU) 2020/1828 (Data Act)," https://eur-lex.europa.eu/eli/reg/2023/2854/oj, December 2023.

[17] S. Kashyap, C. Schaffer, T. Fischer, M. Zauner, F. Fischer, M. Kurz, G. Hartner, S. Grünberger, and O. Hödl, "Empowering energy communities and p2p energy sharing: A novel end-to-end ecosystem for planning, deployment, and operation," *SIGENERGY Energy Inform. Rev.*, vol. 4, no. 4, p. 238–244, Feb. 2025. [Online]. Available: https://doi.org/10.1145/3717413.3717436

[18] M. Booshehri, L. Emele, S. Flügel, H. Förster, J. Frey, U. Frey, M. Glauer, J. Hastings, C. Hofmann, C. Hoyer-Klick, L. Hülk, A. Kleinau, K. Knosala, L. Kotzur, P. Kuckertz, T. Mossakowski, C. Muschner, F. Neuhaus, M. Pehl, M. Robinius, V. Sehn, and M. Stappel, "Introducing the open energy ontology: Enhancing data interpretation and interfacing in energy systems analysis," *Energy and AI*, vol. 5, p. 100074, 2021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2666546821000288

[19] S. Küfeoğlu and Şahincan Üçler, "Designing the business model of an energy datahub," *The Electricity Journal*, vol. 34, no. 2, p. 106907, 2021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1040619020301998

[20] EDA, "Energiewirtschaftlicher Datenaustausch GmbH," accessed: February 6, 2025. [Online]. Available: https://eda.at/

[21] Energinet, "Energinet," accessed: February 6, 2025. [Online]. Available: https://energinet.dk/

[22] Elering, "Elering," accessed: February 6, 2025. [Online]. Available: https://elering.ee/en

[23] Fingrid, "Fingrid," accessed: February 6, 2025. [Online]. Available: https://www.fingrid.fi/en/#

[24] MFFBAS, "MFF: Sharing Energydata," accessed: February 6, 2025. [Online]. Available: hhttps://www.mffbas.nl/en/

[25] Acquirente Unico, "Acquirente Unico - Portale SII," accessed: February 6, 2025. [Online]. Available: https://siiportale.acquirenteunico.it/

[26] Datadis, "Datadis," accessed: February 6, 2025. [Online]. Available: https://datadis.es/home

[27] G. Naeem, M. Asif, and M. Khalid, "Industry 4.0 digital technologies for the advancement of renewable energy: Functions, applications, potential and challenges," *Energy Conversion and Management: X*, vol. 24, p. 100779, 2024. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2590174524002575

[28] M. Rayati and M. Bozorg, "Pricing differentially private smart meter data in distribution networks," in *2022 18th International Conference on the European Energy Market (EEM)*, 2022, pp. 1–6.

[29] EDDIE, "European Distributed Data Infrastructure for Energy," 2024, accessed: February 6, 2025. [Online]. Available: https://eddie.energy/

[30] O. Borgogno and G. Colangelo, "Data sharing and interoperability: Fostering innovation and competition through apis," *Computer Law & Security Review*, vol. 35, no. 5, p. 105314, 2019. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0267364918304503

[31] International Electrotechnical Commission (IEC), "Common Information Model (CIM) – IEC 61968, IEC 61970, and IEC 62325 Standards for Power System Data Exchange," https://webstore.iec.ch/, 2024, accessed: February 6, 2025.

[32] J. J. Simmins, "The impact of pap 8 on the common information model (cim)," in *2011 IEEE/PES Power Systems Conference and Exposition*, 2011, pp. 1–2.