DIGITAL ENERGY SYSTEMS AND FUNDAMENTAL RIGHTS: SMART METERING IN THE EU AND THREE CEE COUNTRIES

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Article provides a comparative legal analysis of smart metering regulations in Hungary, Slovenia, and Croatia, assessing how national frameworks align with EU objectives on energy efficiency, consumer rights, and data protection. While Hungary applies a pilot-based, cautious rollout with unclear long-term goals, Slovenia offers detailed technical standards and data categories but shows enforcement gaps. Croatia adopts a forward-looking, consumer-oriented and cybersecurity-aware model, yet requires refinement in definitions and data retention rules. The article concludes that an optimal regulatory model could combine Hungary's flexibility, Slovenia's data precision, and Croatia's consumer protection. However, effectiveness depends on full alignment with the GDPR and the establishment of clear, enforceable rights for data subjects. The article also proposes two follow-up directions: (1) developing a practical guide for consumers on their rights regarding smart meters, and (2) exploring competition law implications related to exclusive access to consumer data in liberalized energy markets. Without harmonized EU-level data governance, smart metering may risk reinforcing regulatory inconsistencies and market imbalance.

Key words: Smart metering; energy regulation; data protection; legislative quality; consumer rights.

1 INTRODUCTION

While the cost-of-living crisis of recent years boosted the acceptance of utilizing devices aiming to optimize consumption, their popularity had already been increasing due to legislative mandates (Directive (EU) 2023/1791, Article 9)[2]

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[2] Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on Energy Efficiency and Amending Regulation (EU) 2023/955 (Recast). 2023. OJ L 231: 1.

and the broader shift towards digitalized energy systems to achieve – first and foremost – climate goals.

Smart meters are advanced devices that enable real-time monitoring and recording of energy consumption and can maintain two-way communication with the utility provider, which allows remote monitoring for optimized billing. They are "an electronic system capable of measuring electricity fed into the grid or electricity consumed from the grid, providing more information than a conventional meter, and transmitting and receiving data for information, monitoring, and control purposes using electronic communication." (Directive (EU) 2019/944, Article 2).[3] They often support dynamic pricing models and facilitate energy efficiency by empowering users to adjust their consumption patterns based on real-time feedback.

The advantages of putting smart meters into operation are diverse. It provides consumers with detailed insights into their energy consumption to address the growing sustainability awareness, encouraging a more conscious behaviour in reducing energy waste. For utility service providers, smart meter technology streamlines billing, improves demand forecasting and troubleshooting and reduces operational costs by removing human intervention. Moreover, these devices support overall modernization and would have the potential to connect themselves to a higher order of arrangements supporting other innovative concepts, such as smart cities.

Although smart meters offer significant benefits, their implementation is accompanied by various challenges. Privacy and transparency concerns are prominent as these devices collect granular data about household energy use, potentially revealing personal habits. Additionally, cybersecurity (Directive (EU) 2023/1791, Article 18) risks arise from the increased digitization of energy infrastructure as the internet connection is the ultimate platform for transferring information. The upfront cost of deployment, combined with technical issues such as interoperability (Commission Implementing Regulation (EU) 2023/1162), have also generated resistance among stakeholders.[4]

It is essential to analyse the legal context surrounding individuals who utilize smart meters, examining their status and defining characteristics. Typically, such individuals possess attributes that qualify them as subjects under data protection regulations (Regulation (EU) 2016/679, Article 4).[5] Furthermore, they often meet the criteria for being classified as consumers (Directive 2011/83/EU, Article 2), natural persons who, under civil law, enter contractual relationships with service providers.[6] These providers are frequently in significantly more powerful positions, resulting in a profoundly asymmetrical relationship. When comparing various regulatory frameworks, evaluating the effectiveness of the protection of the rights in place they offer to such individuals is crucial.

[3] 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). 2019. OJ L 158: 125.

[4] 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. 2023. OJ L 154: 1.

[5] 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). 2016. OJ L 119: 1.

[6] Directive 2011/83/EU of the European Parliament and of the Council of 25 October 2011 on Consumer Rights, Amending Council Directive 93/13/EEC and Directive 1999/44/EC of the European Parliament and of the Council and Repealing Council Directive 85/577/EEC and Directive 97/7/EC of the European Parliament and of the Council. 2011. OJ L 304: 64.

This study aims to uncover the regulatory surroundings within select Central and Southeast European countries, exploring some particularities and underlining good practices and legislative challenges while considering the relevant EU framework. Through comparative analysis, we aim to evaluate and identify the most optimal approach regarding smart metering that captures the ideal relationship and balance concerning fundamental rights. In achieving that, we would explore the relevant case law and utilize testing tools to determine the quality of legislation used. The study exclusively examines the EU regulatory framework and the Hungarian, Slovenian and Croatian regulations on this subject, focusing solely on residential consumers and the application of smart meters in the context of electricity.

The three CEE countries were selected for comparative analysis based on the relatively similar yet divergent post-socialist transition histories and comparable but different paths in energy market liberalisation and digitalisation, including smart meter penetration. The broader relevance for EU and the region is in how mid-sized economies with comparable energy infrastructure challenges highlight regional regulatory inconsistencies, that could be informative regarding broader EU harmonization efforts. Research will be limited to the policy and legal aspects of digital energy systems.

This study will utilize a combination of logical, dialectical, dogmatic-normative, and comparative methods. The logical method will be used in an informal manner to ensure the acceptability of the legal argumentation employed (Dewey 2013, 181–191). The dialectical method will be used to weigh and counterbalance different arguments and achieve a conclusion according to the principles of rational discourse (Valauri 2010, 415). The normative-dogmatic method will be employed in the sense that law will be treated as a normative phenomenon, exerting influence on pressing societal issues (Vachev 2023, 289–299). The discussion section will use a comparative method to critically assess the merits and shortcomings of legal solutions in select national jurisdictions (e.g., Hungary, Slovenia, and Croatia) (De Cruz 2024). A state-of-the-art legislative quality analysis per the model of Xanthaki will support it (Xanthaki 2010, 111–128), adapted to the needs of the present study.

Within the confines of this article, a smart meter will be a device that fits the definition of an IoT (Internet of Things) device. It is a connected device that collects, transmits, and potentially processes data to improve consumer experience. It is important to acknowledge that it performs its activity on a greater scale during the application of AI technology—by its very nature. It collects data so extensively that we might not even comprehend it. As a result, the scope of personal data extracted may expand with the proliferation of AI, making information relevant that previously was not deemed significant. This lack of transparency can lead to a "function creep" (Koops 2021) where data is used for purposes beyond those initially disclosed, as under GDPR, personal data should only be collected for specific, explicit and legitimate purposes and should be limited to what is necessary. However, AI and machine learning systems often require large datasets to function effectively, potentially conflicting with these principles.

The structure of the present article is such that after the introduction, the second section will analyse the European Union-level provisions on smart metering. In the third section, solutions from individual national jurisdictions (Slovenia, Hungary, Croatia) will be discussed in three subsequent subheadings. In the

fourth part, a discussion will be performed, and a legislative test quality will be employed. Conclusions and recommendations for further research will wrap up the scholarly article.

2 EUROPEAN UNION REGULATION ON THE UTILISATION OF DATA FROM SMART METERS

The serious attempts by the European Union to regulate the utilization of smart meters began in 2012 when there were already commission recommendations for the roll-out of smart metering systems (2012/148/EU). [7] The real breakthrough, however, came with the European Green Deal, as Baumgart and Espinosa note, the "Twin Transitions" of the EU – green and digital – reinforce each other, and smart meters are a central enabler of this combined transformation (Baumgart and Espinosa 2024). The European Green Deal is the EU's overarching strategy to make Europe climate-neutral by 2050. This ambition covers several areas, including increasing energy efficiency and integrating digital technologies into energy systems. To achieve these goals, the importance of smart meters has increased significantly, leading to changes in legislation (European Commission 2024). The integration of smart metering is crucial for the EU's Digital Single Market and energy union, yet varying national regulations pose significant barriers to achieving a cohesive framework (Dąbrowski 2022, 92–119). The question is that while the EU legislation has succeeded in defining the objectives of smart metering, the means of achieving them are often left too flexible, causing diverging national regulatory practices which may hinder internal market integration or not (Baumgart and Espinosa 2024).

According to Article 2, (23) of EU directive 2019/944, 'smart metering system' means an electronic system capable of measuring electricity fed into the grid or electricity consumed from the grid, providing more information than a conventional meter, and transmitting and receiving data for information, monitoring, and control purposes using a form of electronic communication. It is therefore clear that the smart metering system also raises serious data protection issues on the consumer side. As Lavrijssen and others highlight, the co-existence of energy law and data protection law creates tensions, particularly due to the potentially conflicting obligations under the GDPR and the directive 2019/944 (Lavrijssen, Espinosa and ten Caten 2022, 1088).

The use of smart meters is inevitable for developing sustainable, flexible energy systems and achieving the energy targets set in the European Green Deal. Smart metering systems allow consumers to monitor their energy consumption in real-time, so they can manage it more consciously, reducing energy use and associated costs, and therefore contribute to optimizing energy consumption; also, with their use, it is possible to have access to dynamic electricity price contracts. Moreover, these tools support the integration of renewable energy sources such as solar and wind energy into the grid by providing accurate data on the balance between generation and consumption and, last but not least, contribute to grid stability and resilience: real-time data allows operators to manage energy allocation better, react to changes in demand and prevent grid congestion (European Commission n.d.; EU directive 2019/944). On the other hand, as Slate et al. point out, the integration of digital solutions and artificial intelligence into

[7] Commission Recommendation 2012/148/EU of 9 March 2012 on Preparations for the Roll-Out of Smart Metering Systems. 2012. OJ L 115: 1.

energy utilities brings major opportunities for automation and optimization, but also raises concerns about explainability, trustworthiness, and ethical deployment, especially when AI systems make near real-time decisions based on personal consumption data. Furthermore, the integration of AI introduces concerns about explainability, human oversight, and unintended consequences, especially when automated decisions affect system-critical infrastructures (Slate et al 2024; Szuchy 2023).

Smart metering systems, their functions and the rules for their installation are regulated in detail in Articles 19 to 21 of EU directive 2019/944. Article 19 requires Member States to promote the installation of smart meters to increase energy efficiency. The devices must be interoperable with consumer energy management systems and smart grids. The deployment of smart meters may be subject to a cost-benefit analysis, and Member States must ensure that the devices comply with EU standards. Old meters cannot remain in service after 2031 if they do not meet the new requirements. In this manner, the member states have a relatively wide margin of appreciation in smart meter implementation, allowing for flexibility regarding deployment strategies. At the same time, this discretion is not unlimited. It should namely be compliant with GDPR and avoid fragmenting the internal market (Baumgart and Espinosa 2024).

Article 20 sets out minimum functionalities for smart meters, including providing real-time energy consumption data, compliance with cybersecurity and data protection rules, and accurate energy measurement fed back into the grid. Consumers should have free access to their data and be supported to use smart meters to their full potential. Also, Article 20 states that smart metering systems and the related data disclosure shall comply with relevant Union security rules, and that the privacy of final customers and the protection of their data shall comply with relevant Union data protection and privacy rules; the issues related to data management are explained in more detail in Article 23.

Under this provision, Member States – or, if they have so provided, the competent authorities designated by them – are required to lay down the rules under which authorised parties may have access to end-users' data. The data includes consumption and metering data, as well as any data that is necessary for switching providers, demand-side response or other services. Member States are required to establish a data governance system that ensures efficient, secure and privacy-appropriate access to and exchange of data. Regardless of the data governance model used, data should be provided to all right holders in a non-discriminatory, simultaneous and easily accessible manner, and access procedures should be made publicly available. The applicable rules for data processing must comply with EU law, particularly the General Data Protection Regulation (EU) 2016/679 (GDPR) (Camões 2023, 89-116). Member States or competent authorities have the power to authorise, certify and, where appropriate, supervise data management parties and may also decide on the appointment of compliance managers to monitor the provision of non-discriminatory data access and compliance with the directive. End users should not incur any additional costs if they request access to their own data or if they make their data available to others (Holéczy and Varallai 2022, 47–64). Member States determine the fees for which right holders can access this data and are obliged to ensure that the fees charged by regulated providers are reasonable and duly justified.

Article 21 details consumers' rights if a Member State does not introduce a mandatory smart metering system. All consumers have the right to apply for

installing a smart meter on fair terms and to receive clear information on its features, services, and costs. The devices should be installed within four months, and the authorities should regularly update the relevant prices and information.

This has clarified why energy legislation is important from an energy management perspective. However, the data protection issues for residential consumers should also be considered regarding their use; furthermore, addressing privacy concerns is essential for fostering consumer trust, necessitating a legal framework that mitigates risks associated with data handling (Orlando and Wandevelde 2021), because – for instance – legislation mandates that all new meters in multi-apartment buildings be remotely readable, emphasizing the need for compliance with data protection regulations due to the personal data processed by these systems (Polčák 2023).

As regards the obligation of Member States, when it comes to data protection regarding the use of smart metering systems, Article 9 (2) b) of Directive 2012/27/EU [8] has already mentioned that Member States shall ensure the security of the smart meters and data communication, and the privacy of final customers, in compliance with relevant Union data protection and privacy legislation. Preamble (57) of EU directive 2019/944 states that following the introduction of smart metering systems, Member States have now developed or are developing different data management models. Regardless of which model is used, it is paramount that Member States establish transparent regulation that guarantees non-discriminatory access to data, the highest level of cybersecurity and data protection, and the impartiality of data controllers.

From a data protection standpoint, some authors argue that smart meter deployment may conflict with the principle of data minimisation under the GDPR. Since smart meters measure and store data at very short intervals, the potential for profiling increases significantly. It has been suggested that anonymisation and purpose limitation need to be enforced more stringently to ensure legal compliance (Lavrijssen, Espinosa and ten Caten 2022; Camões 2023; Szuchy 2022a). This concern is empirically supported by large-scale studies, which show that smart meter data – collected at high temporal granularity – can reveal highly specific occupant behaviour patterns, including presence, routines, and even appliance use. This level of inference significantly increases the risk of profiling, as well as potential secondary uses of data beyond the original energy service context (Horvath et al 2019).

Article 34 highlights the Tasks of distribution system operators in data management and emphasizes that Member States shall ensure non-discriminatory data access for all eligible parties under equal terms while implementing compliance measures to prevent unfair advantages for distribution system operators and vertically integrated undertakings in smart metering data management, under data protection regulations and relevant directives. This was mainly handled by the unbundling of distribution system operators, mentioned in Article 35.

Regarding the pace of smart metering system deployments, ANNEX II of EU directive 2019/944 earmarked for those Member States that have started the systematic roll-out of smart metering by 4 July 2019, at least 80% of end-users must be equipped with a smart meter by 2024 (Jones 2025). Overall, while the EU has established a foundational regulatory structure, ongoing challenges

[8] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on Energy Efficiency. OJ L 315: 1.

remain in harmonizing national laws and enhancing consumer confidence in smart metering technologies (OECD/KDI 2021).

As noted by Noorman et al., it must be emphasised, that the use of AI and digitalisation in energy systems increases the risk of privacy violations and cybersecurity breaches, necessitating robust legal and technical safeguards (Noorman, Espinosa Apráez and Lavrijssen 2023, 2110). According to the ANNEX IV of the Regulation (EU) 2024/2847 of the European Parliament and of the Council of 23 October 2024 on horizontal cybersecurity requirements for products with digital elements and amending Regulations, smart meter gateways within smart metering systems as defined in Article 2, point (23) of Directive (EU) 2019/944 of the European Parliament and of the Council are counting as critical products with digital elements.[9] In this regard, ANNEX I summarises the essential cybersecurity requirements of these critical products with digital elements.

The main statements are that advanced encryption mechanisms must protect the confidentiality of data, while its integrity must be preserved against unauthorized modification, and any breach must be reported. The principle of data economy requires that only data necessary for operations should be collected, while users should be able to delete or transfer their data to other systems securely. Systems should detect and report data breaches and ensure that security updates are available quickly and free of charge to minimize vulnerabilities and maintain data security. Article 8 of the Regulation (EU) 2024/2847 states that to ensure device compliance, the Commission will be empowered to adopt legal acts to determine which products containing digital elements should obtain a European cybersecurity certificate with at least a "substantial" trust level.

Overall, smart metering systems have privacy, competition and cybersecurity implications. Having outlined the European Union's comprehensive framework for smart metering, which emphasizes energy efficiency, consumer empowerment, and robust data protection under directives like 2019/944 and regulations such as 2024/2847, it is evident that member states face the challenge of aligning national policies with these standards while addressing local contexts (Hoffman 2023, 65; Ručinská et al 2023, 26). The following section turns to the national implementing measures in Hungary, Slovenia, and Croatia, examining how each country translates EU requirements into domestic legislation, with particular attention to consumer rights, data management, and legislative alignment, laying the groundwork for a comparative evaluation of their approaches.

3 NATIONAL IMPLEMENTING MEASURES

3.1 Hungarian smart metering regulation

Regarding regulatory specificities, Hungary's approach is one of Europe's most extreme and long-lasting forms of government intervention in energy pricing. While other European countries implemented temporary caps and subsidies during, e.g. economically challenging periods, Hungary maintained artificially low, fixed prices as a core economic policy (Böcskei 2015, 94–114) for nearly a

[9] Regulation (EU) 2024/2847 of the European Parliament and of the Council of 23 October 2024 on Horizontal Cybersecurity Requirements for Products with Digital Elements and Amending Regulations (EU) No 168/2013 and (EU) No 2019/1020 and Directive (EU) 2020/1828 (Cyber Resilience Act).

decade – a model rarely seen elsewhere (Fischerauer and Johnston 2016, 458–474).

The household utility cost reduction program ("rezsicsökkentés") refers to a series of government measures introduced in 2013 to lower household energy prices. The primary goal was to protect households from fluctuations in global energy prices and to prevent energy providers from increasing costs. The process unfolded through several stages and expanded in 2014, covering water, sewage, waste collection fees, gas, electricity, and district heating prices. Until 2021, households continued to receive energy at regulated prices, and the system was financed through state-owned energy companies and various taxes. In 2022, the angle shifted. As the global energy crisis led to a sharp rise in energy prices, the government had to amend the utility cost reduction program as it had placed a substantial financial burden on the country: households continued to receive energy at regulated prices up to a designated consumption threshold. However, businesses lost access to regulated utility prices and had to purchase energy at market rates. Consumers exceeding the average consumption limit also had to pay the higher, market-based rates.

The household utility cost reduction program was narrated as a social policy (Bouzarovski et al 2016, 1151–1170) measure (to prevent energy poverty) but has been heavily contested concerning EU regulations, particularly regarding energy market competition, state intervention, and fair pricing practices. The European Court of Justice addressed Hungary's energy price regulations in Case C-771/18, highlighting the importance of fair network access charges which were part of the broader concept of the household utility cost reduction program.[10] While the ECJ found that Hungary failed to ensure effective judicial remedies, it did not find the price regulation itself (e.g. restrictions on passing cost to consumers) to be in breach of EU law.

The Internal Energy Market Directive (2019/944) in Article 5 emphasizes that electricity prices should be cost-reflective and encourage energy efficiency. It also suggests that while suppliers shall be free to determine the price at which they supply electricity to customers, Member States shall protect energy-poor and vulnerable household customers with public intervention which the Hungarian regulation evidently considers.

However, according to paragraph 4 of Article 5, public interventions in the price setting for electricity supply shall be clearly defined, transparent, non-discriminatory and verifiable, amongst many other conditions. The most significant criticism of the Hungarian regulation has been that it lacks transparency regarding price (Weiner and Szép 2022) generation. It is therefore welcomed that in 2016 the government proposed a regulation to support the roll-out of smart meters in a carefully thought-out and rational manner. The Government Decree No 26/2016 suggests a program sought to ensure that smart meters would be fully compliant with EU requirements and contribute to Hungary's long-term energy goals, including cost-reflective pricing and integrated smart grids.

While the relevant European Union regulation contains a regulatory framework, the Hungarian legislator has used a particularly distinct approach regarding smart metering systems and national implementing measures. This divergence in national implementation is also highlighted by Szuchy, who explains that although EU law has significantly shaped Hungarian energy legislation, domestic

[10] Case C-771/18, European Commission v Hungary, EU:C:2020:584.

policy remains cautious and often fragmented in its uptake of smart grid technologies (Szuchy 2024, 305–334). According to the Act LXXXVI of 2007 on Electric Energy, Section 3, point 48a, 'Smart meter' shall mean remotely accessible metering equipment capable of receiving remote instructions for information, control, monitoring and inspection purposes. At the same time, the law does not deal with the regulation of smart meters any further.

However, in Section 170, subsection (1), point 19 gives authorization to the government to decree the rules for the implementation of pilot projects for the roll-out of smart meters, including the rules relating to and for the installation of smart meters, also covering the rights and obligations of those participating in the pilot projects, the related duties, data processing and data protection regulations, and regulations for the disclosure of data and information relating to the pilot projects and the conclusions thereof.[11] At the same time, on April 4, 2024 that 650 thousand smart meters were in operation in the country (E.ON 2024), in other words, the Electricity Act has not been updated for some time, moreover, Szuchy highlights that while the government has initiated several smart grid-related actions, these often remain at the policy level without comprehensive implementation in the legal corpus (Szuchy 2022b, 553–575).

Regarding the installation of smart meters, based on Section 14/B. of the Government Decree No. 273/2007 (X. 19.) on the implementation of certain provisions of Act LXXXVI of 2007 on electric energy, the DSO is required to install a smart meter at low-voltage connection points (with a maximum of 3x80 A) where no indirect or prepaid meter is installed, in the following cases:

1. New installations or capacity upgrades where the total power demand (excluding separately metered controlled circuits) reaches or exceeds 3x32 A,
2. Household-sized renewable energy generators (HMKE) are connected to the electricity network at the consumer site,
3. The certification period of the existing meter expires in a location with a household-sized generator,
4. The site's annual electricity consumption (excluding controlled circuits), calculated based on a profile-based distribution tariff, reached or exceeded 5000 kWh/year during the previous billing period,
5. Upon user request, if the consumer pays the applicable fee for voluntary installation.[12]

If any of these conditions are met, the DSO is obligated to install a single smart meter that measures the total electricity consumption outside the controlled circuit. The regulation also states that if the existing meter already complies with smart metering settlement requirements, the DSO is not obliged to replace it. Once a smart meter is installed under these conditions, the DSO is only allowed to replace it later with another remotely readable (telemetric) device. Importantly, refusing to install a smart meter in cases where installation is required by law constitutes a breach of contract, which may result in penalty payments by the DSO. Beyond the mandatory cases, any consumer has the right to request smart meter installation from the relevant DSO, provided they pay the legally defined installation fee.

[11] Government Decree No. 26/2016 (II.25.) on the Rules for the Implementation of the Central Pilot Project Related to the Introduction of Smart Metering.
[12] Hungarian Act LXXXVI of 2007 on Electric Energy.

The Electricity Act has strict regulation related to Data Disclosure, Treatment of Restricted Information, Confidentiality chapter. Section 150, subsection (4) deals with the processing of the data of natural persons -although, indeed, the law does not explicitly state that this would also apply to data measured by smart meters. Authorized distribution network operators and electricity suppliers shall exchange data under the Data Exchange Code regarding the particulars of natural person users and other relevant persons, in particular data for the identification of final customers and the service location and the details of supplies and data required for administrative purposes, concerning the operation of the electricity market and for handling customer submissions, to improve the efficiency of electricity supply and services. Although the Hungarian legislation refers to data protection in formal terms, it does not adequately address the legal status of the data generated by smart meters. In particular, the distinction between technical data and personal data suitable for profiling is not explicitly clarified, which raises concerns under the GDPR (Szuchy 2021, 239–247).

Regarding which participants in the electricity market, for what purpose and type of user data is stored is set out in Section 155. The provisions of Section 155 govern the processing and use of data collected by remotely accessible metering equipment. According to subsection (1), authorized network operators shall be entitled to process such data for purposes including the development of the public utility network, monitoring of the security of supply, improving energy efficiency, conducting settlement procedures, identifying cases of unauthorized electricity usage, analysing consumption patterns, operating metering equipment, customer switching, and the provision and use of system services and distribution flexibility services.

Subsection (2) sets out the categories of data that authorized distributors must manage under specific regulatory provisions. These include voltage quality data, network quality data, data stored in error registers, equipment data and identifiers, event log entries, and load curves. According to subsection (3), these data shall be retained by the authorized network operator for five years. As provided in subsection (4), other authorized operators may only access this data to the extent necessary for fulfilling their duties as specified in their operating license.

According to Subsection (5), electricity suppliers may process the data collected by remotely accessible metering equipment for settlement with customers, customer switching, providing distribution flexibility services, the combination of power plants, electricity storage and customers, and improving energy efficiency. In line with Subsections (6) and (9), aggregators are entitled to process such data for settlement among market participants involved in aggregation, for providing distribution flexibility services, combining different energy system components, improving energy efficiency, and aggregator switching. Aggregators are also required to retain the data for five years.

Subsection (7) stipulates that aggregators shall make the data collected by their metering equipment available to authorized network operators in the composition and at the frequency specified in the Distribution Code. Finally, under Subsections (8) and (9), energy communities are likewise authorized to process data for the purposes of internal settlement among members, provision of flexibility services, energy system integration, and improvement of energy efficiency. The duration of data retention for these entities is also limited to a maximum of five years.

In practice, the Hungarian Energy and Public Utility Regulatory Authority (MEKH) oversee smart metering implementation, including approving pilot projects, monitoring compliance with data protection standards, and enforcing installation obligations through audits and penalties. For instance, MEKH has facilitated the rollout of over 650,000 smart meters by 2024 (E.ON 2024), providing practical guidance on cybersecurity and consumer complaints, though challenges persist in scaling beyond pilots (Szuchy 2024).

When it comes to metering and data protection, Act on Electricity regulates smart metering through precise provisions on measurement, data reading, and data protection. According to Section 40 Subsections (1)-(4a), authorized network operators are responsible for meter readings, which must occur at least annually, or quarterly upon customer request. Customers may also transmit readings via mobile apps (Subsection 4c). Section 43 mandates that all metering data be processed through certified billing systems that meet strict information security standards, verified by accredited bodies (Subsections 4-5). Regarding household-sized power plants, Section 45/A requires active users to cooperate with the national energy data platform and other market actors to enable non-billing data handling under government decree. This supports transparent, secure, and GDPR-aligned data management in the smart metering ecosystem.

It is worth noting that Section 24 Subsection (1) d) requires network operators to take cybersecurity principles into account when maintaining their systems. These operators are also responsible for facilitating the central pilot projects, which the users may join as a project participant by applying for a smart metering device.

Still, as Baumgart and Espinosa (2024) argue, national laws should not only establish retention limits but also provide strong guarantees for transparency, auditability, and consumer rights in accessing, controlling, or deleting their smart meter data. Legal systems must catch up with the hybrid role of smart meters as both technical and behavioural monitoring tools.

3.2 Slovenian regulatory framework on smart metering

The Slovenian national implementing measures on smart metering are the relevant provisions of the Electricity Supply Act (ZOEE).[13] The law uses the terminology 'advanced meter', which, according to paragraph 41 of Article 4 ZOEE, means electronic meters, which measure inbound or outbound energy in the electricity grid (Tomažič 2025, 49). Such meters must collect more information than regular analogue or digital meters and include functionalities for measurement in hourly or shorter intervals. They must, per legal definition, be part of an advanced measurement system, which, per paragraph 40 of Article 4 ZOEE, consists of advanced meters, measurement centres and communication infrastructure connected to the national data hub.

Paragraph 1 of Article 28 ZOEE prescribes a right and obligation to advanced metering. On the one hand, it gives each end consumer the right to have a smart meter installed and measure consumption using an advanced metering system. On the other hand, the distributor may demand that consumers allow the installation of smart meters, with unclear ramifications if they do not comply. According to paragraphs 3 and 4 of the same provision, advanced meters must enable gathering the necessary data according to relevant standards, best

[13] Slovenian Electricity Supply Act (National Gazzette, no. 172/21 and 47/25).

practices, development of the advanced network, and be technically compliant (Batič 2025, 75).

While according to paragraph 5 of Article 28, ZOEE end users contribute to expenses connected to the advanced metering system, paragraph 6 of the same provision enshrines the right to install advanced meters for free. Paragraph 7 of the same provision requires the Slovenian Energy Agency to follow the advances in the state of technics to keep in line with novel technological developments, following the principle of cost efficiency.

Per Article 29 ZOEE, advanced meters must accurately measure energy consumption and production in real time, providing consumers with easy and secure access to this data at no extra cost. These meters must comply with EU cybersecurity and data privacy regulations, including GDPR, ensuring the protection of personal information. Distribution operators must offer consumers guidance on meter management and data processing. Additionally, the meters should enable time-interval metering aligned with the national market's balancing period. Real-time consumption data must be accessible to consumers and authorized third parties for energy efficiency and demand response programs. The meters must also account for electricity fed into the grid by active consumers, and operators must provide accessible consumption and production data for easy comparison of energy offers.

Personal data management, use, storage, and transmission regarding smart metering in the Slovenian legal framework is subsumed to Regulation 2016/679/EU and the Slovenian Act on Personal Data Protection (ZVOP-2). A special legal basis for data protection and legitimate processing is enshrined in Article 30 of ZOEE. The legitimately processed data includes personal information such as name, surname, address, and tax number, the identifier of the delivery point with corresponding unique identifiers of measurement points, and the name and address of that point. Additionally, measurement and billing data directly associated with the system user are processed, including measured working energy in 15-minute or shorter intervals and time aggregates of this energy.

Especially the measured working energy in 15-minute or shorter intervals is of utmost importance for the functioning of the smart metering systems (Chandrasekaran et al 2015, 120–124). This data is stored for a maximum of three years after the end of the year in which it was generated, to ensure data for the efficient operation of the electricity market, the provision of energy services, and for the purpose of operating and ensuring the reliability of supply. However, monthly or longer time aggregates of this data relating to the system user are stored for up to five years. Other personal data of system users arising from contractual relationships are stored as long as necessary to implement pre-contractual measures at the individual's request, to fulfil the contract, and to enforce rights and obligations from the contract or until the expiry of the legal protection period for the contracting parties.

3.3 Croatian legal framework on smart metering

In the Croatian legal framework, the main implementing measures for advanced metering systems are included in the Act on Electrical Energy Market (Beus et al 2018, 346). In paragraph 57 of Article 3, the best available techniques principle is included, which extends specifically to data protection and advanced metering as the most effective, advanced, and appropriate techniques to provide a

foundation for compliance with European Union data protection and security rules.

Smart metering is regulated in the context of systems of advanced metering, which are defined in paragraph 100 of Article 3 of the Act on Electrical Energy Market as an electronic system capable of measuring both electricity delivered to and electricity consumed from the grid, providing more information than a conventional meter, and capable of sending and receiving data through some form of electronic communication for information, monitoring, and control.

Per Article 30 of the Act on Electrical Energy Market,[14] the Croatian minister responsible for energy needs to adopt a decree to prescribe the usage of advanced metering systems (Borozan, Krkoleva Mateska and Krstevski 2021, 8730–8741). These need to fulfil specific requirements; namely, the advanced metering system must accurately measure and deliver real-time electricity consumption data to customers, with secure access to historical and near real-time information. It must adhere to cybersecurity and data privacy standards per EU regulations. The system must display grid contributions to the electricity suppliers' meters. Upon customer request, it must facilitate the sharing of consumption and supply data for comparison purposes. Comprehensive information regarding meter capabilities and data handling must be provided to customers. Finally, the system must enable precise measurement and billing for electricity consumed from and supplied to the grid, supporting system balancing.

Advanced meters are part of advanced metering systems, and electricity system users have the right to such smart meters based on a request to the system operator per Article 33 of the Act on Electrical Energy Market, even when the system operator does not install the advanced meter based on the economic assessment for an individual user.

In Article 35 of the same act, data management and protection are regulated. The Energy Agency is responsible for regulating the management, exchange, and access to end-customer electricity data, including measurement, consumption, and data necessary for supplier switching and demand management, per EU regulations. Data management must ensure secure access, efficient exchange, and data protection. Transmission and distribution system operators are obligated to provide non-discriminatory, simultaneous access to qualified parties. Personal data processing must comply with GDPR. The Agency requires the appointment of compliance officers to oversee non-discriminatory data access, and distribution system operators must also appoint a compliance officer. Access to or requests for data must be provided without charge.

4 COMPARATIVE AND LEGISLATIVE QUALITY ANALYSIS

The analysis and critical assessment in comparative terms and regarding the legislative quality of the three distinct national implementing measures or national legal frameworks more generally need to be performed with a certain degree of systematization. The frameworks are prima facie not wholly distinct, given that they all implement relevant European Union directives at the national level. However, approaches and execution in legislative drafting, content and quality, and individual legal solutions differ to some degree. These differences regarding smart metering implementation will first be ascertained on the axes of

[14] Croatian Act on Electrical Energy Market (National Gazzette, no. 111/21, 83/23 and 17/25).

installation policies, consumer rights, data protection and alignment with European Union standards. Then the slightly limited Xanthaki's test of legislative quality will be performed (Xanthaki 2010, 111–128).

Regarding installation policies, Hungary's approach relies on pilot projects in line with the Electricity Act. It is a controlled, state-driven process that stops short of a nationwide deployment. Compared to the Slovenian and Croatian approaches, the focus on testing through pilots might limit scalability. In this sense, the Slovenian approach is more normatively driven. The right to advanced meters is semi-mandatory as the distribution network operators may demand installation, with the possibility of users opting out in certain circumstances. On the other hand, users may also demand the installation of smart metering systems. Legal consequences of refusal to install smart meters on either the part of end users or the distribution company are not entirely clear and might entail lengthy legislative proceedings in the case that interested parties want to pursue them. The Croatian approach lies on the other end of the spectrum, with voluntary installation based on consumer and end users' requests. It thus takes a voluntaristic approach.

Regarding consumer rights, Hungarian electricity legislation generally lacks specific provisions on smart meters. Protection is limited to the rights and obligations of individuals or companies participating in pilot projects, and the utility cost reduction program prioritizes cost-effectiveness and low prices. However, a right to universal access to smart meters or their free installation is lacking. Slovenia grants consumers the right to free installation, real-time data access, and transparency. However, a broader protective framework focused specifically on smart metering, like that of pilot project participants in Hungary, is lacking. Croatia similarly to Slovenia, grants consumers the right to smart meters and emphasizes consumer choice and data sharing for comparing energy offers. Such a consumer-centric approach is closely aligned with the fairness principles of the European Union law (Michaelis et al 2024) and fosters market participation by consumers and other end users.

Regarding data protection, the Hungarian Electricity Act (in Sections 150 and 155) allows for broad processing by many actors, like network operators, suppliers, aggregators and energy communities. While implicitly, the data protection is tied to the rules of GDPR, the explicit connection is missing. The required data retention period is five years. According to Section 40, responsibility for readings is with the authorized network operator and a wide array of methods for data transmission, including with the use of mobile apps is available. Croatia mandates GDPR-compliant data management, with free consumer access and non-discriminatory sharing. In cybersecurity, the principle of best available techniques is a welcome addition (Tomažič 2022, 153–172). The Croatian framework is unnecessarily ambiguous about data retention length. The Slovenian approach from Article 30 ZOEE lists specific data types, with a retention period of three years for detailed data and five years for aggregate data.

From the standpoint of legislation as national implementing measures (Ferrod et al 2023), all three national legislative frameworks are, in principle, compliant with minimum European Union standards. While more specific data protection rules could improve the Hungarian approach in the sectoral legislation, Croatian could be emphasized as a model on the issue of cybersecurity, and the Slovenian approach has very precise and appropriate data protection provisions. The differences reflect the centralized approach of Hungary and Croatia's consumer-driven normative framework, with Slovenia falling between the two extremes. A

general legislative quality test will be applied before ascertaining the best practices from each approach.

It will follow the Xanthakian approach, focusing on legislative quality, which is seen through the lens of legislation's effectiveness, supported by clarity, precision, and unambiguity, as well as cost-effectiveness (Xanthaki 2024). Since the economic analysis of law is beyond the scope of the present article, the test will be performed in a limited manner, focusing on a qualitative and logically supported understanding and analysis of the national implementing measures (i.e. legislative frameworks) on smart meters in the Hungarian, Slovenian and Croatian legal systems.

In this sense, clarity, precision and unambiguity are three connected but slightly differing criteria with clarity relating to how well the particular or general auditorium can understand the legislation it addresses (Long 1983, 107–117), precision pertaining to specificity in defining rights and obligations and unambiguity referring to the absence of unclear or contradictory provisions (Xanthaki 2016, 1–18; Harašić 2011, 64).

In comparing the three national approaches on clarity, Section 3, point 48a of the Hungarian Electricity Act sufficiently and appropriately defines smart meters as pieces of remotely accessible metering equipment, but the focus on pilot projects from Section 170 leaves the consumers and other stakeholders in the fog regarding the long-term goals, which might only be inferred by looking at policy priorities at the national and EU level. While the Slovenian framework defines smart meters as advanced meters in Article 4, paragraph 41 of ZOEE, it also defines advanced metering systems with a slightly differing definition without resolving the relationship between the two. The Croatian approach is very clear and straightforward regarding the consumer-centric focus and the best available techniques to bolster the cybersecurity of smart meters. However, it is subject to a similar drafting lack of clarity in terms of the relationship between advanced meters and advanced metering systems, leading us to the conclusion that while all three national frameworks are clear enough, they are both lacking a bit in execution and could be improved in this segment.

Regarding precision, the Hungarian approach sufficiently lists the rules for installation, data processing and obligations of participants in pilot projects in Section 170 and data categories in Section 155. However, imprecise consumer protections and lack of a specific prescription of a universal right to smart metering limit their applicability, throwing doubt on the preciseness of implementing measures as outcomes of legislative intent and European Union goals. Slovenian ZOEE is precise in defining the functionalities of smart meters, especially regarding real-time data from article 29 and data types from article 30. However, imprecisions are present regarding the legal remedies and enforcement in case of instalment refusals, both on the side of the distributor, and the end user. Croatian approach is very precise regarding consumer rights from Article 33 of the relevant act, operator obligations from Article 30 and data management from Article 35; however, explicitly stated data retention periods are lacking in electricity sector legislation.

Although it is scarce regarding specific issues, the Hungarian approach is clear in its execution and language from the drafting standpoint. In the Slovenian framework, the cost-sharing provisions in connection to free installation requirements from Article 28 of ZOEE entail potential ambiguity and conflicting provisions. The keyword approach from Article 4 ZOEE is very welcome and

appropriate. The wording in the Croatian system is very clear, with few vague or open-ended notions left unexplained.

To summarize the findings, Croatia's approach seems to be the strongest contender for the best of the three analysed national frameworks on smart metering systems, with minimal issues regarding the implementation and interpretation of the rules for end users. If we were to piece together a best normative framework based on the findings, it would incorporate elements of all three systems.

A combined approach to smart metering regulation should thus be based on Croatia's consumer-centric model. This namely grants free installation and data access upon request. Slovenian data-protection rules are the most precise of the three analysed implementing measures and should be taken as a benchmark. Hungary's pilot framework is a welcome approach to inform the initial testing of new solutions, combined with Croatian best techniques and principles regarding cybersecurity.

Such a hybrid model should, however, avoid ambiguity in consumer rights and GDPR linkage as witnessed in the Hungarian model, the Slovenian model's unclear refusal consequences, which could lead to prolonged court disputes or lack of protection of rights, as well as steering clear of double, unclear definitions of smart meters versus smart metering systems as seen in the Croatian and Slovenian legal frameworks. Mandatory elements should be balanced with opt-out options based on network capabilities and a normative right to smart metering systems.

5 CONCLUSIONS

The study's comparative legal analysis showed that while Hungary, Slovenia and Croatia are striving to meet the EU's regulatory objectives on smart metering, there are still significant differences in national implementation in terms of legislative accuracy, consumer rights protection, data management practices and cybersecurity. The cautious, pilot project-based approach of Hungarian regulation does not provide a clear picture of long-term objectives and does not ensure sufficiently articulated and enforceable rights for consumers and data protection. While the Slovenian model has the merit of defining detailed data categories and technical requirements, it also contains enforcement and conceptual inconsistencies. The Croatian regulation is explicitly consumer-oriented and forward-looking from a cybersecurity perspective but needs further clarification on the use of definitions and the rules on the duration of data storage.

An optimal regulatory model could be developed by combining elements of the three regimes: the Croatian consumer protection and cybersecurity solutions, the Slovenian data protection granularity and the Hungarian pilot-based flexibility. However, all this can only be effective in terms of legal certainty and consumer confidence if national regulations avoid conceptual ambiguities, are fully aligned with the GDPR and provide explicit and enforceable rights for data subjects in the context of the use of smart metering.

In summary, the overarching trend reflects a heightened regulatory intent, signalling the onset of a new wave of legislative measures aimed at addressing both the risks and the benefits associated with digital products and connected devices (Regulation EU 2024/2847). This evolving framework is likely to give

rise to legal and operational complexity, accompanied by corresponding growth in litigation (see CJEU Case C-468/24) as stakeholders and citizens seek greater clarity.[15]

As a potential continuation of this study, a practical and societal value could be added by developing a public-facing, consumer-oriented guidebook based on the findings of the comparative legal analysis. This guidebook would translate the complex regulatory landscape into accessible language, helping household consumers understand their rights and obligations regarding smart meters. It would include practical instructions, identify the relevant supervisory authorities for data protection and energy regulation, and provide contact information for filing complaints or inquiries. Furthermore, the handbook would highlight the significance of user data protection and empower consumers to exercise control over their personal information in compliance with the GDPR (Fratini and Pizza 2018).

Further research integrating the findings into a broader electrical engineering and computer science driven studies would obviously also be of merit as would scaling the research to include other countries.

Another promising avenue for further research lies in exploring the competition law implications of smart metering systems. As smart meters generate vast amounts of consumer data, service providers with exclusive access to these datasets may gain significant market advantages. This raises concerns regarding market entry barriers for new players and the potential for anti-competitive behaviour, both at the EU and Member State levels (Jianxiao et al 2023). A robust regulatory framework would therefore not only protect individual data rights but also ensure a level playing field in liberalized energy markets.

In this context, the design of a harmonised, interoperable EU-wide data governance system emerges as essential. Such a framework would allow data portability and equal access while safeguarding cybersecurity and data minimisation principles as outlined by the GDPR. By addressing these challenges, policymakers can simultaneously enhance consumer trust and foster innovation in the energy sector.

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[15] Case C-468/24, Netz Niederösterreich.

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DIGITALNI ENERGETSKI SISTEMI IN TEMELJNE PRAVICE: PAMETNO MERJENJE V EU IN TREH DRŽAVAH SREDNJE TER VZHODNE EVROPE

Članek ponuja primerjalno pravno analizo ureditve pametnega merjenja na Madžarskem, v Sloveniji in na Hrvaškem ter ocenjuje, kako se nacionalni okviri usklajujejo s cilji EU na področju energetske učinkovitosti, pravic potrošnikov in varstva podatkov. Medtem ko Madžarska izvaja previdno uvajanje na podlagi pilotnih projektov z nejasnimi dolgoročnimi cilji, Slovenija ponuja podrobne tehnične standarde in kategorije podatkov, vendar izkazuje vrzeli pri izvajanju. Hrvaška sprejema napreden, v potrošnika usmerjen in kibernetsko varnostno ozaveščen model, ki pa potrebuje izboljšave pri definicijah in pravilih hrambe podatkov. Članek ugotavlja, da bi optimalni regulativni model lahko združeval madžarsko fleksibilnost, slovensko natančnost podatkov in hrvaško varstvo potrošnikov. Vendar je učinkovitost odvisna od popolne usklajenosti z GDPR ter vzpostavitve jasnih in izvršljivih pravic nosilcev podatkov. Članek predlaga tudi dve nadaljnji smeri raziskovanja: (1) izdelavo praktičnega vodnika za potrošnike o njihovih pravicah v zvezi s pametnimi števci ter (2) raziskovanje pomena prava konkurence v zvezi z izključnim dostopom do potrošniških podatkov na liberaliziranih energetskih trgih. Brez usklajenega upravljanja podatkov na ravni EU, glede pametnega merjenja, tvegamo, da bo to okrepilo regulativne neskladnosti in neravnovesje na trgu.

Ključne besede: pametno merjenje; energetska regulativa; varstvo podatkov; kakovost zakonodaje; pravice potrošnikov.