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SMART GRID IMPLEMENTATION AND USER ACCEPTANCE OF TECHNOLOGY

IMPLEMENTAREA SMART GRID ȘI ACCEPTAREA TEHNOLOGIEI DE CĂTRE UTILIZATORI

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Abstract: Smart Grid is an advanced power grid system that integrates digital technology, two-way communications, smart sensors and process automation to streamline the production, transmission, distribution and consumption of electricity. The implementation of smart grid components in the Oltenia region has been analysed by tackling network improvement projects on both the transmission and distribution sides. Through the SMART TRANSFORMATION program of the distribution operator in the region, smart grid components such as: Smart Metering Deployment, Meter Data Management and Metering Data Collection Systems, Advanced Distribution Management System and Asset Management System are being implemented. Among the renewable energy sources, the category of prosumers was analysed, as their number has been continuously increasing in recent years in the Oltenia region. To understand the degree of acceptance of smart grid components (smart meters, prosumer applications, smart devices) by consumers in the Oltenia region, we applied the Technology Acceptance Model (TAM). The assessment of the results highlighted a positive perception of the use of technology, as it was considered to be both beneficial and user friendly.

Key-words: *smart grid, prosumers, TAM, Oltenia.*
Cuvinte cheie: *smart grid, prosumatori, TAM, Oltenia.*

1. INTRODUCTION

Smart Grid is the current direction of the power grid, in which the countries set targets related to climate change, energy security, green economy and the smart grid implementation is done according to the conditions of each state (Sun et al., 2011). A smart grid means using modern technologies at every level: energy production, transmission, distribution and energy use by the consumer (Abdullah & Hassan, 2022). The smart grid is an improved power grid infrastructure whose targets are efficiency, reliability, security, integration of RES (renewable energy sources) and storage devices, using management algorithms, automated control and communication technologies (Ellabban & Abu-Rub, 2016). In short, a “smart grid”

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has been described as “the use of sensors, communications, computational ability and control in some form to enhance the overall functionality of the electric power delivery system” (Gellings, 2009).

In the old paradigm of power and energy systems, the transport of energy has flown from central production plants to end consumers; in the new paradigm of smart grids, the energy flows in different directions, integrating renewable energy sources and energy production by consumers (prosumers) (Gomes et al., 2023).

The transformation of the power system into a smart one should ultimately position the consumer as the primary end-user, entitled to advantages such as reduced energy tariffs, ease of involvement in energy production as a prosumer, easier access to information related to energy produced and consumed, the security of uninterrupted energy supply and the protection of data provided to the grid. In a more extensive plan, the smart grid implementation aims to reduce carbon emissions by including renewable energy, increasing storage capacity and, in the European Union, increasing independence from fossil fuels and energy imports, but also greater resilience to energy crises (e.g. in the case of cyber-attacks or extreme phenomena).

The analysis of smart grid components and the development of solutions to improve their efficiency has been addressed in numerous studies, both in Romania and at the international level. Concerning prosumers, studies in Romania have addressed topics such as: the transition paradigm from consumer to prosumer in Romanian and EU cities (Șanta, 2022), promotion schemes (Bălan et al., 2019), the role of prosumers in the energy transition (Florea et al., 2024), good practices applied by prosumers in Romania and Italy (Savastano et al., 2020) and aspects of their energy efficiency (Dobrea et al., 2020; Scripcariu et al., 2020). In other studies, various smart grid components have been examined, including: energy storage solutions (Wade et al., 2010; Carpinelli et al., 2013; Saha, 2013; Sbordone et al., 2015; Ye et al., 2016; Al-Hallaj et al., 2017; Longe et al., 2017; Molina, 2017; Pinnangudi et al., 2017; Sanduleac et al., 2017; Lund, 2018; Zame et al., 2018; Chakraborty et al., 2019; Kolokotsa et al., 2019), efficiency of smart meters (Arenas-Martínez et al., 2010; Römer et al., 2012; Grigoras, 2018; Diahovchenko et al., 2020; Luca et al., 2023), energy management systems (Mahmood et al., 2008; Molderink et al., 2010; Denysiuk et al., 2016; Rathor & Saxena, 2020; Meliani et al., 2021), cybersecurity (Flick & Morehouse, 2010; Khurana et al., 2010; Metke & Ekl, 2010; Aloul et al., 2012; Yan et al., 2012; Knapp & Samani, 2013; Wang & Lu, 2013; Komninos et al., 2014), the inclusion of prosumers in the management mechanism (Rathnayaka et al., 2011; Razzaq et al., 2016; Zafar et al., 2018), business models for prosumer profitability (Rathnayaka et al., 2014; Rodríguez-Molina et al., 2014) etc. In addition to approaches that highlight specific components, studies have also been conducted which propose comprehensive models for assessing smart grid implementation (Lyulyov et al., 2021), analysis or comparison of implementation in developed and developing countries (Nejad et al., 2013; Fadaeenejad et al., 2014; Xenias et al., 2015; Ponce-Jara et al., 2017; Zhang et al., 2017; Brown et al., 2018; Al-Badi et al., 2020; Saidani Neffati et al., 2021)

or that examine opportunities, challenges and issues related to the implementation of new technologies (Kappagantu & Daniel, 2018; Shrivastav et al., 2021).

2. THE CONCEPT OF SMART GRID

The concept of "smart grid", described from the beginning as the convergence of electric system and information technologies, is based on Advanced Metering Infrastructure or AMI (Borlase, 2013), a system that measures, collects, and analyses the energy usage and communicates with the metering devices such as electricity meters, gas meters, heat meters, and water meters, either on request or on a schedule (Muthamizh Selvam et al., 2016).

2.1 Smart grid in the United States

According to the 2009 concept of the U.S. Department of Energy (DOE), the smart grid was not considered a "thing" but rather a "vision", that will enable consumer participation, accommodate all generation and storage options, enable new markets, meet power quality needs, optimize assets and operate efficiently, anticipate and respond to system disturbances (self-heal) and will be resilient against attacks and natural disasters (NETL, 2009). In 2007, through the Energy Independence and Security Act (L110-140, 2007), the US announced its support for the modernization of the transmission and distribution system by achieving the following aspects, which together characterize a smart grid: (1) increased use of digital information and control technology to improve reliability, security and efficiency of the electric grid; (2) dynamic optimization of grid operations and resources, with full cybersecurity; (3) deployment and integration of distributed resources and generation, including renewable resources; (4) development and incorporation of demand response, demand-side resources, and energy-efficiency resources; (5) deployment of "smart" technologies for metering, communications and distribution automation; (6) integration of "smart" appliances and consumer devices; (7) integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles and thermal storage air conditioning; (8) provision to consumers of timely information and control options; (9) development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid; (10) identification and lowering of barriers to the adoption of smart grid technologies, practices and services.

In terms of significance and duration, in 2008, the transformation of the U.S. grid into a smart one was compared to the construction of the interstate highway system or to the development of the Internet. The triggers for the transition to the new type of power grid were the massive blackouts that affected the US in recent decades, especially the one in 2003, the desire to make the grid more efficient, to have better security, to reduce greenhouse gases and, last but not least, global competitiveness. In terms of overall vision, for the U.S. Department of Energy, the smart grid would be: "intelligent, efficient, accommodating, motivating, opportunistic, quality-focused, resilient, green" (DOE, 2008).

2.2 Smart Grid in the European Union

"The Smart Grids European Technology Platform for Electricity Networks of the Future" began its work in 2005 and described the smart grid as a new concept for electricity networks across Europe, an initiative to respond to the rising challenges and opportunities and to bring benefits to all users (EUR22040, 2006). The European Smart Grid Task Force, established by the European Commission (EC) in 2009, defined smart grids as "electricity networks that can efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure an economically efficient, sustainable power system with low losses and high quality and security of supply and safety" or as "an upgraded electricity network to which two-way digital communication between supplier and consumer and intelligent metering and monitoring systems have been added" (EC, 2011).

ENTSO-E Association (the European Network of Transmission System Operators for Electricity) proposed in 2010 a "9-year development and demonstration programme to accelerate innovation and the development of the electricity networks of the future in Europe, a so-called smart grid". The deployment of smart grid has been expected to unfold progressively over the 2010 – 2030 period and to generate benefits such as: increased hosting capacity for renewable and distributed sources of electricity; the integration of national networks into the European network; a high quality electricity supply for all customers; the active participation of users in markets and energy efficiency; the anticipation of new developments such as a progressive electrification of transport; the opening of business opportunities and markets for new players in the smart grid arena (ENTSO-E, 2010).

ENTSO-E proposed a smart grid model with six levels, which includes the major functionalities of the network (Fig. 1). The main stakeholders involved in designing "The European Electricity Grid Initiative – EEGI" and implicitly of the smart grid included (ENTSO-E, 2010): the generation companies and generator manufacturers, particularly those involved in solar and wind electricity production; the retailers and aggregators (energy suppliers); the equipment manufacturers and ICT industry; consumers, whose present and future needs (smart buildings, smart appliances, electric cars) and data protection have an impact on networks, research performers, governmental and regulatory bodies.

In 2011, three European Standardization Organizations (ESOs) – The European Committee for Standardization (CEN), The European Electrotechnical Committee for Standardization (CENELEC) and The European Telecommunications Standards Institute (ETSI) elaborated the final report that outlined the standardization requirements for implementing the European vision of smart grids, considering the initiatives of the Smart Grids Task Force of the European Commission. ESOs` report assessed existing standards, identified gaps and made recommendations starting with the definitions of basic terms, like *smart grid, intelligent grid, smart metering, demand side management, demand response, prosumer, microgrid, self-healing* etc. and continuing with conceptual architecture

– the major challenge for smart grid to interconnect a variety of (electricity and communication) networks that will have to support, over time, the business needs of stakeholders, such as: actors from energy markets, service providers – metering operators, ICT service, electric power grid equipment, vendors etc., home customers, industrial customers, transmission, distribution, generation, grid operations etc. (ESOs, 2011).

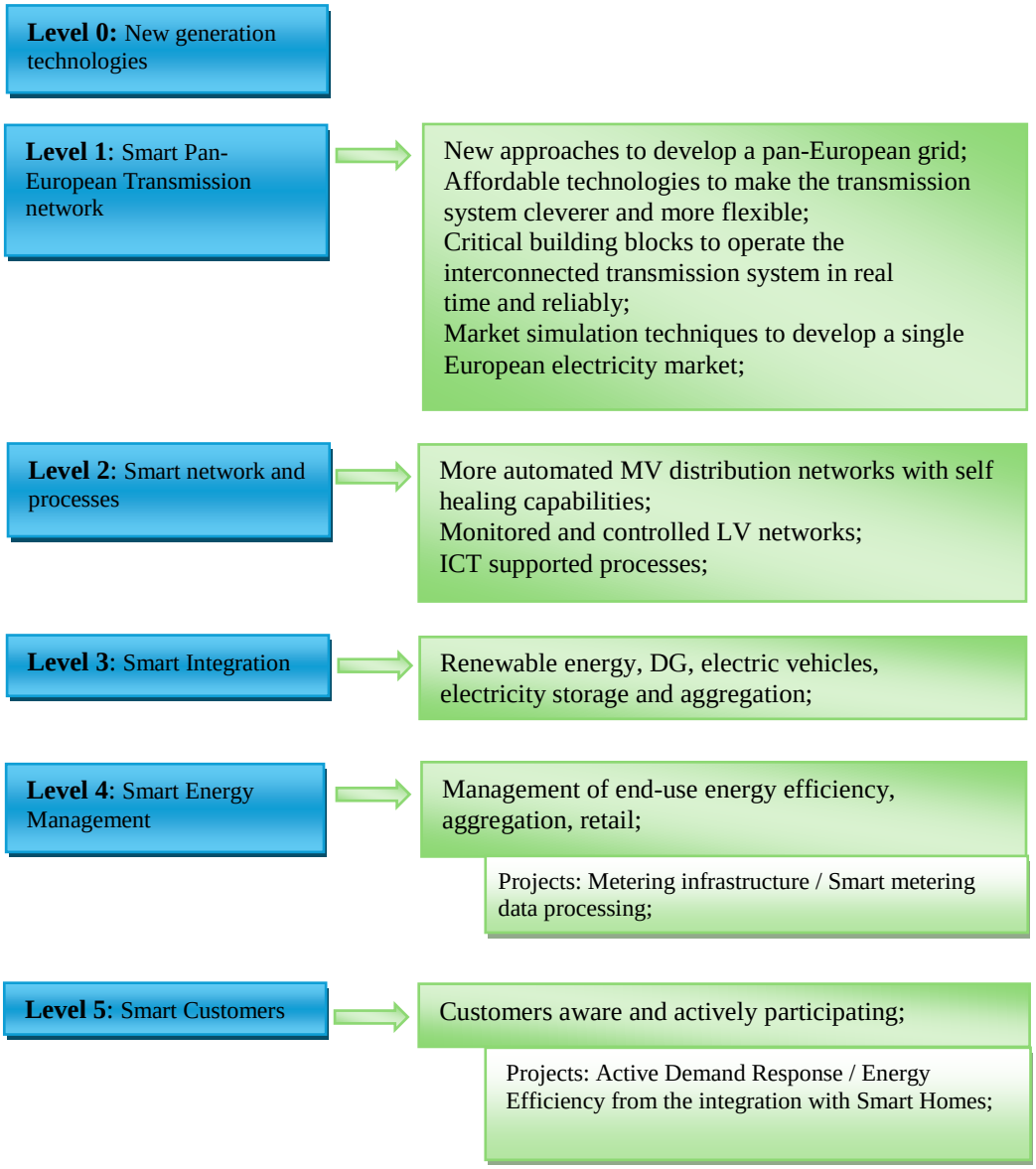

Fig. 1 SMART GRIDS MODEL in Europe – functional levels
(Source: ENTSO-E, 2010)

2.3 Introducing the smart grid concept in Romania and the Oltenia Region

2.3.1 Electricity transmission in Romania

Since 2000, when electricity transmission services were separated from production, distribution and supply activities, Transelectrica has become the only electricity transmission operator in Romania. The main activities carried out by Transelectrica are: electricity transmission, operational management of the National Energy System, organization and administration of the electricity market, operation of interconnections and international transit of electricity, issuing green certificates on the energy market to producers of electricity from renewable sources, etc. Transelectrica's policy aims, among others, to: achieve an asset management based on the Smart Grid reference architecture; modernise power stations to follow the "Digital Station" concept; adopt the most efficient practices and standards in the field of information security etc. (Transelectrica, 2018b). The company's strategy includes a series of "smart initiatives", such as: implementing the technologies necessary to monitor and control the network and its components; installing sensors and developing smart infrastructure to monitor the technical condition of critical assets; designing and implementing security solutions to guarantee confidentiality, availability and integrity of information (Transelectrica, 2018a).

In the current geopolitical context, marked by the war in Ukraine, energy security poses a significant challenge for the countries in the region, including Romania. In its 2025–2035 Energy Strategy, Romania aims to invest in the modernization and digitalization of its energy transmission infrastructure, enhance the capacity for integrating renewable energy sources, as well as smart grid development and cybersecurity. The national target for electricity transmission is to expand cross-border interconnections to at least 15% of the total installed capacity by 2030 (Romania'sEnergyStrategy, 2024). The most relevant projects related to the expansion of interconnections in which Romania is involved are:

- The Black Sea Corridor cross-border project for the development of the electricity transmission network (ID 138 in ENTSO-E’s TYNDP), to strengthen the interconnection between Romania and Bulgaria through the construction of new high-voltage transmission lines;
- The Mid Continental East Corridor cross-border project for the development of the electricity transmission network (ID 144 in ENTSO-E’s TYNDP), aimed at strengthening interconnectivity between Romania, Serbia and Hungary;
- The North CSE Corridor project (ID 341 in ENTSO-E’s TYNDP), for enhancing interconnectivity between Romania and Serbia;
- The HU–RO project (ID 259 in ENTSO-E’s TYNDP), for the interconnection between Hungary and Romania;
- The Georgia–Romania submarine cable interconnection project in the Black Sea (ID 1105 in ENTSO-E’s TYNDP).

According to the 2025–2030 National Integrated Energy and Climate Change Plan, an individual project currently being implemented by Transelectrica, which also covers the Oltenia region, is the “Integration of electricity generation from

power plants in the southern and south-western parts of the country", to which we can add the "Rehabilitation and modernization of existing power stations" project, carried out in cooperation with electricity distribution operators and included in the RET Development Plan for 2024 – 2033 (NECP, 2024; Transelectrica, 2024).

2.3.2 Electricity distribution in the Oltenia region

The accession of Romania to the European Union in 2007 led to the transposition of the European Directives on smart metering and the Smart Grid concept into Romanian legislation (Romania'sEnergyStrategy, 2007). Among the first smart meter installation projects in Romania was the one implemented by Electrica Transilvania Sud in the city center of Brașov in 2010 (Adevarul.ro, 2010), but it was followed by projects in all regions of the country.

In the Oltenia region, electricity distribution was privatized and taken over by the CEZ group from the state-owned company Electrica Oltenia SA, the main electric power distributor and supplier in Oltenia, in 2005. In 2007, an unbundling process followed, the result being a legal division of the company into CEZ Distribuţie SA – the electricity distribution operator, later rebranded into Distribuție Energie Oltenia (DEO) and CEZ Vânzare SA – the electricity supplier, (currently Premier Energy Furnizare). In the 2009 annual report of the Romanian CEZ group, CEZ Distribuție introduced the concept of smart grid as a specific objective for the distribution network and in the 2011 annual report it announced the completion of the SCADA integration in 11 stations and the replacement of 140,000 old meters with new meters (a type of smart meters) (CEZ, 2011).

Currently, the electricity distributor in the Oltenia region continues to pursue the targets set at the national level through Romania's Energy Strategy with 2025–2035 horizon and a perspective extending to 2050. This strategy aims at modernizing distribution networks, adapting them to integrate prosumers, implementing smart meters for real-time monitoring and control, developing digital platforms for demand management and energy flow optimization, enhancing network security etc. Among the specific objectives included in the Strategy, with reference to energy distribution, it is relevant to mention: the digitalization of transformer substations and remote network control solutions (integration of substations into SCADA systems); the deployment of smart meters; the protection of critical infrastructure against physical, cyber and natural hazards; the reduction of energy losses in transmission and distribution networks; ensuring universal access to electricity for all consumers (Romania'sEnergyStrategy, 2024).

According to the Development Plan of Distribuție Energie Oltenia for the period 2026–2035, the operator aims to ensure that all users of the distribution network are integrated into the Smart Metering System by December 31st, 2033. The MDM & MDC (Meter Data Management and Metering Data Collection) systems pursue the following objectives: providing accurate and timely information for billing purposes; progressively incorporating data from multiple sources, including GIS, MWM (Mobile Work Management), SCADA and SAP; avoiding the operation of multiple interfaces between metering and billing systems and so forth (DEO, 2025).

3. DATA AND METHODS

The study regarding the implementation of smart grid functionalities in the Oltenia region is carried out through the analysis of official reports published by the relevant authorities and grid system operators. At the level of renewable energy generation, the analysis focuses on the prosumer category, while, at the electricity distribution level, the study examines the projects already implemented by the local energy distributor or those currently underway.

Though the key focus of the development of the smart grid is technology, the consumers are another equally important component of the smart grid (Ellabban & Abu-Rub, 2016). Thus, special attention should also be paid to residential consumers and their involvement in the new technology. Any technological innovation should take into account, on the one hand, being related to technological tools and, on the other hand, the entities that should accept, adopt and use it (Ellabban & Abu-Rub, 2016). In the end, customer acceptance will dictate the efficient implementation of smart grid mechanisms (Gomes et al., 2023).

The Technology Acceptance Model (TAM) has been applied in numerous studies to predict and explain customers` acceptance of a new technology (Davis, 1989) and also to study consumers` acceptance of smart grid products and services (Park et al., 2012; Abu et al., 2014; Orillaza et al., 2014; Toft et al., 2014; Chen et al., 2017; Ianole-Călin & Druică, 2022; Gomes et al., 2023). According to the TAM, the acceptance of a new technology depends on the belief that it is both easy to use and beneficial in achieving a personal goal. For instance, in the case of the smart grid, one such advantage could be a lower electricity bill (Toft et al., 2014). The Technology Acceptance Model is often used for explaining technology acceptance (Aburbeian et al., 2022) and the initial version included two exogenous variables (Davis, 1989): perceived usefulness (PU) and perceived ease of use (PEOU).

In order to understand the degree of acceptance of new smart grid technologies by residents of the Oltenia region, we applied the Technology Acceptance Model (TAM) and we used an online questionnaire with 22 questions, structured in three parts: the first part addressed the perceived usefulness of the technology (PU), the second part focused on the perceived ease of use of the technology (PEOU) and the third section included data on the respondent's profile. The response options were based on a 5-point Likert scale (1 – total disagreement / useless / very difficult to use, 5 – total agreement / very helpful / very easy to use), to which a response option was added for consumers who do not have a smart meter, a smart device or they are not prosumers. The questionnaire was applied to a number of 114 households and included an introductory part in which users are briefly presented with the concept and components of a smart grid. The survey was conducted in the Romanian language and it was addressed to the residents of Oltenia, being distributed by e-mail, on social networks and on WhatsApp groups. Participation in the survey was voluntary and everyone was free to participate. The questionnaire items are presented in Appendix A. The automated data analysis was conducted using Excel's statistical functions, including AVERAGE, STDEV.S, CORREL (Pearson correlation coefficient) and COUNTIF.

4. RESULTS AND DISCUSSIONS

4.1 The number of prosumers is constantly growing

Electricity production from renewable sources is necessary not only for the implementation of the smart grid, but also to achieve the EU's climate neutrality target by 2050. Moreover, Romania's targets regarding electricity production are closely linked to the EU's targets, the current updated objective for Romania being to reach a share of energy from renewable sources in gross final energy consumption of at least 38.3% by 2030. This objective can be achieved by installing new wind and photovoltaic plants (NECP, 2024). Thus, the prosumer (the consumer who is also an energy producer) becomes a very important stakeholder, both for the implementation of smart grids and for achieving the energy targets in Romania and the EU.

The number of prosumers who received a Grid Connection Permit increased exponentially between 2019 and 2024 in the Oltenia region (Fig. 2). This rise in the number of permits – from 24 in 2019 to 14,258 in 2024 – reflects the promotion of programs aimed at encouraging the production and use of green energy, as well as the growing public interest in reducing electricity costs. This steady growth can be linked to government support measures, financing programs and the decreasing cost of photovoltaic equipment. The trend also highlights a shift in consumer mentality, with individuals becoming more actively involved in both the production and consumption of electricity.

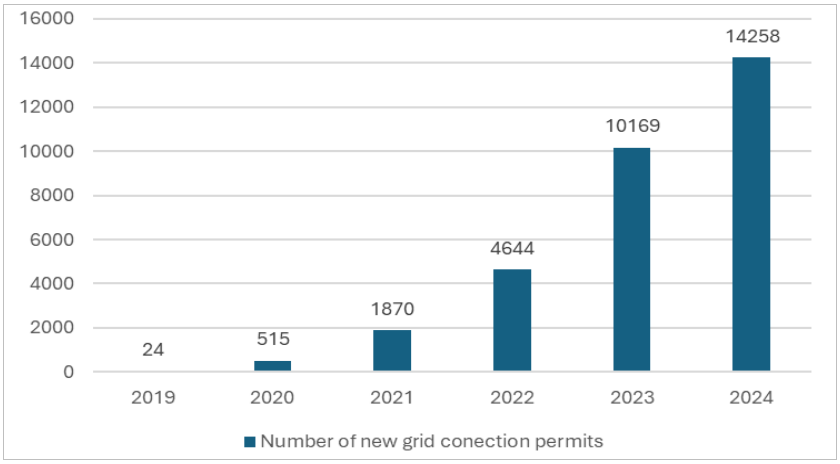

Fig. 2 New Grid Connection Permits issued by DEO for prosumers during the 2019 – 2024 period, for the Oltenia region

(Data source: https://www.distributieoltenia.ro/)

The distribution of grid connection permits for prosumers in the counties of Oltenia (Fig. 3) shows a high interest in green energy throughout the region, but with variations depending on the county. The highest number of connection requests was recorded in Dolj county (32%), while Gorj and Mehedinți counties accounted for only 13% and 12%, respectively. In most counties, the percentage of connections is correlated with their total number of inhabitants, except for Gorj,

where the number of permits is lower compared to the population registered at the 2021 Census. The lower share of permits issued in Gorj could be explained by a limited access to support programs, a reduced awareness of the prosumer concept or a generally lower level of public interest.

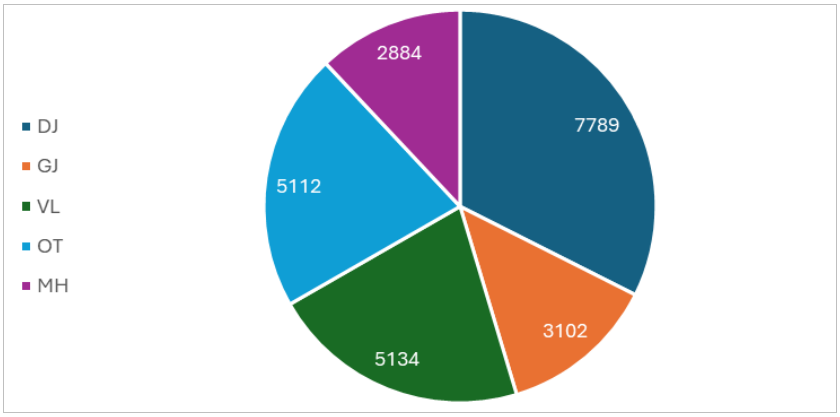

Fig. 3 Grid Connection Permits issued by DEO for prosumers in the 2019 – 2024 period, in the Oltenia region, by county (Dolj, Gorj, Vâlcea, Olt, Mehedinți)

(Data source: https://www.distributieoltenia.ro/)

At the national level, by the end of 2023, the electricity distribution operator with the most grid connection permits issued in Romania was Distribuție Energie Oltenia (DEO) – the operator from the Oltenia region (Fig. 4).

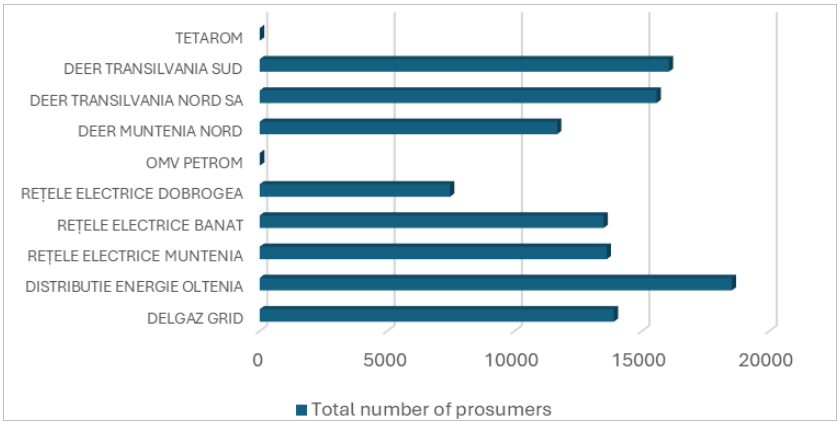

Fig. 4 Grid Connection Permits issued by electricity distribution operators until 31.12.2023 in Romania (Data source: NECP, 2024)

Both in the Oltenia region and at the national level, at the end of 2023, most of the prosumers were private individuals (95,205), with legal entities in the prosumer category accounting for 15,150 in Romania.

In addition to the national 'Casa Verde Fotovoltaice' program and ANRE-regulated facilities for prosumers, funding for the installation of approximately

20,000 photovoltaic systems in Dolj and Gorj counties was also made available through the National Recovery and Resilience Plan (NRRP), as part of Romania's green energy transition efforts.

Regarding the total installed power (IP) of prosumers (Fig. 5), at the end of 2023, at national level, the highest values were recorded at Distribuție Energie Oltenia (228507 kW).

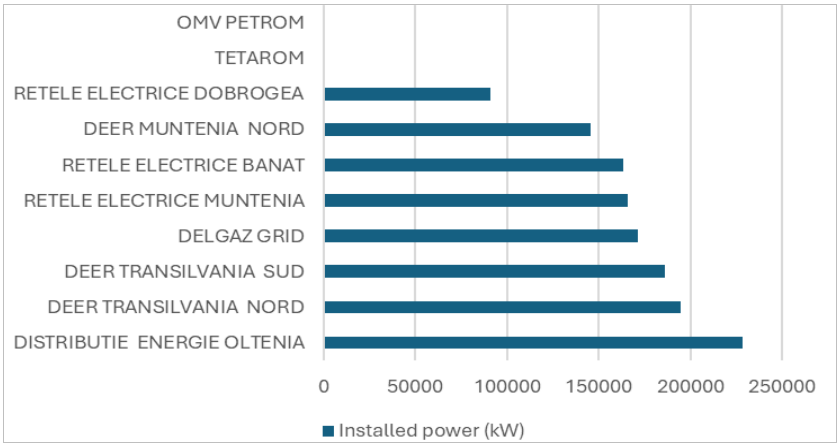

Fig. 5 Total installed power for prosumers with IP ≤400 kW, at distribution operators in Romania, until 31.12.2023

(Data source: NECP, 2024)

In the present study, the category of prosumers refers to private individuals and legal entities who own renewable power plants with installed electrical power of no more than 400 kW per place of consumption, these being the ones who benefit from regulated facilities.

At the national level, the structure of electricity production by source (Fig. 6) indicates that renewable energy accounted for 45.64% (ANRE, 2024), while both the number of prosumers and the production of green energy continue to increase.

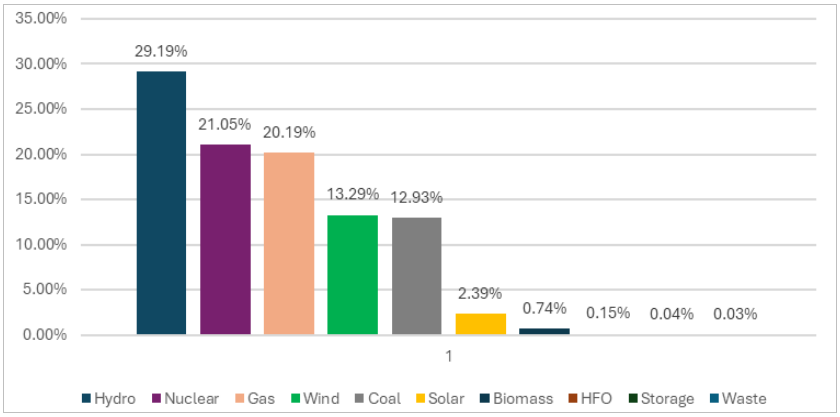

Fig. 6 Structure of electricity production by type of source, Romania, 2024

(Data source: ANRE, 2024)

4.2 Implemented or Ongoing Projects in Electricity Distribution in the Oltenia Region

Distribuție Energie Oltenia, the operator responsible for electricity distribution in Oltenia, has implemented the **SMART TRANSFORMATION Program,** which includes several subcomponents (DEO, 2023, 2025), among which:

- **MDM & MDC (Meter Data Management and Metering Data Collection)** – ensure the storage, processing and transmission of data collected from smart meters, enabling data exchange with other databases, including GIS and SAP;
- **MWM (Mobile Work Management**) – implemented since 2018, with continuous improvements currently being pursued;
- **GIS Implementation Project** – supports the storage, analysis and processing of spatially distributed information related to the power grid, such as location, routes, coexistence with neighboring buildings and properties, structure, volume, technical and functional characteristics, load etc.;
- **ADMS (Advanced Distribution Management System) Project** – a software platform designed to optimize and manage distribution processes. Among its functionalities the automatic restoration of service interruptions (self-healing) can be mentioned;
- **AMS (Assets Management System)** – implemented in December 2024;
- **ESB (Enterprise Service Bus**) – implemented to integrate MWM, MDM, GIS, SAP, AMS, and ADMS systems. To support efficient data exchange, the ESB system will be further developed as new systems, such as E-Analytics and the DEO Customer Platform, are introduced.

In addition to the projects already implemented and operational, several new systems are targeted for deployment as part of DEO's digitalization strategy:

- **BPM & DMS (Business Process Modelling and Document Management System);**
- **DERMS (Distributed Energy Resources Management System)** – enables the management of network connections for photovoltaic power plants and electric vehicle charging stations, including their integration and communication, as well as the control of equipment to balance the electricity grid and optimize reinforcement costs;
- **Advanced Analytics** – will facilitate a more accurate forecasting of dispatched energy, consumption and losses due to own technological use;
- **Digital DEO Project** – brings to the forefront the digital interaction with customers, suppliers and prosumers through a unified platform where any issue related to electricity distribution can be addressed;
- **SAP HANA** – by combining multiple data management capabilities and providing immediate access to all types of data from a single system, it simplifies IT architecture, fosters innovation and removes barriers to digital transformation.

4.3 Consumer perception of the usefulness of technology (PU) and ease of use (PEOU) in the case of Smart Grid components in the Oltenia region

From the 114 completed questionnaires, 95 were relevant, while the remaining 19 respondents answered either that they were not prosumers or did not have a smart meter. Of the last category, 85% lived in urban areas, where the possibility of becoming a prosumer was available only to homeowners and not to those living in collective housing. As to smart meters, their installation by the energy distributor took place only in certain neighborhoods of cities in the Oltenia region (DEO, 2020).

Demographically, the 95 respondents included 20 women and 75 men. The participation in the survey was open to all demographic categories, with the only criteria being residence in the Oltenia region. However, most of the respondents were men, while just over 21% were women interested in a topic related to the acceptance and use of technology. Previous studies also indicate that, in the context of information technology use related to electronic data management systems, gender acts as an influencing factor in technology adoption, with men generally being more tech-savvy than women (Goswami & Dutta, 2015). Nonetheless, 60% of female respondents expressed strong agreement regarding the improvements brought by technology and its ease of use.

Regarding age distribution, out of the 95 responses, 5 were from individuals under 25, 52 from those aged 26–45, 28 from the 46–65 age group and 10 from respondents over 66 years old.

Only slightly more than 5% of respondents were young people under the age of 25, a situation likely explained by the low proportion of this demographic among homeowners (McKee, 2012; Lennartz et al., 2016; Dewilde, 2020). Nevertheless, their responses indicated a complete agreement regarding the usefulness and ease of use of new technologies. As young people have grown up in an environment where technology has been an integral part of their daily life, the acceptance of new technologies tends to be faster and requires less effort (Tully, 2003).

Most of the questionnaire responses came from individuals in the 26–45 age group. For the most part, their answers highlighted the benefits brought by the new technology, the ease with which they have adapted to using it, as well as a strong intention to recommend it to others or to purchase additional smart devices in the coming years. A similar trend was noticed among respondents aged 46–55.

Although the overall trend was also positive in the case of responses received from people over 66 years old, there were also reactions of disagreement regarding the ease of understanding new technologies or the adequate amount of information received from smart meters. Regarding the acceptance of technology by elder adults, numerous studies have been conducted, the results of which have identified a series of factors influencing its use and acceptance, such as: previous experience with and use of technology, factors related to the characteristics of the technology (e.g., cost, security), social influences, intergenerational support, the level of trust in the specialists who installed the respective technology, among

others (Peek et al., 2014; Tsertsidis et al., 2019; Ghorayeb et al., 2021; Wei et al., 2023). There are also studies showing the predominance of positive attitudes among elder adults, which contradict stereotypes suggesting that seniors are afraid of or are unwilling to use technology (Mitzner et al., 2010).

In terms of education, the largest group of respondents comprised high school graduates (38 persons), followed by college graduates (27 persons). The respondents' residence environment was peri-urban for 42 participants, urban for 38 and rural for 15 (Fig. 7, a-d).

For the automated analysis of the data, the questions in the two sections were coded, so that those in the section related to the usefulness of the technology received the codes PU1-PU9 and those in the section targeting the ease of use of the technology received the codes PEOU1-PEOU9 (Appendix A).

Table 1 presents the average of respondents' answers to each question, as well as the standard deviation for each one. The average results for each question are, in most cases, above the value of 4, showing both the users' appreciation of the use of the technology, but also the agreement that the new technology (smart meters, applications for prosumers) is easy to use. The standard deviation, which is a measure of variability (Altman & Bland, 2005) for each question, shows a dispersion of the answers between 0.8 and 1.6, which presents a moderate value, allowing us to conclude that the respondents have close perceptions in their answers to the questions.

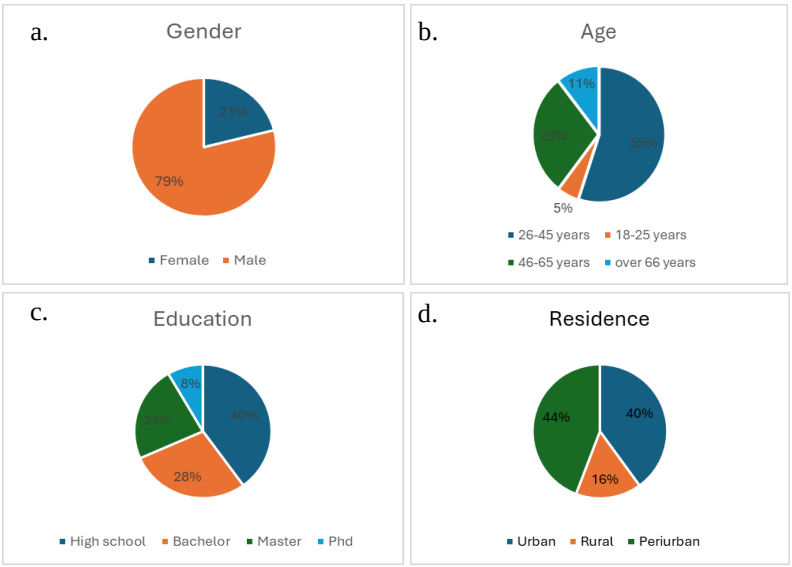

Fig. 7 Demographic data of respondents
(Data source: Authors' processing)

The correlation between the mean values of the answers to the questions in the two sections (PU and PEOU) is 0.71, which shows a strong positive correlation between the average of the answers.

Table 1 The average and standard deviation for each question

Questions	Average	Standard deviation		Questions	Average	Standard deviation
PU 1	4.3	0.9		**PEOU 1**	4.4	1.0
PU 2	3.2	1.6		**PEOU 2**	4.1	1.3
PU 3	4.0	1.3		**PEOU 3**	3.7	1.0
PU 4	4.2	1.2		**PEOU 4**	4.3	0.9
PU 5	4.4	1.0		**PEOU 5**	4.2	1.1
PU 6	4.5	0.9		**PEOU 6**	4.2	1.1
PU 7	4.2	1.3		**PEOU 7**	4.1	1.2
PU 8	4.1	1.2		**PEOU 8**	4.4	0.8
PU 9	4.6	0.8		**PEOU 9**	4.4	0.8

(Source: Authors' calculation)

The questions to which most respondents indicated total agreement in the first section are those concerning the change in consumption behaviour as a result of the installation of a photovoltaic system and related technology (PU6, PU5), but also the one concerning the benefits of new renewable energy production projects (PU9).

From the second section, the most relevant questions with a total agreement answer are PEOU1, PEOU8, PEOU9 regarding the appreciation of the ease of use of smart meters, the intention to purchase new smart devices, but also the use of the electronic billing system, compared to the one in which invoices were received in print.

A significant share of respondents does not consider the installation of a smart meter to be useful in reducing the frequency and duration of interruptions in the supply of electricity.

Concerning the respondents' place of residence (Fig. 8), no significant differences are noted in the average responses, these having close proportions, regardless of residence.

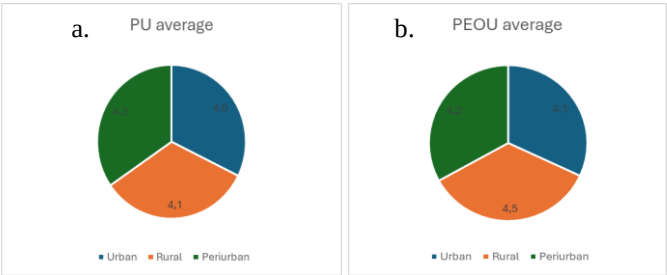

Fig. 8 Average responses by area of residence

(Data source: Authors' calculation)

With respect to the limitations of the study, although efforts had been made to ensure that the sample was relevant to the Oltenia region, it is acknowledged that a more detailed analysis would require a larger sample, stratified by counties and that respondents should be surveyed through additional methods, not only online. The use of a complementary method, such as semi-structured interviews, could provide a more precise identification of the factors influencing the respondents' perceived usefulness and ease of use of the technology. However, the primary objective of this study was to assess the degree of smart grid technology implementation in the region.

5. CONCLUSIONS

The transformation of the classic electric power system, in which energy production was centralized and the flow was unidirectional, namely from producers, who mainly used hydrocarbons as an energy source, to consumers, is no longer a target, but a reality that is taking place.

For the proper functioning of the new system, modern solutions for the management of the transmission and distribution network are necessary. The smart grid components analysed in the study help manage the network in the new paradigm and bring benefits to all stakeholders in the energy system.

Although there are still many steps to be taken before the full implementation of a smart grid, some of the components have already been implemented or are in the process of being implemented.

In the Oltenia region, both the transmission operator and the distribution operator have taken important steps, which are summarized as follows: modernisation and SCADA control of electrical transformer stations; implementation of remote-controlled equipment in distribution networks, capable of isolating the fault area and automatically re-powering consumers (self-healing); implementation of the smart metering system and the information systems necessary for data management; implementation of an ADMS system, capable of managing both remote-controlled elements and energy sources in the distribution network area remotely.

The Oltenia Region, especially its southern part, has one of the highest levels of sunshine in Romania, being conducive to the development of energy projects from photovoltaic sources – prosumers & producers, which have the potential to replace conventional sources in the area (coal). As the present study underlines, the number of prosumers in the Oltenia Region has increased steadily in recent years and these projects could be further supported and financed.

Regarding the acceptance of the new technology by users in the Oltenia Region, the responses to the applied questionnaire showed the intention of users to continue employing the technology, which they consider mostly useful and easy to use. The results underline the fact that users perceive the technology in a positive way and appreciate its improvement, which will rise the comfort of their lifestyle.

This study provides an image of both the current stage of smart grid implementation in the Oltenia region and the degree to which these technologies are accepted by end-users. By correlating technical progress with consumer perceptions, the research offers relevant insights for policy makers, distribution operators and technology providers, supporting the design of targeted measures to accelerate smart grid adoption.

A possible direction for future research involves comparing the implementation of smart grids in the Oltenia region with other regions of the country, as well as extending the comparative study to the international level. Furthermore, the study could be extended to investigate consumer acceptance not only of smart grid components, but also of other types of new technologies applicable to infrastructure.

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Appendix A. The structure of the online survey regarding Smart Grid technology acceptance

Code	Perceived usefulness (PU)	Code	Perceived ease of use (PEOU)
PU1	To what extent do you consider smart meters useful, given that they no longer require manual index readings by a human operator?	PEOU 1	Smart meters automatically transmit consumption data. Do you find it helpful not having to manually report your monthly index or allow access for meter reading?
PU2	Do you think the installation of a smart meter helps to reduce the frequency of interruptions in the electricity supply?	PEOU 2	Is the data provided by smart meters sufficient and easy to interpret?
PU3	Has having a smart meter and access to detailed information on your consumption habits changed your consumption behavior?	PEOU 3	If you have a smart meter and were disconnected from the grid for non-payment of the bill, was the reconnection process simple?
PU4	Do you appreciate being billed monthly for the exact amount of energy consumed, rather than an estimated amount, due to smart metering?	PEOU 4	If you don't already have a smart meter installed, would you like to have one?
PU5	If you are a prosumer (you have installed photovoltaic panels in your own consumption installation), does the information received from the photovoltaic system help you better understand your home's energy consumption profile?	PEOU 5	If you are a prosumer, is the information received from the photovoltaic system easy to understand?
PU6	If you are a prosumer, have you changed your consumption behavior to use as much energy as possible produced by your own panels?	PEOU 6	Was the photovoltaic panel application easy to understand, without special training?
PU7	Have you noticed a reduction in the cost of electricity in the bills you received from the supplier since you became a prosumer?	PEOU 7	If you own smart home devices (remotely controlled via phone, computer, or tablet - e.g., smart lighting, vacuum cleaners, washing machines, central heating, heat pumps), do you find them easy to use?
PU8	If you are a prosumer, to what extent would you recommend installing photovoltaic panels to other people?	PEOU 8	Do you intend to purchase (additional) smart home devices in the next period (1–3 years)?
PU9	To what extent do you appreciate the fact that renewable energy power plant projects (photovoltaic, wind, micro-hydropower, biomass) help create a cleaner environment for the future?	PEOU 9	Do you believe that electronic electricity billing is more convenient for consumers compared to receiving printed bills?

(Source: Questions designed by the authors)