
Interoperable solutions for implementing holistic **FLEXI**bility services in the distribution **GRID**

Market roadmap

Deliverable 8.13

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ABBREVIATONS

AI: Artificial intelligence
CA: Consortium Agreement
CC: Communication Committee
DERs: Distributed energy resources
DMP: Data Management Plan
DoA: Description of Action
DSOs: Distribution System Operators
EC: European Commission
ER: Exploitation Results
EVs: Electric Vehicle
GA: General Assembly
GW: Giga Wattage
H2020: Horizon 2020
IPR: Intellectual Property Right
KPI: Key Performance Indicator
M: Month
PC: Project Coordinator
PH: Project Handbook
R&D: Research and Development
RES: Renewable Energy Sources
SC: Steering Committee
SME: Small and Medium Enterprise
TP: Technical Partner
TSOs: transmission system operators
WP: Work Package

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EXECUTIVE SUMMARY

The following deliverable (D8.13) is the direct result of the work carried out during T8.4 (Market Roadmaps). This document was elaborated in order to identify the opportunities and risk for FLEXIGRID solutions entrance in the European market.

Thus, this deliverable is made of three parts constituting the main body: a market outlook in Europe for smart grids and renewable electricity, an updated stakeholder analysis, and recommendations for solutions entrance in the European market.

The first part of this deliverable is dedicated to the market outlook in Europe. Two markets were studied: the smart grid market end the renewable electricity market, as they are the most relevant to the FLEXIGRID project. For each of these market outlook analysis market health, production, consumption, employment and constraints were studied. This allowed and comprehensive view to be exposed for these markets current and future development. Both markets are found healthy but housing a number of constraints which might hinder their development.

The second part of the main body of this deliverable presents an updated stakeholder analysis. Indeed, some of the solutions have specific replication strategies (exposed in D8.12: Exploitation Strategy - M48) which were used in part here to identify specific potential customers. Thanks to this identification of potential and targeted customers each solution is presented with specific recommendations in its market entrance. Those stakeholder analysis are directly integrated within the specific market analysis made for FLEXIGRID solutions.

The second section of this deliverable also delves into how FLEXIGRID solutions derive value in the current and the future market, an in-depth exploration of each solution market outlook, growth prospects, triggers, the inherent value of the solutions in the market, and potential risks within the intricate landscape of the EU energy market.

Finally, general recommendations and conclusions are proposed at the end of this document. They take into account the analysis carried out in the whole document to supply suggestions for FLEXIGRID solutions market entrance.

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1. INTRODUCTION

The FLEXIGRID project falls within the European and International smart grids and renewable energy market framework. Indeed, FLEXIGRID solutions developed during the four years of the project have been analysed to allow a successful entrance within the European market and a replicability in different environments.

Therefore, the different tasks within WP8 ensured that the business cases and exploitation strategies were created to identify the most convenient ways for market development and replication of results. The future of FLEXIGRID solutions was supported jointly with the WP7, WP8, and WP9.

Task T8.4 specific objective along with other tasks within WP8 (T8.1, T8.2, T8.3, and T8.5) is to prepare FLEXIGRID solutions to enter the European market, construct suitable business models, and ensure the exploitation of results is successful and replicable on the market thanks to the strategy prepared in collaboration with FLEXIGRID partners. Therefore, T8.4 combines the description of previously drawn business models and exploitation strategies, updated in D8.4 and D8.12, and focuses the data on final customer to describe final results on customers' perspectives. A particular focus will be given to stakeholder interactions, contractual relations, service provision and remuneration model.

Indeed, this deliverable aims at explaining and integrating FLEXIGRID activities from the market perspective. D8.13 leverages on the experience gained from the demo cases. It analyses the market steps to be performed out of the project and the sectorial peculiarities of the proposed FLEXIGRID solutions and results. Then, D8.13 opens on an analysis of the market outlook in Europe focused on smart grids and renewable electricity to introduce the context FLEXIGRID solutions evolve in. It will be followed by an updated stakeholder analysis to support the exploitable results description according to the final customers. Finally, general recommendations are produced to ensure the successful entrance on the market of FLEXIGRID solutions.

2. MARKET OUTLOOK IN EUROPE

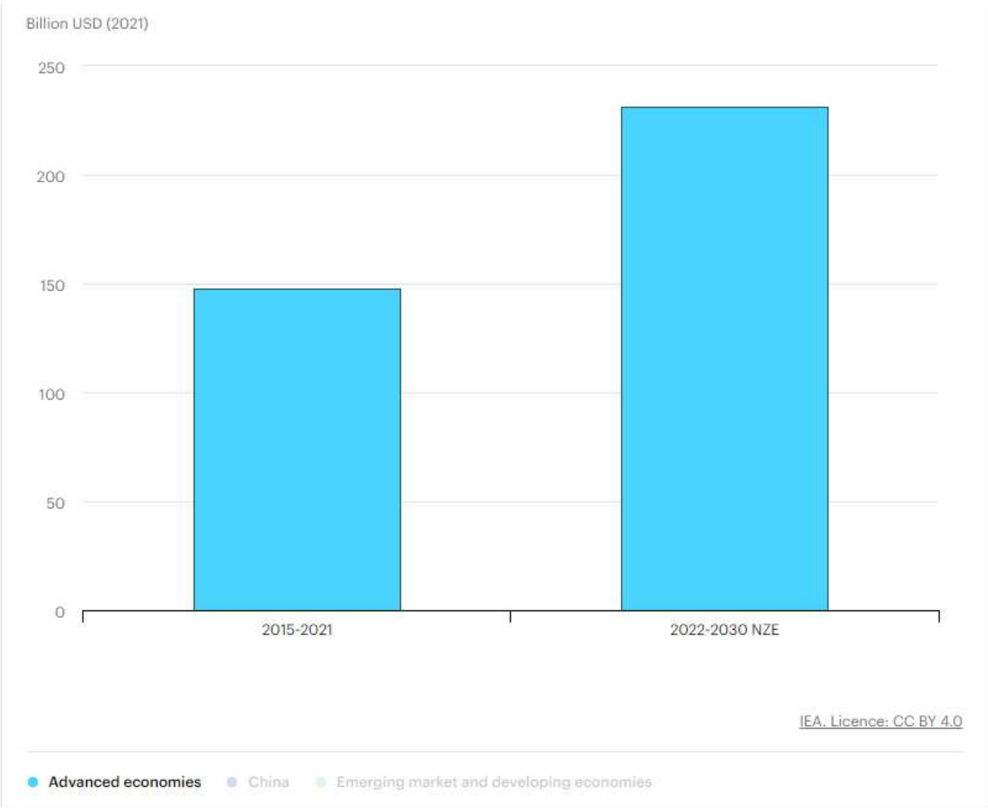
An in-depth market analysis was previously prepared for deliverables D8.2 and D8.3 focusing on the demo countries Croatia, Spain (analysis in D8.2), Italy and Greece (analysis in D8.3). Therefore, an analysis of smart grids and renewable electricity in Europe will contribute to paint the context into which FLEXIGRID solutions evolve. In addition, it will be useful to contextualise market steps to be performed out of the project and the sectorial peculiarities of the proposed solutions along with FLEXIGRID results.

2.1 Smart grids

Market Health

Smart grids' market is by all report expanding (IEA, 2022a). Indeed, in Europe TSOs and DSOs concur in their need to modernise infrastructures, connect distributed energy resources, digitalise grids, and adapt to the rapid development of electric vehicles (IEA, 2022a). Thus, increase of investments and expansion of the market is foreseen. The IEA reports that investments which reached 148 billion USD between 2015 and 2021 should also increase to reach 231 billion USD between 2022 and 2030 in order to remain within net zero scenario objectives (Figure1) (2022a).

Figure 1: Average annual investment spending on electricity grids in the Net Zero scenario 2015-2030 in advanced economies.



Indeed, transmission and distribution grids are to play an important role in the energy system transition towards a clean transition. The war in Ukraine strained the European energy market and accelerated the path toward electrification and renewable energy integration in the energy mix. It is necessary to adapt the electricity grid to these rapid developments of smart grid infrastructures. According to the IEA:

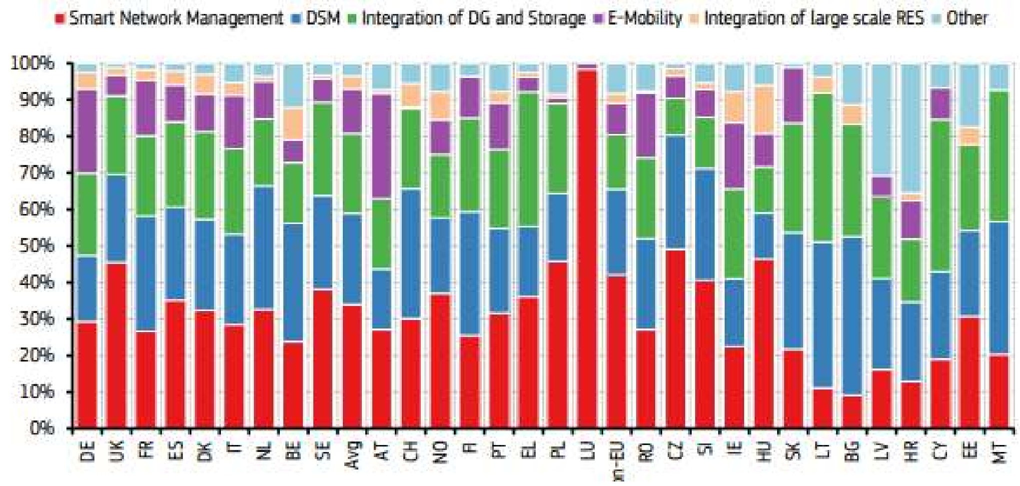
> The distribution sector accounts for around 75% of all investment in digital infrastructure with the rollout of smart meters and the automation of substations, feeders, lines and transformers via the deployment of sensors and monitoring devices. Digital investment in distribution also includes network digital twins and non-wire alternatives, such as flexibility services and distributed stand-alone storage systems. (IEA, 2022a)

Thus, in the next decade smart grids will benefit from digital investment to improve the grid flexibility, control, economic efficiency, and security.

The European Commission values smart grids for their consumer empowerment potential, their contribution to the reduction of GHG emissions thanks to the integration of renewable energy sources and the efficient integration of energy storage and electric vehicles to the grid 'while providing an opportunity for economic growth and worldwide technological leadership of EU technology.' and 'maintaining stability and efficiency of the system.' (EC, 2023a). The EU presents itself as the main investor in Europe for smart grid projects and infrastructures developments. Furthermore, 'The growth in home energy management system market is also expected to come from increasing investments in the smart grid infrastructure' (JRC, 2022). As countries update their infrastructure to match growing energy demands, investments in smart grids increase.

Strong differences in terms of number of projects and investments exist between EU member states. Indeed, the beneficial environment in those countries contribute to attract investments. Favourable regulations, and the adoption of roadmaps sets Denmark, Germany, Ireland, France, Austria, Slovenia, Sweden and the United Kingdom apart from other EU members for investors (JRC, 2017). Furthermore, 'national-specific circumstances, including the state of the electricity grids, the level of RES penetration, the existence of a favourable national and regulatory environment, the company culture of the different stakeholders' influence investments levels and explain the difference observed between member countries (JRC, 2017). The sector of investment within smart grids also allows to differentiate between EU members as the analysis in Figure 2 below can attest (JRC, 2017).

Figure 2. Percentage distribution of total investment per smart grid domain and country in the EU



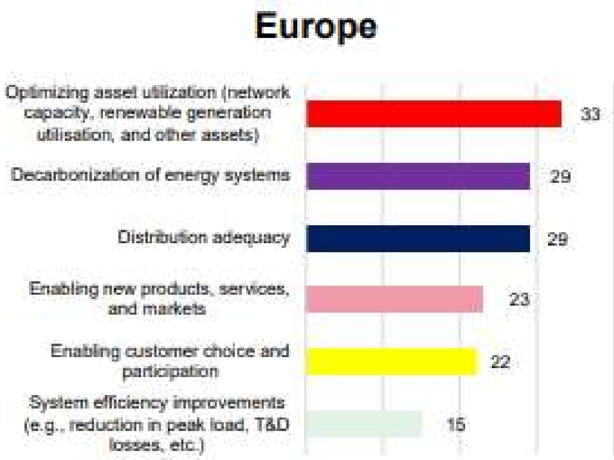
In addition, the deployment of smart meters is a priority for the European Union. Indeed, by 2030, 266 million electricity smart meters will be installed corresponding to a 92% penetration rate at EU level for households and SMEs (EC, 2019). As to investments made in Europe by 2020, an estimated 35 million euros will be dedicated to smart meters installations (JRC, 2022).

With its agreement to stop the sales of new CO2 emitting vehicles by 2035 (EC, 2022a), the European Union intends to rapidly construct an electric fleet. The shift towards zero-emission mobility will weight in electric grids. In 2020, the existing charging infrastructures were not numerous enough to provide with the increase of EV in Europe (Barreto, Faria, Vale, 2022). In 2021, investment in public charging infrastructure increased by 20% (IEA, 2022a). Thus, an important development of smart grids in Europe can be foreseen. In addition, charging the vehicles in itself also provides a challenge to the grid and smart grids are paramount to control it efficiently. Indeed, to avoid EVs 'to be charged in an uncontrolled way during a specific instance where the demand for grid load is higher' smart grids will be determinant (Barreto, Faria, Vale, 2022). EVs will be integrated in smart grids as Smart grid solutions thanks to the Vehicle-to-Everything (V2X) technology, enabling charging and discharging according to the demand with a bidirectional data flow proper to smart grids.

Drivers for Investments in Europe

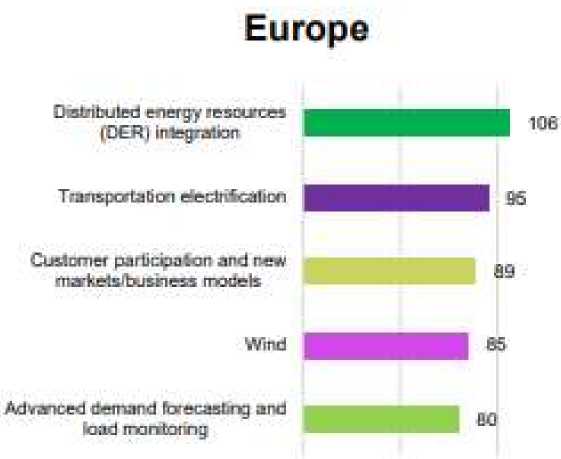
Smart grids in Europe are influenced by certain drivers. Knowing them can contribute to the comprehension of current priorities in deploying smart grids in Europe. The International Smart Grid Action Network reports that ten European countries (9 EU members: Austria, Belgium, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden; in addition to the United Kingdom) identified the top 6 drivers as 'Optimizing asset utilization', 'Decarbonisation of energy systems', 'Distribution adequacy', 'Enabling new products, services, and markets', 'Enabling customer choice and participation', and 'System efficiency improvements' (Figure 3) (ISGAN, 2021). Therefore, the priorities for the EU revolve around optimisation and efficiency of the grid, participation of prosumers in the market and empowering consumers, decarburization, GHG reduction, and integrated management of resources.

Figure 3: Top-6 Ranked Motivating Drivers from Clustering Analyses in Europe



Furthermore, in the same analysis, ISGAN reports that European government selected a top 5 smart grids technologies to focus on. The Technology priorities identified were in order: 'Distributed Energy Resources (DER) integration', 'Transportation electrification', 'Customer participation and new markets/business models', 'Wind', and 'Advanced demand forecasting and load monitoring' (Figure 4) (ISGAN, 2021). This data coincides with the drivers analysed earlier. Indeed, European member countries are dedicated to the optimisation and efficiency of the grid, consumer empowerment and prosumers entry on the smart grid stage, the decarbonisation of the energy sector, and the integrated management of distributed resources of renewable energy including wind power.

Figure 4: Top-5 Ranked Technology Priorities across All Drivers in Europe



Production

As previously demonstrated the Smart grid market is in good health and foreseen to expand further in the next decade. Smart grid technologies are essential to develop further renewable energy integration in the energy mix and to update the electricity grid. It is essential for renewable energy growth to be linked with increased investment in flexibility (IEA, 2023a). Indeed, French experts estimate that for every 2 GW of installed Renewable Energy, about 1 GW of flexibility solutions should follow (TSG, 2022). As Renewable Energy installation grow in capacity all around Europe, smart grid infrastructures need to follow and production grow.

Moreover, as climate change worsens, extreme weather events are to be expected more often. A need for a more flexible and secure electricity supply all around Europe to shield the populations and infrastructures exists (IEA, 2023a). The current European need for smart grid solutions is to rise the production in the next years.

The several smart grid domains mentioned earlier are all witnessing production increase. Electric vehicle charging infrastructure on its own for example reached a production value of 875 M€ in 2019 (JRC, 2022). On the other hand, smart meter production as a European Commission priority can also be influenced by the European demand for the home energy management systems (JRC, 2022). Therefore, as home energy management need rises, smart meter production rises. In turn the growth of smart meter use increases the need for software and hardware solutions related to data operations (E.DSO, 2023). Thus, smart grid production implies a holistic process of production for the whole smart grid sector.

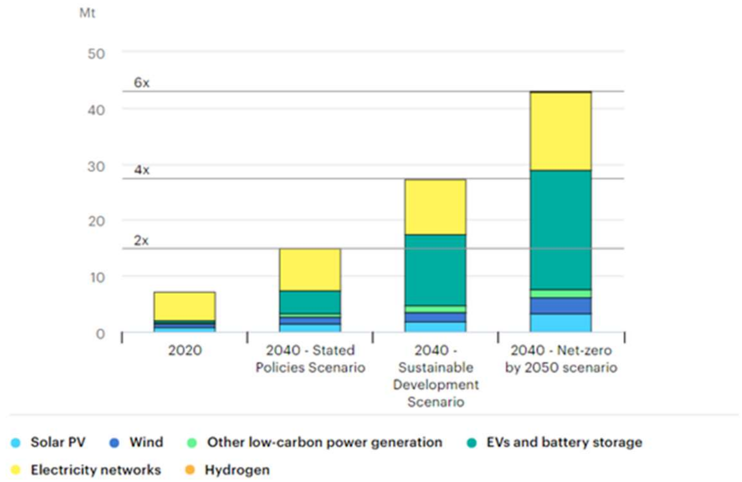
Smart grid production is increasing but issues related directly to manufacturing ensue. Raw material and resources needed to produce a number of Smart grid technologies are metals as copper, aluminium, nickel, lithium, and refined metal (JRC, 2022); as well as rare earth elements (also identified as REE) as dysprosium, praseodymium, neodymium, hafnium, lanthanum and cerium; metalloids like gallium, indium, tellerium, cobalt, erbium and silicon; and other materials as graphite and cadmium-telluride (David and Koch, 2019). These Critical Raw Materials (CRM) are paramount for smart grid production and their provision and recovery is challenging (David and Koch, 2019). Figure 5 below demonstrates the CRMs needed for some smart grid devices and related fields as renewable energy production and energy accumulation (Figure 5) (David and Koch, 2019). Therefore, smart grid production is dependent of the mining, exploitation and refinement of their rare raw materials.

Figure 5. Example of smart grids and related fields devices need in CRMs

Governance Domain	Exemplifying Device	Exemplifying Material
Energy allocation control	Semiconductor (cognition), mobility, (e.g., smart meter in-house)	REEs: Dysprosium, hafnium, neodymium, praseodymium, samarium, terbium
	LCD/PDP touch screen (visualization), mobility (e.g., smart meter, in-house)	REEs: Yttrium, cerium, europium, terbium Critical metalloids: Gallium, indium, tellurium
	Sensors with integrated processors, optical fiber (e.g., outdoor, in-house)	REEs: Erbium, hafnium, neodymium Critical metalloids: Silicon
Renewable energy production	Wind energy: Permanent magnet	REEs: Neodymium, praseodymium, dysprosium
	Solar: Photovoltaic panel	Critical metalloids: Gallium, indium, silicon, tellurium
Energy accumulation	Electricity storage, rechargeable lithium-ion batteries (e.g., electric vehicles)	REEs: Lanthanum, cerium Critical metalloids: Silicon metal, graphite, cobalt

Electricity networks and solar photovoltaic production are particularly demanding in these REE and more specifically in metals. Electricity networks on their own could grow copper production from 20.5 Mt in 2020 to 23-24 Mt or 30 Mt in 2030 depending on the scenario (David and Koch, 2019). As another example, lithium demands are also expected to rise by 2030. Indeed, about 500,000 metric tons of lithium carbonate equivalent (LCE) were produced in 2021 and three million to four million metric tons are expected to be needed in 2030 (David and Koch, 2019). Finally, the rise in production of lithium-ion battery Electric Vehicles on its own contributed by 16% to the growth of the market which is expected to grow above 92 billion USD in 2024 (David and Koch, 2019). The rise in need for raw material has been induced by the increased production of smart grids and renewable energy. As the need for smart grid has been demonstrated to carry on expand further in the next decade the trend the rise in CRM exploitation is to continue. Figure 6 below demonstrates that by 2040 the demand for mineral related to clean energy technologies will continue to rise from twice as high to six times as high as the demand in 2020 (Figure 6) (IEA, 2023b). In addition, the two sectors to weight the most in this increased demand scenarios are electricity networks in which smart grids intervene the most, and EVs and battery storage, also related to smart grid. Therefore, CRM needs to develop smart grids and related technologies is growing. However, the scarcity of these raw material makes the exploitation challenging.

Figure 6. Total mineral demand for clean energy technologies by scenario, 2020 compared to 2040.

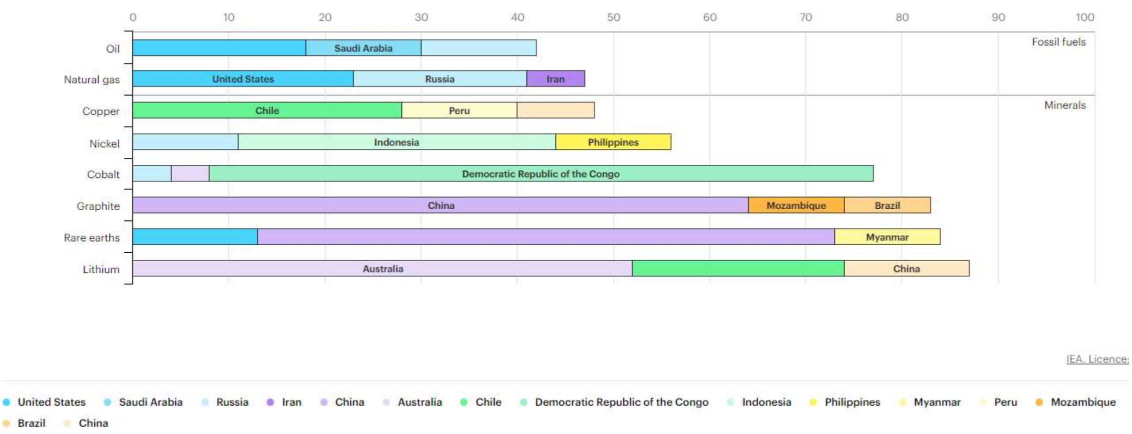


Furthermore, the exploitation of CRM, which has been demonstrated to be challenging on its own due to their scarcity, also generates health and environment issues. REE mining activities contaminates the soil and water, the waste composed of uranium, thorium and alpha particle emissions are also harmful to the environment (David and Koch, 2019). Even REE processing is harmful to workers as it induces radioactive materials, radon and monazite gases, as well as alpha and gamma rays (David and Koch, 2019). Therefore, the threat to human health and to the environment provoked by REE activities is to consider when observing the rising smart grid production.

David and Koch advance the recycling solution to avoid the nefarious effects of REE mining and processing activities (2019). However, not all CRMs can be recovered due once again to their effect on human health, the cost of such endeavour, or the simple lack of structures to collect the materials. For example, 'New photovoltaic materials, such as CIGS, are considered toxic and are related especially to pulmonary and reproductive toxicity' (David and Koch, 2019). Therefore, as smart grid production rise and CRM waste accumulate, a proper recycling solution is to be planned. The toxicity of some of these REE needs to be handled to avoid environmental issues and counterbalance the initial goal of the rise of smart grid solutions: protect the environment through the reduction of GHG emission.

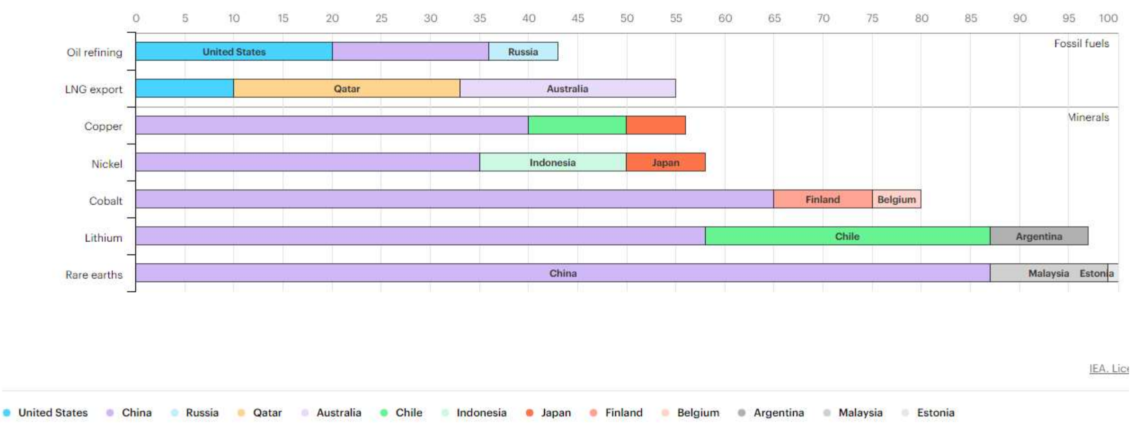
As the needed raw materials for smart grid production are rare, the supply is limited. EU supply in overall CRM is not endangered. Indeed, silicon, silver, indium, selenium, copper, gallium, tellurium, and cadmium required for the photovoltaic sector, as well as lithium and cobalt for electric vehicle batteries, and carbon fibre composites used in wind turbine blades are not materials to worry about as the EU shows better resilience in supply acquisition (JRC, 2016). However, Europe demonstrate a low resilience regarding REE supply as neodymium, praseodymium and dysprosium used in the wind and electric vehicle sectors, as well as for graphite and lithium-ion batteries (JRC, 2016). The EU remain dependent of its production of smart grid and renewable energy from foreign countries CRM supply. This high dependency to a handful of countries if visible in Figure 7 below. In terms of minerals, three countries produce anywhere from 48% (copper) to 87% (lithium) of the extraction in 2019 (IEA, 2023b). Graphite identified earlier as one of EU's low resilience materials is extracted at 64% in China (Figure 6) (IEA, 2023b). The European smart grid sector then remains highly dependent of foreign market and policies regarding raw material for technologic production.

Figure 7. Share of top producing countries in extraction of selected minerals and fossil fuels, 2019.



Moreover, the EU also remains highly dependent to refined metal supply. Once the REE are mined, their exploitation continues to transform them and make them suitable for use in smart grid technologies. China is currently the major player in the production of refined metal, followed by Chile, Japan and the Democratic Republic of Congo (David and Koch, 2019). This power repartition is also foreseen as remaining this way in the years to come. Figure 8 demonstrates the clear hegemony of China in the refined minerals industry, processing up to 87% of processed REE in 2019, or 58% of processed lithium in the same year (Figure 8) (IEA, 2023b). Once again, three countries are holding the majority of the supply necessary of smart grid production. Thus, the European smart grid production is highly dependent from external players and their supply. Both raw material and refined metal are critical components of future technologies, and their access can become challenging.

Figure 8. Share of top producing countries in total processing of selected minerals and fossil fuels, 2019.



Consumption

As previously stated, smart grid production is to follow its consumption and therefore is to increase in the next years. Indeed, DSOs consumption of smart grids is growing, and their need for flexibility in particular in drives their expansion (E.DSO, 2023). The electrification of the energy demand is also accelerating to contribute to climate neutrality 'with the share of electricity in final energy consumption growing from 23% today to around 50% by 2050 according to certain scenarios' (JRC, 2022). Furthermore, smart grid consumption is to increase in the next years as 'the European grid must be adapted to the emerging energy transition power system, characterised by high and increasing variable RES shares, flexibility, and decentralised co-existing with centralised in one system' (ENTSO-E, 2020). To integrate climate objectives in energy policies, smart grid technologies are essential.

Smart grids use entails a new way of energy consumption for the whole chain of electricity stakeholders. The electricity network is in need of digitalisation because of its heightened integration implying an increased need for smart grids in the next decade (E.DSO, 2023). In addition, smart grids create more capacity to electricity network infrastructures to improve services (E.DSO, 2023). Thus, electricity network and consumption of technology adapted to the grid is changed by smart grids. New data and new services brought by smart grids change the way of consumption and allow for new patterns to be created. Indeed, the increasing volume of data produced thanks to smart devices related to the electricity network can boost the European economy as a whole, as nearly all economic sectors rely on the energy sector (E.DSO, 2023). A more efficient way of consuming electricity is open for all stakeholders.

On the end-consumer side for example, the use of smart grid technology allows the access to the 'prosumers' status: consumers also producing electricity at home, as well as active players in the electricity consumption. Prosumers are evolved users consuming electricity of their own production and storage solution (ISGAN, 2020). The smart grid solutions integrated to their home converted their energy consumption from a conventional form to a smart form integrated in climate change fight schemes. However, without going so far as to producing their own electricity, consumers thanks to smart grids technologies become actors of their own electricity consumption by becoming more aware (JRC, 2022). Indeed, real-time consumption data becomes available to consumers allowing them the ability to influence it near instantaneously (JRC, 2022). Smart grid technologies regarding transparency of the market, simple information gathering, and reliable products and services make consumers more active and effectively change consumption patterns (CEDEC, 2014). Smart grids allow for consumers and prosumers alike to have a heavier weight on the electricity market. Power balance change thanks to new consumption patterns resulting from smart grid technologies.

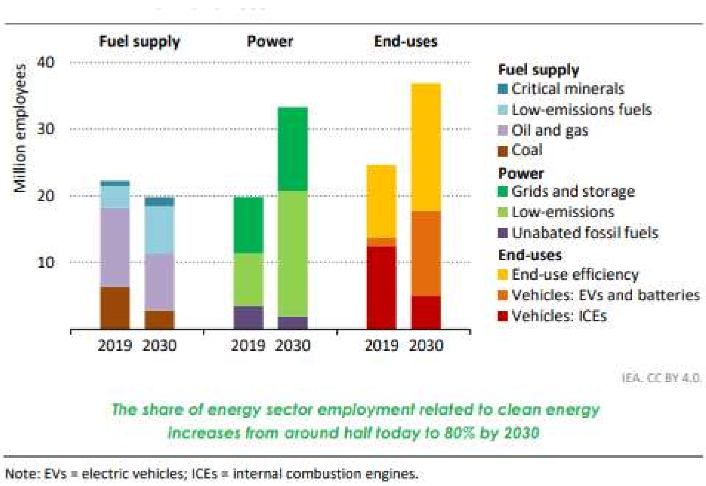
On the other hand, for DSOs and TSOs, the use of smart grid solutions enables the creation of further services to the grid as well as enabling demand response through automation and distribution management (JRC, 2022). Therefore, smart energy consumption resulting from smart grids installation is as useful for DSOs, TSOs, and consumers. Smart grid consumption for DSOs curves congestion, allows a better integration of renewable energy, creates new consumption patterns and reduce global electricity consumption for end-consumers (JRC, 2022). The grid then becomes more efficient, more stable, and more flexible through new consumption pattern instituted with smart grid solutions.

Employment

Employment in the smart grid sector in Europe is expanding. Ten years ago, the European Federation of Local and Regional Energy Companies stated that the increasing number of smart grid projects in Europe will have a positive impact on regional development, local job creation, economic activities and infrastructures (CEDEC, 2014).

Employment growth related to smart grids will take place globally in the next decade. Indeed, the energy power sector will experience the most growth due to Net Zero Emission Scenario enactment: 4 million jobs in power grids and storage to be created by 2030 (Figure 9) (IEA, 2022b). According to Figure 9, power grids will 'maintain their 4% annual employment growth thanks to rising electrification rates and new investment in grid upgrades and expansion.' (IEA, 2022b)

Figure 9. Global energy employment by technology in the NZE Scenario 2019 and 2030.



Furthermore, in 2021, ENTSO-E's Ten Year Network Development Plan reports the creation of 1.7 million jobs in EU member states in order to achieve European energy policy goals as well as EU Recovery Plan targets (ENTSOE-E, 2020; JRC, 2022). This contribution from smart grids in terms of jobs created would contribute to improving the economic situation in Europe after the COVID-19 pandemic and the toll the War in Ukraine had on the energy sector.

Constraints

This accelerated change in grid utilization stresses the grid and the transformation make new developments more complex (ISGAN, 2020). Indeed, as smart grid are developed, the network becomes a conglomerate of solutions. However, Europe remains a step ahead regarding this issue thanks to the development of a framework supporting the European Smart Grid Plans: the Smart Grids Architecture MODEL (SGAM), accelerating development processes and facilitating standards enhancement (Norouzi et al., 2022).

In addition, other challenges arise for the smart grid market. Indeed, public opposition to this development are reported to rise due to privacy concern by end-consumers (ISGAN, 2020). Smart grid solutions, gathering more data than ever expose consumers to 'denial-of-service attacks, viruses, malware, phishing, and other forms of cybercrime.' (Norouzi et al., 2022). Security issues are then an important side of smart grid constraints.

As previously analysed, raw material needs for smart grid production has the potential to become a major issue. Indeed, the environmental and health issue raised by the increasing needs of the global market, the scarcity and therefore dependence of Europe regarding the mining and processing activities for certain CRMs are concerning for the future of smart grids.

Path dependency to previous decision-making politics in electricity networks can also be listed as a constraint in smart grid development. Indeed, the previously centralised electric system led to supporting technologies creating a pattern supporting itself (Norouzi et al., 2022). This can install an inertia due to the path-dependence paradigm, locking the situation and impeding smart grid development.

For additional information, a further developed analysis of barriers and obstacles to smart grid has been produced for the deliverable D7.2: Obstacles to innovation report. This deliverable focuses on the obstacles encountered during the FLEXIGRID project and the lesson learnt regarding the barriers to smart grid development.

2.2 Renewable electricity

Market Health

Just as the smart grid market, the renewable electricity market is reported to be expanding and expected to keep expanding in the next years. In particular in the European Union, countries have both vowed to rise their Renewable electricity share in their energy mix on a national level as well as on the EU level. At the national level, member states drafted NECPs (National Energy and Climate Plans) clearly setting new targets up to 2030 (see Figure 10) (EEA, 2022).

Figure 10. European member states targets for shares of Renewable energy

At the EU level, targets for Renewable electricity shares have been raised in recent times. Indeed, up to 2020 the Commission set the RED (Renewable Energy Directive) which were achieved and adapted as RED II. Thus, in 2018 RED II legally settled a target of 32% of RE shares in the European Union energy mix for 2030 (EC, 2022b). Then in 2021 and 2022, those targets were raised again through the European Green Deal first and then the REPowerEU Plan to attain 40% and 42.5% (aiming for 45%) respectively (EC, 2022b; EEA, 2023). These increased objectives were driven by the need to mitigate climate change but mostly on a more short-term basis, to curtail European dependence to Russian fossil energy. All these targets were accompanied with legal framework to ensure their completion, making renewable energy expansion easier.

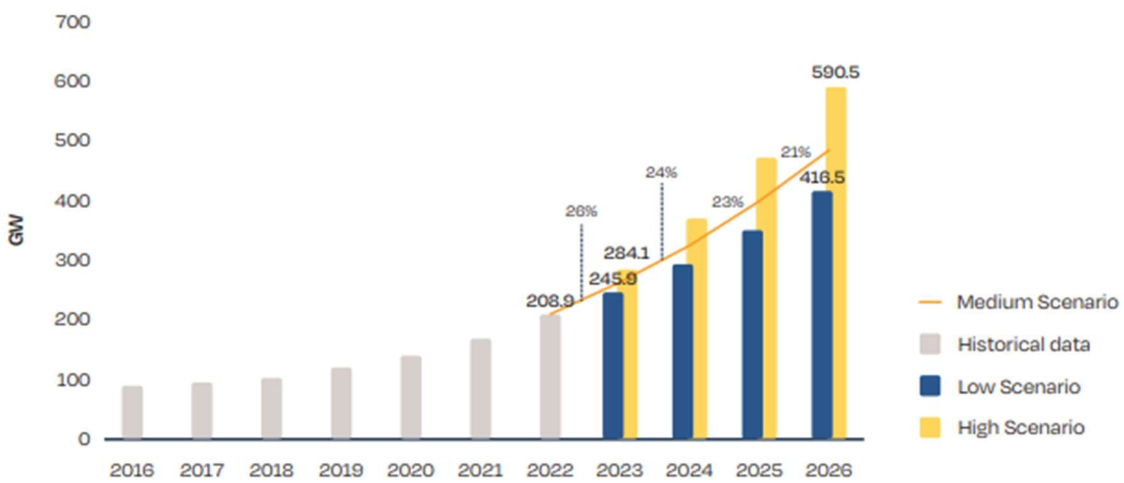
Thanks to this clear plan to ensure the rise of renewable electricity in the European Union, the market is healthy and open to new opportunities. Member countries are planning and executing the development of renewables. Of the renewables available to them, the IEA identified wind and solar PV as 'holding the greatest potential to reduce European Union's power sector dependence on Russia by 2023' (2023). A focus on those two sectors is therefore following in the next paragraphs. Moreover, the EU's will to rapidly transform the transport sector will also be a driver for renewable energy and renewable electricity. The IRENA identified electric vehicles as one of the decisive means to accelerate renewable electricity deployment and rise in the EU energy mix (2018).

The REPowerEU plan is supported by reforms and investments in the form of loans and grants managed by the Recovery and Resilience facility for a total of 300 billion euros (EC, 2023c). This expansion of the market trend is clearly encouraged on an institutional and financial level by the European Union. The challenge while attainable is significant. Indeed, the EEA estimates that 'reaching the target will require a challenging annual increase of 2.4 percentage points every year until 2030, which is triple the historical rate' (2023). Then renewable electricity is identified as a crucial sector for the EU's future.

While currently, the biomass sources are making up the bulk of renewable energy supplies as 41% of the renewable energy mix in 2021, wind represents 13% and solar PV less than 6% (EEA, 2023). While solar PV remains a marginal source, it is growing the fastest among the other sources with a 13% increase from 2020 to 2021 (EEA, 2023). This statistic makes it a crucial source for the EU power mix. In addition, wind and solar power are representing 75% of the options to ensure REPowerEU success (IRENA, 2018). A focus on those two sources is essential to understand the shape of the future of electricity power in the EU and the whole of Europe. As variable renewable energy with uncertain production, accommodating the electricity network for change (through smart grids for example) will be necessary.

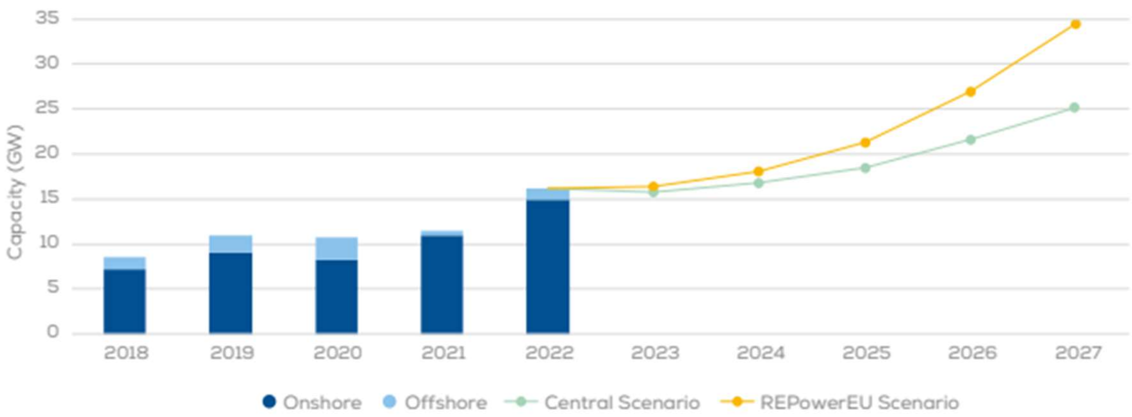
The solar PV market is expected to grow to support the EU energy transition plans. Indeed, an additional 275.2 GW in average is to be added to the already existing European PV capacity between 2023 and 2026, which will double the PV market capacity (representing 209 GW today) (SolarPower Europe, 2022). This rapid installation within European frontiers would allow to reach the REPowerEU target which is set at 400 GW by 2025. Figure 11 proves that even the pessimistic scenario imagined by SolarPower Europe would reach EU targets, and that the PV market will continue to grow in the next years.

Figure 11. EU cumulative solar PV market SolarPower Europe scenarios 2023-2026



The wind power market is also foreseen to expand in the next few years. However, the growth of wind power in the EU should not be as prompt as in the PV market. While 205 GW were installed in 2022 in the EU, an additional 31 GW a year should be installed to meet the expected 440 GW capacity expected in 2030 by REPowerEU scenarios (WindEurope, 2023). As demonstrated in Figure 12 by WindEurope, the rate of installation is slower than for PV solar power, with an expected average of 20 GW per year, less than would be needed to reach REPowerEU goals (2023). However, market growth is still expected as wind installations will be increasing in the next years. Thus, the market can be deemed healthy, at the renewable electricity, PV solar, and wind power level.

Figure 12. EU new wind installations WindEurope scenarios 2023-2027



Production

As the renewable electricity EU market presents a good health, production will be growing in the next years. The previous figures presented demonstrate an expected growth in production (figure 10, 11, and 12). The production of renewable electricity and production capacity deployment is accelerating due to the renewable energy target set by the European Union.

Renewable electricity is one of the solutions deemed cost-effective for both the climate change and the energy crisis economic challenges (IEA, 2023c). Indeed, renewable electricity and especially wind and PV powered productions have been identified as means to curb the rise of energy prices. Therefore, a number of incentives have been unfolded to accelerate the implementation of renewable electricity generators, as well as increased ambitions and schedules moved forward to ensure a real acceleration in production (IEA, 2022c).

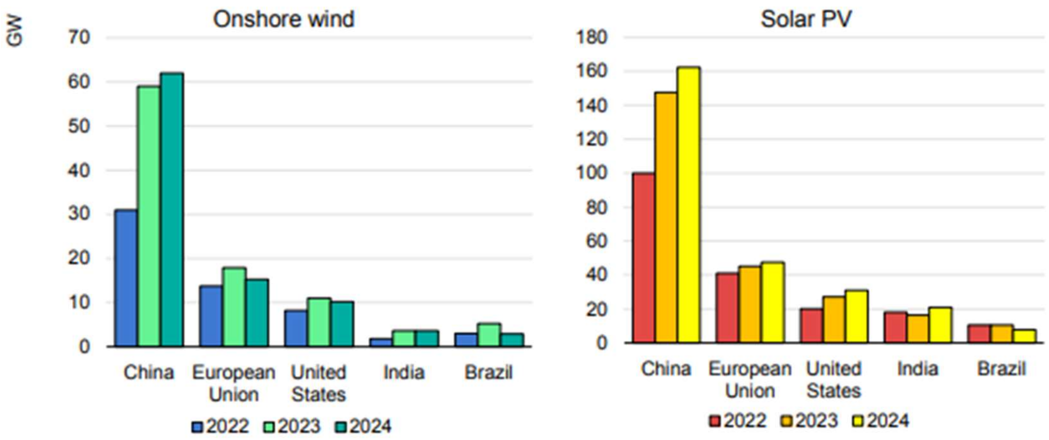
Overall, renewable energy investment in the European Union should increase about 155 billion annually between 2019 and 2023 (IEA, 2023e). Regarding the European Union investment in variable renewable electricity in particular, an estimate of 200 billion euros is expected to be invested on deployment between 2021 and 2023, and about 50% would be returned as savings in energy bills by 2023 alone while still providing for the following 20 to 25 years (IEA, 2023c). The Innovation Fund, dedicated to funding project including technologies reducing GHG emissions, injected alone 1.8 billion euros directly to hydrogen, solar, wind, and batteries European projects by mid-2022 and plans on rising its budget to 3 billion euros for 2023 (IEA, 2023e).

Production of wind and PV solar electricity is variable by nature. Thus, their production and introduction in the EU energy mix calls for smart networks. Flexibility and smart grid solutions will be crucial to ensure the best use of renewable electricity capacity. High levels of renewable electricity such as solar PV and wind power representing the most important GW capacities in the IRENA's European Remap case (327 GW for wind and 270 GW for solar PV) (IRENA, 2018).

The prosumer status which was presented in section 2.1 of this deliverable (D8.13) is also performed thank to the production at users' level of renewable electricity. This allows citizens to play an active role is the energy transition. Coupled with the smart tools which grant them power over their consumption, the access to small-scale production will have an important impact on the overall production on variable renewable electricity.

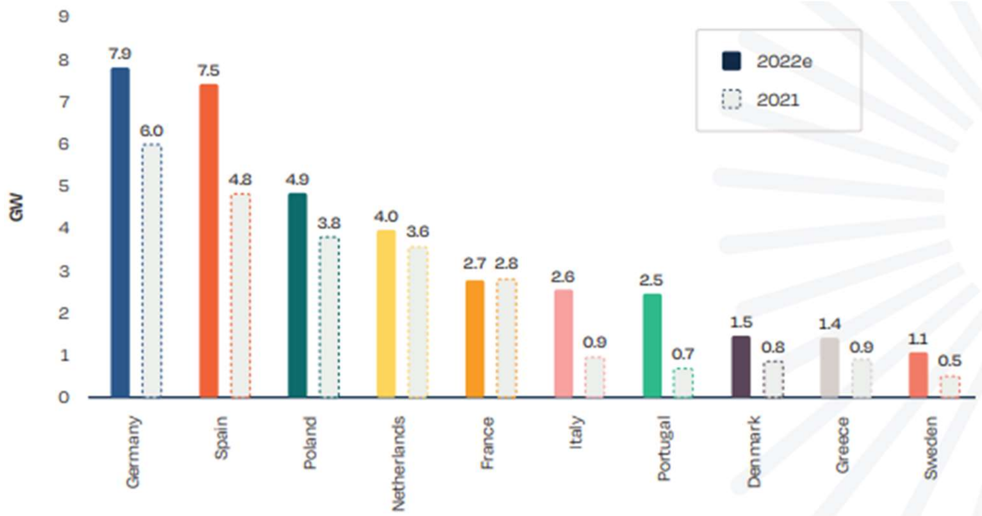
The European Union worked and continues working toward increasing its renewable electricity capacity. As demonstrated in the following figure 13, the European Union is the second region adding the most net renewable electricity capacity after China in Onshore wind and solar PV, with an average of 15 GW per year added to the renewable electricity capacity for onshore wind and 40 GW for solar PV (IEA, 2023d). Altogether, the EU added 90 GW of solar PV and wind capacity to its network, 'This capacity has displaced almost 10% of hard coal and natural gas generation' (IEA, 2023c). This added capacity implies added production in the EU and therefore an energy mix evolving toward renewable electricity. As stated above, the numerous incentives ranging from energy prices to institutional planning for transition and the will to shift toward an energy independent Europe will continue to push the increase of renewable electricity.

Figure 13. Net renewable electricity capacity addition by country or region 2022-2024



Regarding solar production, EU member states increased by 47% their Solar PV capacity between 2021 and 2022 (SolarPower Europe, 2022). The top 5 of EU solar markets sizes can be ranked as follows: Germany, Spain, Poland, the Netherlands, and France (Figure14) (SolarPower Europe, 2022). With an expanded capacity of production in solar electricity, those countries are building their energy transition toward more sustainable and clean electricity.

Figure 14. EU27 Top 10 solar PV markets 2021-2022



On the other hand, wind power capacities have also been improved in the European Union. Indeed, in 2022 the European Union added 19 GW of wind power to its electricity network (WindEurope, 2023). While this number is not enough according to WindEurope to reach REPowerEU targets (an average 31 GW of new installations would be needed), it is still improving current capacities (2023). Onshore and offshore installations show a difference in deployment acceleration. Of this new power, 87% of the installation were onshore and located in in Germany, Sweden, and Finland, whereas offshore capacities were added in majority in the UK, and France (WindEurope, 2023). The top 5 of EU wind markets sizes can be ranked as follows: Germany, Spain, France, Sweden, and Italy (WindEurope, 2023). Together with PV solar electricity, increased capacity of production in wind electricity paves the way for an added production of renewable electricity and diminution of fossil fuel use.

Renewable electricity and more specifically wind power and solar PV electricity face the same challenge that smart grids regarding materials for production. As described in the previous section (2.1), raw materials, such as the previously identified CRM and rare earth materials are needed for the production of renewable electricity installations. Just as demonstrated in Figure 5, wind and solar devices require similarly rare materials such as neodymium, praseodymium and dysprosium for wind, and gallium, indium, silicon, and tellurium for solar (David and Koch, 2019). While as demonstrated before, solar PV and wind are not the technologies which will require the most minerals, their increased production to provide more capacity will play a part in the rising demand of materials. The difficult recycling conditions and dangerousness are the same than they are for smart grid technologies materials.

The photovoltaic sector shows better resilience in some materials than others. In the previous section, silicon, silver, indium, selenium, copper, gallium, tellurium, and cadmium all elements required for the photovoltaic sector were mentioned as materials the European Union demonstrated a good degree of resilience in supply acquisition. However, resilience in the supply acquisition of silicon, silver and indium is evaluated as medium (JRC, 2016). Polysilicon is also a material the European Union is not resilient toward. Processed polysilicon in wafers is controlled at 95% by the top ten producers (IRENA, 2022). While the global PV solar scene recently experienced a polysilicon shortage due to low production levels which increased module prices, this particular challenge is today solved unlike the inverters shortage (SolarPower Europe, 2022). This particular issue is now avoided but might reappear in the future as the

European Union shows low resilience to this material which supplied is controlled in Asia. In turn, solar PV manufacturing is an activity concentrated mostly in China in every step of the supply chain:

> 'For wafers, China has a near-complete monopoly, with 96% of global production in 2021. For cells, it commanded an 84% share of global capacities and 79% of production. For modules, the shares were 81% and 78%, respectively. Malaysia, Thailand and Viet Nam have become manufacturing and assembly hubs, principally for Chinese companies, together representing close to 9% of cell and module production.' (IRENA, 2022).

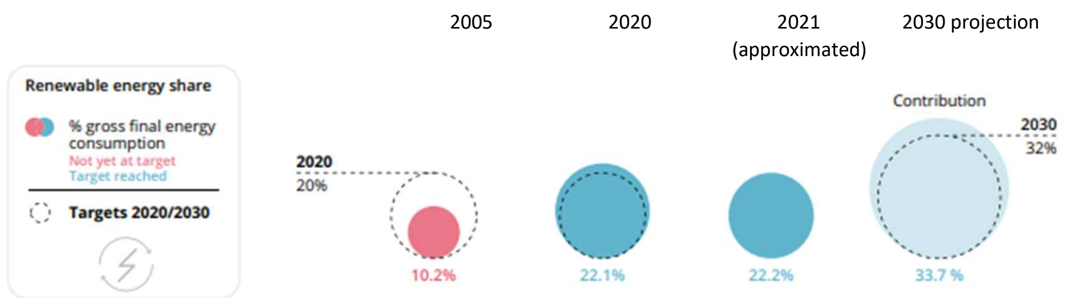
Then, the stakes of PV solar electricity production include the production of modules and the dependence and low resilience regarding module acquisition and construction.

The wind sector resilience performance is also divided. As mentioned before, the EU resilience regarding carbon fibre composites used in wind turbine blades is high (JRC, 2016). Yet, materials needed for wind turbine generators such as neodymium, praseodymium and dysprosium demonstrate a low resilience performance from the EU (JRC, 2016). Thus, just as the photovoltaic sector, the wind sector shows different resilience levels to different materials. Production will be dependent from the European Union ability to secure those rare and critical materials for the production of installations and the consequent production of renewable electricity.

Consumption

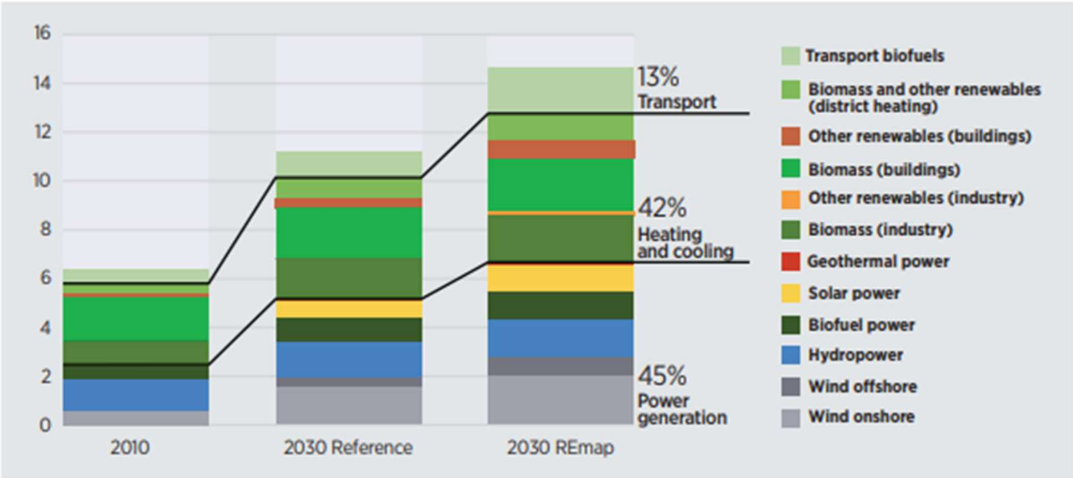
The European Union settled goals for renewable energy and renewable electricity consumption. While previous targets were reached, for example the 20% renewable energy share at the EU level was overachieved at 22% of renewable energy in the energy share was consumed in 2020 (EEA, 2022). This level of renewable energy consumption was roughly maintained in 2021 thanks in part to the increased consumption of renewable electricity generated by wind and solar power (EEA, 2023). This percentage of renewable electricity share was raised and is still rising due to the new EU goals. Indeed, this rise in consumption of renewable energy as a whole in the EU was important as goals could be heightened. The goal of 32% RE share in the 2030 EU energy mix declared by RED II was already achieved by 2022. Figure 15 illustrates this, REDII goals had been passed in 2022 as renewable energy share reached 33,7% (EEA, 2022).

Figure 15. Achievement of 2020 targets and progress towards achieving 2030 targets in the EU-27



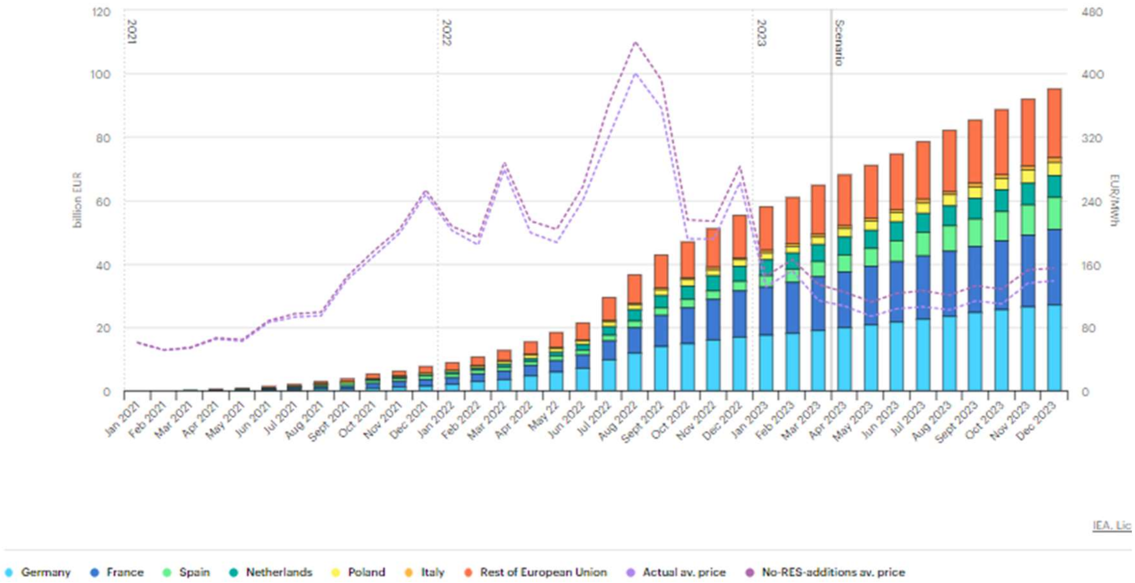
In the European energy consumption, the biggest share of renewable energy can be found in the electricity consumption (EEA, 2022). The rise of renewable electricity consumption and its integration in electricity network is a priority to reach the new and more ambitious REPowerEU goals. Renewable electricity generated by solar, wind and hydro power are to be mainly consumed in power generation application (Figure 16) (IRENA, 2018). This consumption of renewable electricity just as its production encourages savings in both prices and fossil fuels uses. Indeed, the added solar and wind electricity generators allowed savings estimated at 100 billion euros between 2021 and 2023 in the EU, and 230 TWh of fossil fuels (IEA, 2023c). Consumption is increasing as production allows this conversion in uses.

Figure 16. Breakdown of gross final renewable energy consumption in the EU-28 by source and application in 2010 and 2030 in different case scenarios.



Consumption of renewable electricity rather than fossil fuels has been proved to decrease energy prices. Figure 17 for example demonstrates the decrease over the month during the energy crisis in different parts of the European Union (IEA, 2023c). With the increase of variable renewable electricity, the overall electricity costs are decreasing. The Germany, France, Spain, the Netherlands, Poland and Italy are countries were the wind and or the solar electricity generation installations are important and rising. Thus, the renewable electricity consumption impacts institutional goals, carbon emissions as well as electricity prices, enticing their development.

Figure 17. Cumulative electricity costs decrease due to solar and wind additions, and average European Union wholesale spot electricity price, actual and in no-RES-additions scenarios 2021-2023



The electrification of uses in targeted sectors is to play a major role in the rise of renewable electricity consumptions. Transport, industry and buildings applications for example are being converted to electricity as a solution to rise the consumption of renewable electricity (IRENA, 2018). Some sectors are more efficiently converted than others. The electrification of the transport sector is targeted as crucial to enable energy transition. The rise of renewables in this sector has been identified as an important target in the EU. Renewable energy share in EU transport rose from2% in 2005 to 10.2% in 2020, the new goal for 2030 was set at 14% in 2030 in RED II (EEA, 2022b). Two energy strategies co-exist: the use of biofuels or renewable electricity. While biofuel use is predominant the progress of electrification of transport still played a small role in transport decarbonisation (EEA, 2022b). Electricity consumption and uses will continue to be expanded.

Employment

Just as employment in the smart grid sector, employment in Renewable electricity in Europe is expanding. The acceleration of renewables and renewable electricity installations and integration into the network creates economic activity and new jobs within EU member states borders (IRENA, 2018). The expansion of the renewable sector already created jobs and is set to create more. In 2018 the IRENA estimated that about 1.2 million people were employed in renewables Europe (IRENA, 2018). This number was increased the following years to attain 1.5 million workers in 2022 (IRENA, 2022). Strictly in the EU, the European Commission then evaluated that 1.3 million people were employed in this sector in the EU in 2020, and that an additional 3.5 million jobs should be created by 2030 to achieve REPowerEU goals (EC, 2023b). According to the EC, 'the top 4 countries in terms of employment were Germany (242 100 jobs, 18% of all EU renewable employment), France (164 400 jobs, 13%), Spain (140 500 jobs, 11%) and Italy (99 900 jobs, 8%)' (2022b). These countries have already been identified earlier as leaders in renewables and renewable electricity infrastructure expansion. Therefore, expanded production and rise in employment can be linked.

Looking at renewables in particular such as solar PV and the wind sector, the trend of increased employment is revealed accurate. Even now, these industries employ a significant amount of people: 21% of the renewable energy sector workers are employed in wind power, which represents 280 400 jobs (EC, 2022b). This high share of renewable jobs dedicated to wind is explained by the importance of the EU market and manufacturing. Europe represents about 40% of global manufacturing output and is considered 'the most important exporter of wind power equipment' (IRENA, 2022).

The solar PV sector is also forecasted as employing additional people. In 2021, the IRENA estimates that from the 292 000 jobs related to solar PV in Europe, 235 000 were based within EU member states (2022). This number is expected to drastically increase as the EC estimates that the PV solar sector alone should employ about 1 million workers (of which 66 000 should be dedicated to manufacturing) by 2030 in order to achieve REPowerEU targets (EC, 2023b).

Constraints

The rapid deployment of renewable electricity is bringing forth its own sets of challenge that need to be addressed in order to sustain the industry development. Firstly, while the advancement of renewable electricity to achieve EU goals is attainable, network congestion is to be expected (IRENA, 2018). Indeed, the integration of additional variable renewable electricity stresses the network and challenges the established demand-centred system. Indeed, to smooth renewables integration the whole structure needs to be rethought. Demand needs to be adapted to supply due to the impossibility to act on supply, where before supply was adapted to electricity demand. Thus, to transform the current electricity network into an effective structure integrating renewable electricity, additional flexibility solutions will be crucial.

The uncertain level of production for both wind and solar generated electricity increases the upcoming change challenges for the electrical network. The variability in production and the growing share of renewable electricity in networks entails curtailment (IRENA, 2018). If renewable electricity is being produced and not used, then the network is not adapted to the change in generating sources. This risk might endanger producers' revenues and in turn the deployment of additional wind and solar infrastructures (IRENA, 2018). Then smart grid and flexibility solution will be decisive in the rise of renewable electricity in energy mix shares. In 2018 the IRENA identified that Malta, Croatia, Denmark, Romania, Germany, Bulgaria, the Netherlands and Greece were and would especially endure curtailment issues and therefore would be in need of 'additional cost-effective sources of flexibility (e.g. storage, demand side response, interconnection expansion)' by 2030.

Thirdly, as developed in the previous production section of this renewable electricity market analysis, material acquisition such as raw materials, CRM, rare earth materials and processed minerals constrains renewable electricity deployment. Indeed, the rare quality of some of the material and the monopolisation of these resources hinder the whole supply chain. The European Union resilience regarding the essential resources for renewable electricity deployment ranges from high to low, which might hinder deployment in the mid-term.

Costs and prices can also be listed as constraints to renewable electricity future in the EU. Indeed, while material costs and investment in utility scale are increasing (up to 15 to 25% for solar PV and onshore wind investment costs of new utility-scale, 50% for steel, 70% for copper, and 100% for aluminium in 2022), prices for renewable electricity in the market are decreasing

(IEA, 2023c). This might deter further private investment in renewable electricity projects as the investment return is currently decreasing.

3. FLEXIGRID MARKET OUTLOOK

3.1 Identification of Rs's Source of value

The FLEXIGRID project aims to enhance the power grid's security, reliability, and efficiency by deploying different solutions. The project's market value can be derived from the economic values contributing to these improvements. These economic values are the tangible and intangible resources, capabilities, and advantages the project brings, making it attractive to various stakeholders such as customers and end-users across the energy industry. Each solution deployed in the FLEXIGRID project triggers specific contributions that generate economic value since, as the project is adopted and scaled up, it becomes increasingly apparent, attracting diverse stakeholders across the energy value chain and contributing to the overall transformation of the energy landscape market. The sources of value inherent in the ERs will establish a favourable environment to ensure that the flexible resources and operations introduced by the FLEXIGRID solutions are accessible and cost-effective for consumers, all the while ensuring security, reliability, and efficiency in the challenging energy market.

Additionally, a stakeholder analysis has been carried out along with the setup of a replication strategy in FLEXIGRID WP8 (with the latest update in D8.11 and D8.12). This helped shape the following stakeholder analysis and subsequent solution market entrance analysis and recommendations. Each FLEXIGRID ER had its own list of identified stakeholders updated below. However, some ERs such as ER4 (Energy Box) and ER13 (Fault Locator TDR prototype) determined that the technology was not mature enough yet to name specific stakeholders and customers for its replication strategy, and only mentioned ideas of potential customers. Similarly, the open-source nature of ER10 (Software module for sizing and siting of the battery storage system) did not call for a specific identification of stakeholders to be targeted in the replication strategy. Moreover, due to the maturity and advancement status in the exploitable result development, some ERs were more specific in their stakeholder identification. Namely, ER1a (Secondary substation of the future), ER2 (New generation of smart meters), ER5 (Software module for fault location and self-healing), ER7 (Software module for congestion management), ER8 (Virtual Thermal Energy Storage Module), ER11 (Protection algorithm development to improve current protections used in distribution grids with high RES penetration) and ER12 (Software module for flexibility assets emergency operation) all include specific identified potential customers for their replication strategy. On the other hand, ER3 (Protections for high RES penetration), ER6 (Software module for forecasting and grid operation) and ER9 (FUSE platform) while not supporting named customers, were able to identify categories of customers which are exposed below.

3.2 Secondary Substation of the future

The outlook for the secondary substation of the future solution within the FLEXIGRID project holds significant promise regarding market specificity. According to Verified Market Research report (2023), the substation automation market size is projected to grow at a compound annual growth rate of more than five per cent from 2024 to 2030. Further, the reported study indicates that the substation automation geographically market's dominant growth in coming years will be in North America, Europe, Asia-Pacific and the rest of the world. However, other indicates shows has placed European countries as the top emerging market for substation Automation due to the increasing demand for smart grids and energy efficiency. It is aligned with the ongoing transformations in the energy sector. As the world transitions towards cleaner, more efficient, and digitally integrated energy systems, the secondary substation solution has the potential to play a pivotal role in shaping the future of power distribution and management. It is important to note that regulatory support and incentives for renewable energy integration, smart grid technologies, and energy efficiency further bolster the market outlook for solutions like the secondary substation of the future. As governments and industries worldwide commit to decarbonisation and energy transition goals, innovative solutions aligning with these objectives will likely experience increased demand.

ER1a – Secondary substation (SS) of the future (Lead partner: ORMAZABAL)

Table 1. ER1a Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	Category	Situation vis-à-vis the FLEXIGRID consortium	Relation with FLEXIGRID partner	Knowledge of FLEXIGRID's concept/given ER	Estimated level of interest in FLEXIGRID's concept/ given ER	Reasons explaining the level of interest	Means to use /Actions to undertake to reach out the given stakeholder	Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.
EDP (European)	End-user	Internal	Alliance	Perfectly knowledgeable	High	Several Smart Transformers to be bought from ORMAZABAL. They are interested in replacing some their actual meters with those. They may be interested depending on the results and other factors (budget for equipment, arising needs)	They can be reached through VIESGO. VIESGO is now integrating into EDP	Very high
HEP ODS - other distribution areas (national DSO), Aggregators (national)	End-user	External	Cooperation	Quite knowledgeable	High	Secondary substations of the future are becoming more interesting to system operators that are facing the challenges related to the integration of renewable energy sources and electrification of heating and transport sectors. This solution will help in enabling easier and more reliable planning and operation of smart grids	Direct contact, trade association	High

ER1b – Secondary substation (SS) of the future specially designed for remote isolated areas (Lead partner: SELTA)

Table 2. ER1b Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	Category	Situation vis-à-vis the FLEXIGRID consortium	Relation with FLEXIGRID partner	Knowledge of FLEXIGRID's concept/given ER	Estimated level of interest in FLEXIGRID's concept/ given ER	Reasons explaining the level of interest	Means to use /Actions to undertake to reach out the given stakeholder	Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.
INDUSTRIAL Customer (European): FCA (European), COLLA s.p.a. (Local)	End-user	External	No relation	Not knowledgeable at all	Low	Providing services from the secondary substation and the DSO grid	Directly contacting in order to sell solutions of ER	Low
RES PRODUCER: Sorgenia (European), Iberdrola (European)	End-user	External	No relation	Quite knowledgeable	High	Providing services from the secondary substation and the DSO grid	Directly contacting in order to sell solutions of ER	Very High
DSO (European): E-Distribuzione, SET, ARETI	Utilizer	External	Cooperation	Quite knowledgeable	High	Upgrading the secondary substations within its grid	Workshop, seminary, sector magazines	Low
DSO: ENEL (European), ENDESA (National), UNARETI (National), IRETI (National)	Utilizer	Internal	Cooperation	Perfectly knowledgeable	High	Upgrading the secondary substations within its grid	Directly contacting in order to sell solutions of ER. Showing the result of FLEXIGRID project.	Very High
RES PRODUCER (European): ALPERIA, Dolomiti energia	End-user	External	Cooperation	Quite knowledgeable	High	Providing services from the secondary substation and the DSO grid	Direct contact, trade associations	Very Low
BSP: Aragon Invest (European), EPQ (European)	Utilizer	External	No relation	Not knowledgeable at all	High	Aggregating the energy resources to provide ancillary services	Directly contacting in order to sell solutions of ER	Low

The secondary substation of the future solution in the FLEXIGRID project offers valuable benefits that help create economic advantages for the project's customers. This solution focuses on important customers identified in the business model development document (D8.4). The primary beneficiaries encompass prominent entities, including Distribution System Operators (DSOs) such as EDP, EDYNA, E-Distribuzione, SET, and ARETI at the European level, and national DSOs like HEP ODS. Additionally, RES producers like Sorgenia, Iberdrola, ALPERIA, and Dolomiti energía operating in the European market, technology suppliers such as ENEL-X and Enel Green Power, aggregators, and electrical energy users are pivotal customers. This assortment of customer segments is integral to constructing the project's market value chain. They play essential roles, such as ensuring reliable power distribution, integrating clean energy, supplying technology and equipment, and using energy efficiently. Together, they form a strong partnership that drives the success of the secondary substation solution and brings value to everyone involved in the energy market.

The market outlook for the secondary substation of the future solution is promising. This solution creates multifaceted sources of value in the economic market that enhance efficiency through some of its features, such as advanced secondary substation automation. This feature responds to the current escalating market demands for grid operators to improve the energy balance, voltage regulation and stability, which return optimizing resources for distributors and end-users (commercial and residential). Moreover, the market's growing need for safety and asset protection to safeguard valuable power assets and workers' safety, minimizing downtime, disruptions, and injuries, also makes this solution highly relevant. The economic implications created by the automation of remote capabilities of the solution cannot be overlooked as it plays a significant effort in streamlining operations, thus reducing manual interventions, accurate billing, and efficient maintenance contributes to cost reductions, thus cutting off revenue losses across the distribution value chain. This aligns with the market's drive to reduce financial expenses and improve profitability.

Additionally, the solution supports integrating renewable energy sources and grid flexibility, which are the critical proponents of this solution’s market potential current and future. With this solution distributed energy resources and diverse renewable energy sources such as solar, wind, and biomass become more prevalent; thus, the need to have intelligent systems that effectively manage and balance the variable nature of these sources becomes inevitable; therefore, the solution aligns well with market needs. Thus, integrating renewable energy sources in power systems is expected to generate ample growth opportunities for the global digital substations markets (Markets and Markets, 2019). Renewable energy sources in all aspects are projected to continue moving forward in the electricity market as utilities and regulators prefer them to replace the existing capacity, and end-users increasingly choose to save costs and address climate change concerns.

The solution also improves overall grid network energy supply, resilience, and performance. Thus, this solution addresses current challenges through advanced features and capabilities which create economic value. As the energy landscape continues to evolve, this solution holds the potential to carve out a distinct market niche, driving value and innovation in the realm of power distribution and management.

Despite steady growth over the secondary substations of the future, the solution market value is potentially subjected to various significant risks across the value chain. The success of the FLEXIGRID project and the market value of secondary substations mainly rely on the successful development and integration of advanced technologies into the power systems. Therefore, unforeseen technological challenges, reliability issues and delays in technology readiness, among other exhibits in the market, could lead to delays or cost overruns, adversely affecting the solution market value. Moreover, the solution is cost-intensive and requires heavy investment; therefore, the availability of funding is crucial for developing and deploying the solution. Thus, economic downturns, changes in investors' sentiments in future and difficulties in securing funds will affect the solution market value down the line. The supply chain in the components and technologies used in this solution is highly vulnerable to disruptions such as critical material shortages, geopolitical issues, and logistic delays, causing project delays and high costs. Moreover, If Secondary Substations and related technologies are not adequately protected, potential breaches could disrupt operations, erode trust, and impact market value. In addition to the commonly assessed risks associated with the FLEXIGRID project and its impact on the market value of Secondary Substations, there are additional forms of risk outlined in deliverable D7.2 titled "Obstacles of Innovation." This report delves into distinct risk factors that Europe's journey towards smart metering has been extensive and systematic, guided by a custom-tailored rollout approach designed to circumvent challenges frequently encountered by new coming projects.

3.3 Smart meters with feeder-mapping capabilities

According to the "Europe Smart Meter Market Outlook by 2027" report, the smart meter market is anticipated to expand at an approximate compound annual growth rate (CAGR) of six per cent throughout the projected timeframe. Illustrated in Figure 2 (section 2 of this deliverable) is a comprehensive representation of the total investments allocated to each smart grid sector across European Union member states. As previously mentioned, smart metering deployment holds paramount importance in Europe, with noteworthy uptake particularly observed in medium-low voltage segments. Projections indicate that the European Union is poised to attain an adoption rate of around 92 per cent by 2030 (EC, 2019) and that the residential segment is anticipated to grow at significant rate. Based on the provided details, it's evident that the smart meter holds significant promise and potential market.

Developing and deploying this new generation smart metering with feeder mapping capabilities in the power networks is indispensable for most applications, from the network operator's enterprise to local control applications. Several factors have triggered the growth of this ER Smart metering in the market segment identified in this section. One of the significant market triggers is the installation of variable renewable energy sources on medium and low voltage grids, changing the power distribution systems Flow from unidirectional to bidirectional and changing of load profile (Konrad Diwold, Stifter and Zehetbauer, 2015). Additionally, consumers have increasingly become prosumers creating a need for a customer-centric smart metering system. Again, a new generation of smart meters with AMI systems is essential for DSOs and consumers to take advantage of DERS and other demand-side flexibility programs. The need for more data-driven power systems across the grid keeps pushing the deployment of these smart meters to support analytics that informs the operational and planning decisions and provide visibility for the network asset's utilisation, reliability and safety. Furthermore, digital transformation in the energy sector needs smart meters with advanced features to facilitate cross-sector information exchange and make necessary data available to interested parties.

ER2 – New generation of smart meters (Lead partner: ZIV)

Table 3. ER2 Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	Category	Situation vis-à-vis the FLEXIGRID consortium	Relation with FLEXIGRID partner	Knowledge of FLEXIGRID's concept/given ER	Estimated level of interest in FLEXIGRID's concept/ given ER	Reasons explaining the level of interest	Means to use /Actions to undertake to reach out the given stakeholder	Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.
EDP (European)	End-user	Internal	Alliance	Perfectly knowledgeable	High	They are interested in replacing some their actual meters with FLEXIGRID's solution	They can be reached through VIESGO. VIESGO is now integrating into EDP	High
HEP ODS - distribution areas other than the one participating in the project (national DSO)	End-user	External	Cooperation	Not knowledgeable at all	High	Installation of the advanced metering and communication equipment can increase network's observability and lead to the improved planning and operation of distribution networks. Additionally, equipped end-users can participate in providing flexibility services.	Direct contact, trade associations	High
i-DE	Utilizer	External	Cooperation	Quite knowledgeable	High	Interest in replicating this solution in new smart meter rollouts. Smart meters provide valuable information about the low voltage network and offer new opportunities for network management	Dissemination events or contact by sales representatives	High
UFD	Utilizer	External	Cooperation	Quite knowledgeable	High	Interest in replicating this solution in new smart meter rollouts. Smart meters provide valuable information about the low voltage network and offer new opportunities for network management	Dissemination events or contact by sales representatives	High
E-REDES	Utilizer	External	Cooperation	Quite knowledgeable	High	Interest in replicating this solution in new smart meter rollouts. Smart meters provide valuable information about the low voltage network and offer new opportunities for network management	Dissemination events or contact by sales representatives	High

The prospective customers identified for this ER smart meters equipped with feeder-mapping capabilities within the FLEXIGRID Project primarily encompass those who stand to gain from the advanced functionalities and insights these smart meters offer. This clientele includes diverse stakeholders: Grid operators and utility companies, including Distribution System Operators (DSOs) such as UFD in Spain and EDP in Portugal, as well as other energy market entities across Europe, form a significant segment of potential customers. Manufacturers of smart meters, exemplified by entities like E-REDES and i-DE in Portugal and Spain, are also key potential customers. Research centres engaged in energy-related studies can utilize the data generated by ER smart meters to bolster their analyses and findings. Commercial customers, particularly those specializing in Big Data/AI software solutions and laboratories, are another vital segment. They can harness the data emanating from ER smart meters to craft tailor-made services for their clientele, prime technology markets within the European Union, including countries like Poland and Romania, constitute a noteworthy customer base. These markets can capitalize on the technological advancements offered by ER smart meters to enhance their energy infrastructure and modernize their grid systems. Lastly, industrial and residential energy consumers, who comprise a substantial portion of the target audience, are paramount. More comprehensive understanding of the customer landscape for the next generation of ER Smart Meters (ER2), detailed information can be found in deliverable D8.12.

The market for smart metering equipped with new Advanced Metering Infrastructure (AMI) systems within FLEXIGRID project introduces multiple economic resource values, unlike the standard smart meters in the market. Notably, the source of value for these economic resources created by this solution stems from several interconnected factors. Integrating feed-mapping capabilities into the smart meters within FLEXIGRID solution represents a significant leap for the customers. This new AMI system within the solution brings a consumer-centric approach as it has significantly considered the increasingly informed and digitally-oriented consumer base by providing real-time information about electricity consumption and costs; thus, customers can make informed decisions about their energy utilization and efficiency. As a result, incorporating an interface of this new generation of Smart meters enables energy consumers can optimize their energy consumption, reduce energy bills and contribute to a lower carbon footprint. Also, this solution support data-driven decision making by allowing data collection and transitions and offering a wealth of insights to distributors and consumers. Thus, the distributor can analyse and forecast the power demand pattern. At the same time, the consumers get informed about their energy consumption, enabling proper planning of power infrastructure and upgrades and enhancing overall grid management strategies. Additionally, this solution brings innovative mechanisms for identifying low-voltage feeders connected to all the Smart meters. This innovation has a significant value for distribution companies. With more precise information on the low-voltage feeder's distribution and usage patterns, utility companies can optimize their grid operation, streamline maintenance and introduce efficient resources across the stream. Subsequently, this innovative source of values it creates will enable the utilities to have economic benefits by reducing the operational expenditure (OPEX), directly saving costs. Furthermore, the help of this solution allows energy users to participate in the demand responsive and load management initiatives; hence, energy users can alleviate the grid's stress and contribute to grid stability, an objective of the FLEXIGRID project.

As previously highlighted, smart meters hold immense potential to revolutionize the energy sector, offering numerous benefits that cater to the market's demands. Nonetheless, evaluating possible market value risks that could negatively affect their acceptance, pricing, and market position is crucial. A significant concern arises from the security risks associated with the widespread use of smart meters, which could compromise customer privacy and safety. Recent instances of successful cyberattacks on power systems have escalated these concerns, raising alarms among potential customers considering smart meters with Advanced Metering Infrastructure (AMI) systems. The apprehensions about potential breaches, data security, and unauthorized access have substantially eroded customer trust. This erosion of confidence, in turn, has led to slower market demand and adoption of these smart meters, potentially resulting in reduced market value and share due to hesitant customer acceptance. Additionally, it's vital to recognize that changes in regulations, standards, or policies set by regulatory authorities in the smart meter and energy sector significantly influence market value. Uncertainties or shifts in government policies could lead to deployment delays or changes in investment priorities, further impacting the market landscape.

3.4 Protections for high RES penetration

Europe and the rest of the world have embarked upon a significant energy transition, leading to profound changes in electricity production, distribution, and consumption. Central to this transition are renewable energy sources, which have taken centre stage. Decreasing costs and advancing technologies have fuelled unparalleled growth in renewable energy deployment. Every year, the capacity of renewable energy systems reaches new record highs. In 2021, renewable sources accounted for 21% of the energy consumption in the EU, marking a substantial achievement (EEA, 2022). Notably, the EU is the second-largest growth market for renewable energy systems, trailing only behind China. Over the past years (2016-2021), the EU has maintained a consistent penetration of renewable energy. Still, this pace is projected to double from 2022 to 2027, while globally, the RES is projected to grow by almost 2400 GW (IEA, 2022).

The substantial penetration of renewable energy sources (RES) within the EU energy market has led to significant repercussions for the EU grid network. When RES generation is considerable, it is integrated at the transmission or distribution level or operates within island mode configurations where applicable. Integrating such sizable RES sources into the grid fabric inevitably triggers shifts in network configurations and fault levels. These fault levels are intermittent, and the efficacy of existing protection mechanisms might be compromised due to their predefined parameters. Consequently, incorporating additional protection schemes or modifying the existing ones becomes imperative to accommodate the high penetration of RES. This underscores the ER3 FLEXIGRID solution's purpose: to develop an adaptive protection scheme to the challenges posed by high RES penetration.

The drive to enhance the presence of Renewable Energy Sources (RES) within power systems has given rise to various challenges impacting the European Union (EU) power grid. These challenges have notably affected power quality, system reliability, security, and the overall health of the infrastructure. Notable power quality issues within the grid encompass voltage irregularities, adherence to harmonics regulations, and reverse power flows. These concerns can damage power equipment and, in more severe instances, disrupt the entire operation of the grid. Consequently, the demand for ER protection solutions has grown substantially to sustain the stability of power quality levels within the grid. Distributed Energy Resources (DERs) are integrated into the grid network, necessitating the development of island detection mechanisms for instances of grid outages. These mechanisms enable DERs to continue generating power seamlessly while functioning in isolation mode, known as islanding. This protective system ensures the integrity of power equipment and the safety of maintenance personnel working along the grid infrastructure.

Furthermore, grid codes and regulatory standards establish a framework of control and operational directives for each region's power network. The local authorities and utility entities provide grid codes outlining the technical requirements for integrating and functioning RES systems. Consequently, protection solutions become imperative to guarantee adherence to these stipulated codes and regulations. Another market triggers of this solution in the market are the fault current caused by RES as it significantly differs from the conventional power generators hence the need for modern protection mechanisms. Also, the grid behaviours are significantly affected by various unforeseen factors such as a sudden change in weather, variations of RES output, and sudden change in demand, among others; therefore, this ER protection solutions play a crucial role in ensuring that the grid remains stable, reliable, and safe as the dynamics of grid conditions varies.

ER3 – Protections for high RES penetration (Lead Partner: ZIV)

Table 4. ER3 Potential customers identification and analysis

Most relevant stakeholder ***(please indicate its level of intervention – local/national/European)***	**Category**	**Situation vis-à-vis the FLEXIGRID consortium**	**Relation with FLEXIGRID partner**	**Knowledge of FLEXIGRID's concept/given ER**	**Estimated level of interest in FLEXIGRID's concept/ given ER**	**Reasons explaining the level of interest**	**Means to use /Actions to undertake to reach out the given stakeholder**	**Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.**
TSOs, DSOs, Generator owners, HV / MV customers (National/European). e.g. REE, i-DE, EREDES	End-user	External	Cooperation	Quite knowledgeable	High	Conventional protective relays do not operate correctly in networks with high RES penetration therefore new algorithms must be used. Customers cannot accept erroneous protection operations so in networks with high RES penetration it is a must to use more reliable protection IEDs as the ones developed in FLEXIGRID Project.	Dissemination events, providing samples for evaluation, contact by sales representatives	High
HEP ODS - distribution areas other than the one participating in the project (national DSO)	Utilizer	External	Cooperation	Not knowledgeable at all	High	Installed protection devices can help in changing the network's topology based on the defined goal function. Besides enabling safe operation in cases of the high RES penetration, potential use of protection devices is decreasing network losses, improving RES hosing capacity, Increasing SAID and SAIFI, etc.	Direct contact, trade associations	High

ER11 – Protection Algorithm development to improve current protections used in distribution grids with high RES penetration (Lead Partner: CIRCE)

Table 5. ER11 Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	Category	Situation vis-à-vis the FLEXIGRID consortium	Relation with FLEXIGRID partner	Knowledge of FLEXIGRID's concept/given ER	Estimated level of interest in FLEXIGRID's concept/ given ER	Reasons explaining the level of interest	Means to use /Actions to undertake to reach out the given stakeholder	Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.
Switchgear and protection relays manufacturers: SEL, ABB, Siemens, General Electric, Schneider	Utilizer	External	Concurrence	Not knowledgeable at all	Low	Feedback on customer satisfaction and improvement of the service provided	Installation at customer premises	High
Noark Electiric and Chint Electric, Switch gear manufacturers and home automation manufacturers	Utilizer	External	Concurrence	Quite knowledgeable	High	Feedback on customer satisfaction and improvement of the service provided	Installation at customer premises	High

The ER protection solution for high RES penetration, known as FLEXIGRID, presents a fitting choice for European grid networks, especially those marked by substantial RES integration. Distinguishing itself from other solutions in the market, this ER employs advanced protection relay algorithms to elevate performance standards. Its uniqueness stands out in the European power sector. The primary beneficiaries of this ER encompass European power lines connected to Transmission System Operators (TSOs) and Distribution System Operators (DSOs), notably HEP-ODS networks. Furthermore, prospective customers encompass power generator proprietors, including Distributed Energy Resources (DERs), prosumers, and High Voltage/Medium Voltage (HV/MV) consumers such as REE, i-DE, EREDES. Comprehensive details about these customer groups can be accessed in deliverable D8.12.

This ER solution's substantial value is to protect high RES penetrations to customers. While the solution addresses these critical concerns brought about by integrating renewable energy sources with the existing systems, other values are offered by these solutions to the above-identified customers. Customers value solution which ensures a reliable energy supply in the market. The ER protection solution's ability to protect the high RES penetration, which is highly intermittency and high variability, helps to stabilize the grid, thus reducing power outage occurrence and maintaining a steady energy supply. This FLEXIGRID solution brings technological innovation and advancement to the power systems that make lives more efficient, which aligns with customers' expectations for cutting-edge solutions.

Moreover, the solution enables energy cost savings to customer since, with the high integration of low-cost RES into the grid, it will average the expensive cost of conventional energy sources leading to overall cost savings to the customers. Furthermore, the recent fluctuating fuel prices in the European grid network due to the high prices of fossil fuels can likely lead to unpredictable energy bills. Thus, a solution that supports the interaction of RES in the energy market contributes to stabilizing energy prices, which is key to customers. Protections facilitating high RES penetration can enable customers to make the most of these financial incentives, reducing their upfront investment and ongoing operational costs. In some regions, customers who adopt renewable energy solutions can benefit from incentives, rebates, and tax breaks. The ER solution will enable EU customers to achieve renewable energy and climate targets.

While the ER solution protection for high Renewable Energy Source (RES) penetration offers substantial value, risks, and challenges are associated with their market value. One of the significant risks is the high cost required for development and integration, such as retrofitting, upgrading, and monitoring the existing grid with the new sophisticated protection relays. Such cost can be unbearable to the customers, which lead to an adverse effect on their market. Current economic instability and financial constraints the targeted customer's face, such as utility DSOs, may adversely affect their ability or willingness to invest in new protection solutions, overlooking the long-term benefits. Moreover, the issue of incompatibility between the different systems in different regions with the devices can slow adoption and integration. Therefore, addressing these risks can maximize the positive impact of these solutions on the market.

3.5 Energy Box

Undoubtedly, the energy box market's trajectory points to continuous and progressive growth, driven by escalating interest in the European power system over the past five years. Across the European energy landscape, energy boxes have found application in diverse projects among Horizon2020 Europe and other private projects, most predominantly at the prototype stage. This trend signifies that as this pioneering solution continues to evolve, the energy box's market penetration is poised to expand significantly, owing to its many advantages within this sector.

Numerous factors have been driving the expansion of the energy market. A prominent driver is the rapid evolution of micro-grids and Smart grids within Europe's power market. This evolution is primarily fuelled by the imperative for automation, enhanced asset utilization, and real-time monitoring, all of which contribute to more advanced grid management. Notably, a significant proportion of electricity customers are shifting from mere consumers to proactive electricity producers, often referred to as prosumers. This transformation has led to a notable trend in the distribution network, where a clear inclination toward integrating these elements into the Smart grid framework has emerged. This shift is highlighted by the incorporation of energy boxes, which has played a pivotal role in stimulating the growth of this market segment. Furthermore, integrating renewable energy sources, such as solar and wind power, into the existing energy grid has significantly driven the adoption of energy boxes within the European power market.

In addition, Vehicle-to-Grid (V2G) technology has the potential to significantly impact the energy box market by enhancing its value and relevance. V2G technology allows electric vehicles (EVs) to consume energy from the grid and return excess energy to the grid when parked and connected. This bidirectional energy flow creates a relationship between EVs and the grid and contributes to the overall growth of the energy box market. Moreover, the advancements brought by integrating the Energy Box into Secondary Substations improve grid operations and contribute to the growth of the energy box market. As energy infrastructure evolves to accommodate smarter and more dynamic grids, the demand for solutions like the Energy Box will likely increase. Also, communication through capturing and storing information, the Energy Box enhances data-driven decision-making processes, allowing for more informed energy distribution and management strategies, thus expanding its market value in the Europe power sector.

A thorough market analysis identified numerous significant customers for energy boxes within the European energy markets. As elaborated upon in deliverable D8.12, these key customers encompass a range of essential players, including Transmission System Operators (TSOs). Energy boxes extend various crucial supports to TSOs, including grid stability, seamless integration of renewable sources, and efficient management of interconnections. Distribution System Operators (DSOs) also derive substantial benefits from energy boxes. These advantages span microgrid management, demand response implementation, and voltage control mechanisms. Furthermore, even grid hardware developers, specialized companies focusing on developing grid-related technologies such as smart meters, sensors, and communication devices, express potential interest in energy boxes. These devices have the potential for streamlined data integration and enhanced advanced metering infrastructure. Other targeted customers for energy box includes RES producers, Balancing Service Providers (BSP) and industrial customers with flexible loads. Evidently, each of these stakeholders occupies a distinct niche within the energy landscape, with their interest in energy boxes stemming from the advantages these devices bring to their specific operations and objectives.

Introducing energy box solutions to the market comes with opportunities and potential risks. While these solutions hold significant value for the energy sector, such as those mentioned earlier, they are not immune to challenges. One prominent concern is the considerable initial investment required for production and deployment. Companies venturing into energy box manufacturing face financial risks due to upfront costs, production scalability issues, and uncertain returns on investment. This investment burden can translate into higher consumer costs, potentially impacting affordability. Moreover, the market landscape is populated with several companies offering similar services, increasing competition. As a result, some customers might explore alternative solutions available. To navigate these challenges, it's important to streamline energy box design to lower production costs, mitigating risks while ensuring competitiveness.

The economic value of the Energy Box in the market can be evaluated based on the benefits it will provide prospective consumers. The Energy Box's capability to effectively manage and integrate distributed energy resources, such as solar panels, wind turbines, and energy storage systems, can increase energy self-sufficiency or self-reliance. The Energy Box reduces the high dependence on the grid power, potentially lowering operational and procurement costs from the inefficiency caused by the main grid. Enhancing the decentralization of RES enables the operators to reduce the long distance of transmission and distribution, which results in high losses. It minimizes infrastructure investment, such as complex infrastructure and substations, leading to lower capital investments for operators while simplifying operation and maintenance.

The Energy Box also has the unique capability to enhance existing secondary substations and prolong their lifespan, as well as improve other grid infrastructure without requiring complete replacement. Doing so enhances the efficiency of secondary substations and sidesteps the significant expenses typically tied to infrastructure upgrades. Furthermore, the Energy Box's advanced control and distributed computing features play a crucial role in enhancing the stability and reliability of the grid. This helps minimize downtime and interruptions, which can have economic consequences for businesses that depend on a consistent power supply.

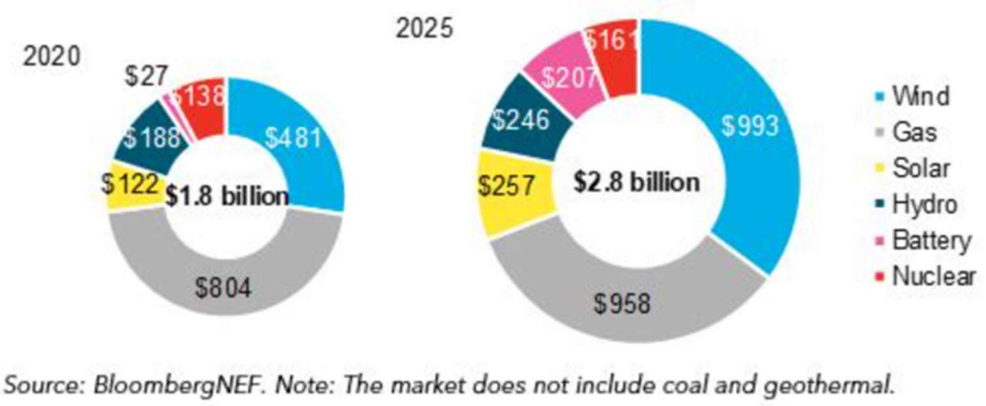
Furthermore, the Energy Box brings substantial market value to customers through its embedded computing and algorithm execution capabilities, which empower the implementation of demand response strategies and peak shaving. This means that customers can actively engage in demand response programs, earning incentives by adapting their energy consumption during high-demand periods and effectively lowering their overall energy expenses. Beyond this, the Energy Box's adept information capture and processing capabilities deliver invaluable insights to customers. These insights enable informed decision-making regarding energy consumption trends, accurate load forecasting, and optimal scheduling for maintenance activities. By optimizing the allocation of resources based on this knowledge, customers can enhance their operational efficiency and minimize costs, ultimately resulting in a significant competitive edge within the market.

Finally, in some cases, customers with the Energy Box might be able to participate in grid services markets. For instance, they could provide grid stabilization services by adjusting energy usage based on grid conditions, earning additional revenue streams. On the other side, as more businesses and consumers prioritize sustainability, the Energy Box's ability to integrate renewable energy sources and reduce carbon emissions can enhance a company's reputation and attract environmentally conscious customers, enhancing sustainability.

3.6 Software module for fault location and self-healing

The FLEXIGRID Project introduces a transformative element to smart grids with its software module, designed to enhance fault location and self-healing capabilities. This innovative solution automatically evaluates grid activities, rapidly identifying, investigating, and appropriately segregating various faults without human intervention. Moreover, it makes intelligent decisions to prevent the escalation of faults and implements self-healing control measures. Deploying this module onto the grid infrastructure ensures continuous and reliable operation and has an attractive Return on Investment (ROI). This robust ROI significantly amplifies market demand and encourages widespread replication of the technology. This heightened demand will drive competition within the market, spurring innovation and encouraging further investment in similar technologies. Therefore, it is expected that this ER software module will receive a favorable market response due to the need for the demand for technologies that enhance grid reliability, minimize downtime, and optimize operational costs, which keep rising (Levent et al., 2022). The global ER software module for fault location and self-healing market value is projected to grow steadily, while the overall market trend suggests a substantial market opportunity as shown in figure 17.

Figure 17. Market size of asset maintenance software by sector in 2020-2025



Europe and China stand out as the largest and most influential markets for grid infrastructure software, showcasing their commitment to advancing the energy sector's digital transformation. Notably, European utilities have pioneered the digitization of the Renewable Energy Sources

(RES) sector. This leadership is evident in their proactive adoption of remote monitoring software applications, which has become a cornerstone in optimizing the performance and reliability of various energy assets.

The market growth for the ER software module, designed for fault location and self-healing solutions, is primarily propelled by the imperative to coordinate and manage diverse renewable energy systems effectively. As the integration of renewable sources continues to increase, the risk of grid instability or even potential blackouts intensifies, particularly during grid fault scenarios or catastrophic events. The prompt clearance of faults becomes essential to mitigate these risks swiftly. Consequently, there is a critical need to implement specialized precautions that prevent extensive outages or cascading blackouts. In response to these challenges, a range of fault detection and self-healing techniques have emerged, many of which are in the developmental stages within the power system landscape, propelling this solution's growth in the market.

ER5 - Software module for fault location and self-healing (Lead partner: CIRCE)

Table 6. ER5 Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	Category	Situation vis-à-vis the FLEXIGRID consortium	Relation with FLEXIGRID partner	Knowledge of FLEXIGRID's concept/given ER	Estimated level of interest in FLEXIGRID's concept/ given ER	Reasons explaining the level of interest	Means to use /Actions to undertake to reach out the given stakeholder	Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.
ENDESA	End-user	External	Concurrence	Quite knowledgeable	Low	No specific interest in the concepts of the project is necessary	Adoption of the solution through CIRCE's servers.	High
IBERDROLA	End-user	External	Concurrence	Quite knowledgeable	Low	No specific interest in the concepts of the project is necessary	Adoption of the solution through CIRCE's servers.	High
NATURGY	End-user	External	Concurrence	Quite knowledgeable	Low	No specific interest in the concepts of the project is necessary	Adoption of the solution through CIRCE's servers.	High
EDP	End-user	External	Concurrence	Quite knowledgeable	Low	No specific interest in the concepts of the project is necessary	Adoption of the solution through CIRCE's servers.	High

ER13 – Fault location TDR prototype (Lead partner: CIRCE)

Table 7. ER13 Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	Category	Situation vis-à-vis the FLEXIGRID consortium	Relation with FLEXIGRID partner	Knowledge of FLEXIGRID's concept/given ER	Estimated level of interest in FLEXIGRID's concept/ given ER	Reasons explaining the level of interest	Means to use /Actions to undertake to reach out the given stakeholder	Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.
EDP (European)	End-user	Internal	Alliance	Perfectly knowledgeable	High	They have identified some areas where the new technology may cover their needs. Interest pending on results	They can be reached through VIESGO. VIESGO is now integrating into EDP.	High
DSOs : E-Distribuzione SpA (Italy), Unareti S.p.A. (Italy), E-REDES (Portugal), UFD Distribución Electricidad, S.A. (Spain), i-DE Redes Eléctricas Inteligentes, S.A.U. (Spain), Energieversorgung Halle Netz GmbH (Germany), Rheinische NETZGesellschaft mbH, Köln (Germany), Enedis (France)	End-user	External	Concurrence	Not knowledgeable at all	Low	No specific interest in the concepts of the project is necessary	Software As a Service. Adoption of the solution through CIRCE's servers.	High
HOPS (national TSO), HEP ODS - distribution areas other than the one participating in the project (national DSO), RES (national)	Utilizer	External	Cooperation	Not knowledgeable at all	High	Implementation of fault location TDR prototype leads to the potential use of relays is decreasing network losses, improving RES hosing capacity, Increasing SAID and SAIFI, etc.	Software As a Service. Adoption of the solution through CIRCE's servers.	High

The ER software module for fault location and self-healing, a central component of the FLEXGRID solution, is strategically designed to cater to diverse customer segments. This software module aims to extend its impact across various EU transmission and distribution networks. It is particularly tailored for potential Distribution System Operators (DSOs) in Spain, encompassing major players like Endesa, Iberdrola, Naturgy, and EDP. Beyond DSOs, the solution has identified additional stakeholders integral to its success. This includes Renewable Energy Source (RES) producers, who benefit from enhanced grid stability, and Commercial and Industrial (C&I) customers seeking reliable energy supply. Furthermore, the software module addresses the needs of Aggregators/ESCOs, improving their capabilities in managing energy resources effectively. More detailed information about potential stakeholders for this solution is available in Deliverable D8.12 Exploitation Strategy.

The market value of a software module for fault location and self-healing in the market can be substantial, both for utilities companies operating medium voltages and their customers. Some of the market value brought by this FLEXIGRID solution includes the reduced grid downtime and improved its reliability. The ability of the ER software module to quickly detect and isolate faults in the distribution grid can significantly reduce grid downtime for then consumers.

Industries and commercial businesses rely on a stable power supply; therefore, any interruption translates to financial losses. The software module value create potential to minimize these disruptions. Reducing the time and resources needed to locate and repair faults is valuable for utility companies. The automation provided by the software module can lead to cost savings and improved operational efficiency for utilities. The software module's ability to precisely pinpoint faults can help utilities allocate repair crews and resources more effectively. This can lead to faster response times and a more targeted approach to addressing issues.

Quick fault isolation and self-healing capabilities can prevent a localized fault from escalating into a larger-scale outage or cascade effect, thereby minimizing the impact on a broader portion of the network. This can save utilities and other customers from the potential costs of widespread outages. Furthermore, the module's ability to adapt to different network sizes and configurations adds value, as it can be deployed in various settings without extensive modifications.

A reliable power supply is crucial for residential customers as well. Minimizing outages and reducing the time it takes to restore power can lead to higher customer satisfaction, a key driver for customer retention. In addition, while there might be an upfront investment in acquiring and integrating the software module, long-term savings from reduced outage-related expenses, maintenance costs, and operational efficiencies can contribute to its overall value.

The software module designed to address fault location and self-healing within data management presents several inherent risks within the market. The core challenge arises from the reliance on third-party assets to manage the critical data necessary for the solution's implementation. This dependence introduces data security, privacy, and overall system integrity vulnerabilities. Since the data managed by these third-party assets pertains to the operational infrastructure of Distribution System Operators (DSOs), any breach or unauthorized access could compromise sensitive information, potentially leading to regulatory penalties and privacy violations.

Moreover, the involvement of sector authorities in controlling the data adds a layer of regulatory compliance risk. If the software module and data management process do not align with sector regulations and standards, DSOs could face legal consequences and operational disruptions. Inherent in this structure is also the challenge of maintaining data accuracy and integrity. Inaccurate or manipulated data could lead to erroneous fault predictions and incorrect self-healing actions, undermining the solution's reliability.

3.7 Software module for forecasting and grid operation

The ER software module for forecasting and grid operation is a FLEXIGRID solution, which is critical for both market operators and traders because it enables them to get a general idea of expected electricity demand, electricity price variations, how much energy supply will be available to power the grid during a given timeframe. In a scenario of renewable energy sources such as solar and wind energy, with this algorithm solution, grid operators can rely on deterministic and probabilistic forecasting to predict the power they can supply a few hours or days in advance and suggest grid operation to ensure supply curve and demand curve balance. The market demand for this novel solution has been significantly increasing due to its numerous benefits to customers. The forecasting algorithms may have a better sense of realistic growth trajectories in the European power market and other sections of the world, including the USA, and it is expected to keep rising as new technologies are adopted on the grid.

The growing use of the FLEXIGRID solution for predicting energy demand and managing the power grid is influenced by various factors. These include technological advancements, the market's behaviour, the practical requirements of running the grid, and changes in the policy that guide the European power market. With renewable energy sources like solar and wind becoming more common in the grid's energy mix, which can be inconsistent, grid operators have to make accurate predictions ahead of time. This helps them handle the changing nature of these energy sources within the grid setup, ensuring the grid remains stable and dependable. Moreover, the European Commission and several member states enforce rules and goals about adding renewable energy to the European grid. They're doing this to decrease the release of greenhouse gases. Therefore, accurately predicting the amount of renewable energy integrated into the grid is important. It will help to plan, determine, and achieve these rules and goals.

Thanks to advancements in technology like data analytics, machine learning, and AI, it's now doable to create better and more advanced forecasting models. As a result, many grid partners are using these technologies to improve their forecasting. Additionally, the advanced software solutions tech companies enable the power companies and grid operators to use these tools to improve their forecasting abilities. Furthermore, the energy markets are moving toward more dynamic pricing models and demand response programs. These initiatives encourage consumers to adjust their energy usage based on price fluctuations. Grid forecasting software can analyse historical consumption patterns and real-time data to predict demand peaks and troughs. It enables utilities to optimize supply strategies and avoid shortages or excess capacity.

ER6 - Software module for forecasting and grid operation (Lead partners: MOH (formerly VERD))

Table 8. ER6 Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	**Category**	**Situation vis-à-vis the FLEXIGRID consortium**	**Relation with FLEXIGRID partner**	**Knowledge of FLEXIGRID's concept/given ER**	**Estimated level of interest in FLEXIGRID's concept/ given ER**	**Reasons explaining the level of interest**	**Means to use /Actions to undertake to reach out the given stakeholder**	**Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.**
Aggregators	End-user	External	Cooperation	Not knowledgeable at all	High	The algorithm will provide better results in terms of demand forecasting which is helpful in terms of better planning and operation of power systems	Workshop, seminars, presentations at conferences, etc.	High

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	Category	Situation vis-à-vis the FLEXIGRID consortium	Relation with FLEXIGRID partner	Knowledge of FLEXIGRID's concept/given ER	Estimated level of interest in FLEXIGRID's concept/ given ER	Reasons explaining the level of interest	Means to use /Actions to undertake to reach out the given stakeholder	Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.
RE Producers	End-user	External	Cooperation	Not knowledgeable at all	High	The algorithm will provide better results in terms demand forecasting which is helpful in terms of better planning and operation of power systems.	Workshop, seminars, presentations at conferences, etc.	High

This FLEXIGRID ER software module, designed for advanced forecasting and grid operations, holds immense potential across diverse segments of the EU energy market. Among the potential customers highlighted in the comprehensive analysis presented in Deliverable D8.12 Exploitation Strategy, key beneficiaries encompass energy producers, grid operators, and end users. Notably, this innovative solution resonates particularly with energy aggregators, ESCOs, renewable energy source (RES) producers, and commercial and industrial (C&I) end users stand out as major beneficiaries of this innovative solution stemming from the FLEXIGRID project. This ER innovative solution within the FLEXIGRID Project will revolutionize the EU energy market by addressing these diverse customer groups' unique needs.

The economic value proposition of this ER- software module for forecasting and grid operation is impactful to the target identified customers. Firstly, the accurate forecasting algorithms aspect enables utility customers to make well-informed decisions regarding the market's energy generation, demand, and electricity price. Such predictive capabilities with this ER of the FLEXIGRID solution enable effective resource allocation, optimized planning, and cost savings.

Moreover, integrating registered measurements from sensors and IEDs ensures data-driven precision, enhancing the reliability of the software module forecasts results. Such advanced and accurate information helps the grid operators and engaged users reduce operational uncertainties, reducing the risks associated with energy management and procurement. Thus, this solution empowers customers to navigate the complex energy landscape with greater confidence, efficiency, and financial prudence. In addition, the optimization algorithm further magnifies the economic benefits. Capitalizing on the forecasting results suggests grid operation strategies that align with demand patterns and maximize the utilization of renewable energy sources. Subsequently, its effects reduce reliance on non-renewable energy sources, potential incentives to end users related to sustainable energy practices, and enhanced grid efficiency.

Lastly, the ER software module's focus on maintaining the security of supply and grid stability reinforces its economic value. Customers can confidently explore renewable energy integration without compromising the reliability of their energy systems, thereby mitigating potential revenue losses due to disruptions.

While this ER software module holds significant potential for enhancing energy forecasting and grid operations, it is also contained a major market value risk includes data privacy and cybersecurity issues. This ER software module relies on data collected from sensors and IEDs, making it vulnerable to cybersecurity threats and data breaches. Ensuring robust cybersecurity measures and complying with data privacy regulations are critical to maintaining customer trust and safeguarding sensitive information.

3.8 Software module for congestion management

This ER software module designed for congestion management and market outlook holds substantial growth and market value potential. The module addresses critical challenges in energy management by providing real-time insights into congestion within the grid and offering comprehensive market flexibility, and it is expected to grow. Moreover, with the energy market's increasing volatility and the integration of renewable sources, the demand for reliable market insights is anticipated to increase. The market value of this software module lies in its ability to optimize energy operations, enhance revenue opportunities, and mitigate risks through addressing congestion issues and offering market insights contributes to improved energy management, reduced costs, and increased efficiency. The software module's growth trajectory closely aligns with the evolving energy landscape and is expected to elevate, underpinning the module's increasing market value.

It is undeniable that congestion is an increasing problem of the power systems nowadays. Therefore, the ER software module for congestion management is a FLEXIGRID solution developed to tackle this growing issue. Nowadays, the increase in distribution network congestion is mainly caused by the change in generation and consumption. In the production sector, the decentralisation of electricity generation and moving towards the variable renewable energy sources has push a notable congestion on the network. In the consumption sector, there have been significantly increase in electricity load connected to the existing grid due to factors such as electrification, increase in urban areas population (urbanisation) in among others. In addition, the EVs high market penetration especially in the EU is another cause of higher stress on the distribution network in the consumer segment even for years to come.

According to the (IEA, 2020) “electric vehicles outlook anticipates an increasing growth over the next decade. According to the stated policy scenario incorporating the existing governmental policies, EVs will reach 145 million in 2030 compared to 7.2 million in 2019. This level of electrisation will lead to 550TWh electricity demand in 2030 (about a six-fold rise from the 2019 level). In Europe, EV demand will account for 4% of electricity consumption (i.e., national/regional) in 2030.”

Besides, the production and consumption factors, new business models recently introduced in the energy market do not consider the boundaries of distribution network operation. Nowadays, consumers often enabled by the aggregators are encouraged to play an active role as prosumers and delivers their services at market of choice. Even though, this business model benefits the services providers, in various circumstance they put the distribution network under stress causing congestion disrupting the smooth operation of the grid. (Attar, Repo and Mann, 2022).

ER7 – Software module for congestion management (Lead Partner: MOH (formerly VERD)

Table 9. ER7 Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	Category	Situation vis-à-vis the FLEXIGRID consortium	Relation with FLEXIGRID partner	Knowledge of FLEXIGRID's concept/given ER	Estimated level of interest in FLEXIGRID's concept/ given ER	Reasons explaining the level of interest	Means to use /Actions to undertake to reach out the given stakeholder	Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.
hotel owners association of Kavala and Thasos and to the Association of Greek Tourism Enterprises (SETE)	End-user	External	No relation	Quite knowledgeable	Low	Feedback from the event	Dissemination event with quantified results of the trials	Very Low

ER12 - Software module for flexibility assets emergency operation (Lead partner: CIRCE)

Table 10. ER12 Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	Category	Situation vis-à-vis the FLEXIGRID consortium	Relation with FLEXIGRID partner	Knowledge of FLEXIGRID's concept/given ER	Estimated level of interest in FLEXIGRID's concept/ given ER	Reasons explaining the level of interest	Means to use /Actions to undertake to reach out the given stakeholder	Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.
ENDESA	End-user	External	Concurrence	Not knowledgeable at all	Low	Possibility to manage the distribution grid in emergency with new methodology	Workshop, seminary, sector magazines	High
IBERDROLA	End-user	External	Concurrence	Not knowledgeable at all	Low	Possibility to manage the distribution grid in emergency with new methodology	Workshop, seminary, sector magazines	High
NATURGY	End-user	External	Concurrence	Not knowledgeable at all	Low	Possibility to manage the distribution grid in emergency with new methodology	Workshop, seminary, sector magazines	High
EDP	End-user	External	Concurrence	Not knowledgeable at all	Low	Possibility to manage the distribution grid in emergency with new methodology	Workshop, seminary, sector magazines	High

Using FLEXIGRID solutions for congestion management presents a substantial value proposition within the energy sector. The FLEXIGRID partners have adeptly identified pivotal customer segments poised to derive optimal benefits from its integration. Of noteworthy mention, Distribution System Operators (DSOs) are strategically positioned to harness the benefits as they gain instantaneous insights into grid dynamics, facilitating swift and corrective actions. Simultaneously, Renewable Energy Source (RES) producers are positioned to unlock rewards, leveraging the solution to make well-informed information regarding the supply or demand of power into the grid. Furthermore, Commercial and Industrial (C&I) customers were identified within the locality where the solution was deployed; for instance, entities the Kavala and Thasos Hotel Owners Association and the Association of Greek Tourism Enterprises (SETE) will benefit from the solution to enable energy management efficiencies and embrace various innovative market flexibility approaches enabled by this ER solution.

This ER software module offers market value to the target customers in the EU energy market. The software algorithms contribute towards grid stability by reducing the risk associated with grid congestion and blackouts, thus reducing the energy demand during peak hours. Moreover, the ER will enhance energy supply and demand efficiency by allowing consumers to make the most of their energy resources, thus optimizing performance while minimizing wastage.

Furthermore, the solution enables grid flexibility and adaptability by helping the customers adapt energy use according to the market signals and tariff changes. Subsequently, the customers can avoid high costs and benefit from lower energy prices. Also, the ER plays an essential role in demand aggregation and smarter energy purchasing during off-peak hours, translating to effective management of peak energy consumption. Thus, customers can reduce their energy bills.

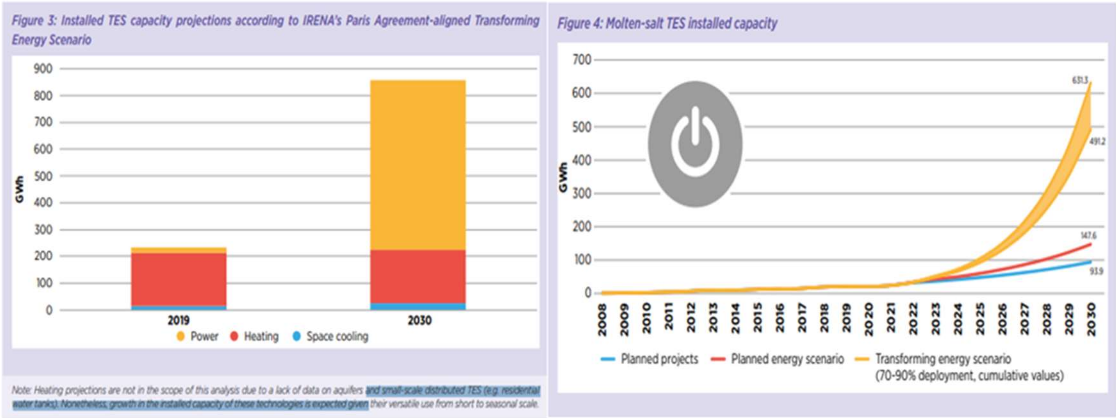
The ER provides an avenue for advanced energy planning within the market by furnishing valuable insights and data through its integrated module. This information significantly enhances the quality of long-term energy planning and strategic decision-making processes. Consequently, the solution plays a pivotal role in boosting business competitiveness by facilitating the proficient management of energy resources and associated costs. Additionally, in regions where energy-related regulations or incentives come into play, the software module is invaluable. It assists customers in aligning with regulatory compliance measures, ensuring adherence to prescribed standards in energy supply and demand dynamics.

An essential market risk for the software module is its reliance on external data sources like market prices and demand forecasts. In the event of disruptions or inaccuracies in these sources, the module's ability to provide accurate and reliable recommendations could be compromised. This dependency on external data introduces a vulnerability that could impact the overall effectiveness of the congestion management solution.

3.9 Virtual thermal energy storage model

The ER-virtual thermal energy storage model solution has emerged recently as a key source of flexibility for the power, buildings, and transport sectors. The special characteristics of smart virtual thermal energy storage, such as a combination of optimally Thermal Energy Storage and Power to Heat technologies and flexibility in a cost-efficient manner, position this innovative FLEXIGRID solution as an attractive solution for energy markets. According to the IRENA, over 234 GWh of thermal energy storage capacity was installed globally by the end of 2019. Moreover, the Paris Agreement aligned transforming the energy scenario with an expected capacity to have increased threefold, reaching at least 800GWh by 2030, as shown in Figure 10 (IRENA, 2020). Additionally, the investment in thermal energy storage applications for power and cooling is expected to reach USD 13-28 billion by 2030 (IRENA, 2020). In Europe it has been estimated that around 1.4 million GWh/year can be saved and 400 million tons of carbon emissions avoided in industrial and building sector by more extensive use of thermal heat and cold storage (Sarbu and Sebarchievici, 2018).

Figure 18. Installed Thermal Energy Storage Market Outlook



Source: IRENA, 2020

There are several key triggers that have contributed to the increasing popularity and expansion of the virtual thermal energy storage solution in the market. One of the main growth cause is the recent global shift from fossil fuels to renewable energy sources such as solar and wind power with objective to lower carbon emissions. Thus, thermal energy storage devices are incorporated to these renewable energy systems to store the excess power generated during the peak production periods which is released when the power generation is low or when the demand is high. This enables a more steadier and constant energy supply, addressing the intermittent character of some renewable energy sources while also boosting their overall efficiency and efficacy. In addition, the growing global population and increased industrial activity lead to higher energy needs. Dealing with the challenge of balancing energy supply and demand creates a big chance in the market for thermal heat storage. This technology can help by storing extra heat when demand is low and releasing it when demand is high. This reduces energy expenses and ensures a dependable and consistent energy supply. Furthermore, the rise in customers' requirements for enhanced energy market flexibility and the integration of energy systems within a unified space has led to an expansion in the market for virtual thermal energy storage models. These models are gaining traction as they optimize demand flexibility, aligning with the evolving energy landscape.

ER8 – Virtual Thermal Energy Storage (VTES) demand response module (Lead Partner: HYPER)

Table 11. ER8 Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	**Category**	**Situation vis-à-vis the FLEXIGRID consortium**	**Relation with FLEXIGRID partner**	**Knowledge of FLEXIGRID's concept/given ER**	**Estimated level of interest in FLEXIGRID's concept/ given ER**	**Reasons explaining the level of interest**	**Means to use /Actions to undertake to reach out the given stakeholder**	**Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.**
DSO (national, European): indicatively: ORES, Fluvius, Enedis, E-REDES, I-DE, Viesgo, Netz Niederösterreich and Energienetze Steiermark	End-user	External	No relation	Not knowledgeable at all	High	ER8 provides flexibility that leads to peak load reduction and congestion management	Contact will be sought during the dissemination events of the project	High

The virtual thermal energy storage model solution offers various benefits to various potential customers, including Aggregators, Retailers, Energy Communities, and Distribution System Operators (DSOs) at national and European levels. Aggregators play a crucial role in optimizing energy resources and demand-response activities. By utilizing the virtual thermal energy storage model solution, aggregators can effectively manage and optimize their portfolio's thermal energy storage systems. Retail energy providers can leverage the virtual thermal energy storage model solution to enhance their services and offerings. Moreover, energy communities consist of individuals, businesses, or organizations collaborating to manage and share energy resources among members. Furthermore, through collaborating with the DSOs within national and European levels like ORES, Fluvius, Enedis, E-REDES, I-DE, Viesgo, Netz Niederösterreich, and Energienetze Steiermark, the solution can serve to many energy distribution networks.

The innovative software that incorporates the existing water heaters and building spaces for thermal energy storage, coupled with Power to Heat technologies, offers a range of economic values to customers in the market. From this ER innovative software, potential stakeholders (customers) will derive various significant economic benefits from adopting the solution. The ER solution ensures that the thermal energy storage and power-to-heat technologies are utilized effectively. This ensures that energy efficiency is improved to reduce energy usage, especially from renewable energy sources. Subsequently, this software optimization algorithm will lower operational costs and reduce carbon emissions.

Moreover, large energy consumers and retailers can benefit from the software's ability to optimize energy procurement strategies. This innovative solution enables the storage of excess energy during the off-peak period, which can be used during peak hours. Thus, customers can strategically manage energy purchases and hedge against Price volatility while making an informed decision in the energy market. Further, this software's predictive capabilities make it easier for customers to participate in demand response programs. The customer can use market signals to earn incentives from aggregators and grid operators, an additional revenue stream.

This ER software offers flexible energy dispatch, thus contributing to grid reliability and stability. Such contribution is valuable to target customers such as energy communities and DSOs. This ER solution will help them mitigate grid congestion by optimizing energy demand parameters, reducing the need for costly infrastructure upgrades. Moreover, the solution will extend the lifetime of the existing infrastructure, such as water heaters, by reducing stress on the equipment and optimizing the operation, hence fewer maintenance and replacement costs.

The virtual thermal energy storage model will face several hurdles that could limit its widespread acceptance and growth. The high initial costs associated with integrating the virtual thermal energy storage systems with the network are a major impediment. While these technologies offer long-term cost savings and energy efficiency benefits, the initial investment may deter some potential customers, limited financial resources available for demand response, smart home, and BMS solutions offers due to the lack of flexibility in the market, especially in some of the EU countries. Other risks include lack of sufficient awareness, comprehension, and the illiteracy of thermal energy storage technology among various customer campaigns due to intrusive demand response solutions currently available. Lastly, concerns regarding data security and privacy cast shadows of doubt in the minds of potential customers.

3.10 FUSE Platform

The ER-FUSE is an open-source digital platform developed within FLEXIGRID solution to coordinate and integrate devices to facilitate exploring and sharing energy-related data with energy stakeholders. A comprehensive study conducted by Duch-Brown and Rossetti, 2020 revealed that the European Union's regional market constitutes a substantial 20% share of global energy digital platforms. By observing the characteristics of open-source digital platforms such as FUSE and those in the European energy markets, it appears that the digital platforms in the European energy sector still tend to be relatively small and concentrated in specific regions, often in the capital cities. Yet, recently, the penetration of digital platforms within the energy sector in the EU has significantly gained traction.

Several key indicators within the market emphasize the significance of certain factors in the adoption and success of this solution. These factors encompass the market adoption rate, digital readiness, regulatory quality, and the quality and diversity of data shared among the energy in the EU regional market; these indicators will collectively shape the platform's presence and impact. Other factors that trigger the adoption of these platforms include the rate at which digital technologies have lowered the costs of collecting, sharing, and using information, transaction costs, and reduced search in the energy market. Therefore, the technological advancement and cost to participate in some of these energy markets have become so little to allow exchanges in collaborative economy platforms and peer-to-peer interactions to emerge (Duch-Brown and Rossetti, 2020).

ER9 - FUSE platform (Lead partner: ATOS)

Table 12. ER9 Potential customers identification and analysis

Most relevant stakeholder *(please indicate its level of intervention – local/national/European)*	Category	Situation vis-à-vis the FLEXIGRID consortium	Relation with FLEXIGRID partner	Knowledge of FLEXIGRID's concept/given ER	Estimated level of interest in FLEXIGRID's concept/ given ER	Reasons explaining the level of interest	Means to use /Actions to undertake to reach out the given stakeholder	Estimated level of influence/power over the adoption and replication of FLEXIGRID solutions.
DSOs	End-user	External	No relation	Quite knowledgeable	Low	Understanding this ER is convenient to improve energy efficiency	Licensing, selling.	Low
the Association of Greek Tourism Enterprises (SETE)	End-user	External	No relation	Quite knowledgeable	Low	Understanding this ER is convenient to improve energy efficiency	Licensing, selling.	Very Low

The FUSE platform has identified the most pertinent stakeholders in the context of the European energy market, primarily focusing on Distribution System Operators (DSOs) and Energy communities. These entities stand out due to their pivotal roles in the energy ecosystem, warranting their integral involvement. Moreover, the FLEXIGRID solution, as comprehensively elaborated in deliverable D8.12, has notably classified commercial end users like the Association of Greek Tourism Enterprises (SETE) as prospective customer among others end users.

The FUSE platform offers substantial economic value to customers in the market, particularly Distribution System Operators (DSOs) and energy stakeholders. FUSE integrating of Edge devices enables real-time data communication between the utilities and locally distributed energy resources. It is, therefore, energy stakeholders to get important information about energy production, distribution, and demand, which enables them to make more informed decisions. Moreover, the platform allows the creation of value-added services in the energy market by fully exploiting the data available from various energy resources. As a result, the utilities can develop innovative solutions that help optimize grid management and enable demand response initiative and energy efficiency.

Adapters in FUSE streamline the data integration process, ensuring data is easily accessible and usable. This simplification leads to efficient data management, reducing the complexities of integrating and managing diverse data sources. Moreover, FUSE optimizes service processes by harmonizing data and streamlining operations. This leads to improved operational efficiency for DSOs, enabling them to respond more effectively to changing energy demands and market dynamics. Further, FUSE's design supports integrating a wide range of devices and data sources. This flexibility allows DSOs to adapt to evolving energy landscapes and expand their services.

Lastly, FUSE's standardized data integration and management approach can aid in meeting regulatory requirements and reporting standards in the energy sector.

The value for the FUSE platform's market prospects within the EU is promising, provided it successfully addresses crucial challenges. These risks are related to interoperability and standardization among energy and information systems associated with data privacy and security across different member states.

4. GENERAL RECOMMENDATIONS AND CONCLUSIONS

To conclude, in its first part, this document analysed the current status and future of two different European markets. Firstly, the smart grid market is healthy and will continue to develop and expand in the European Union. As electricity network are transformed, investment in their infrastructure is to be expected. Production and consumption are rising steadily encourage regional employment to walk the path of independence on an energetic level. However, some constraints related to the added stress brought to the grid, public opposition, material crisis and dependence, and finally the path dependency set previously.

The renewable electricity market is found just as healthy. The EU set institutional targets and is investing massively in the market. Production and consumption are also rising and driving employment level in every step of the supply chain. Constraints are also identified for the renewable electricity market. The material crisis and dependence should also be mentioned, in addition, the potential network congestion, the rising costs and the endangered revenues due to electricity prices are listed as risks in renewable electricity deployment.

Then, the updated stakeholder analysis was presented and potential customers were identified for most of FLEXIGRID exploitable results. This identification made thanks to FLEXIGRID partners, and the subsequent analysis helped shape out the replication strategy and the entrance of FLEXIGRID solutions into the European market. Indeed, the goal of this document is to frame FLEXIGRID's solutions and ERs entry into the European market with recommendations. Then, these analyses were used in the following Solution analysis.

Indeed, the section dedicated to FLEXIGRID solutions identified and studied current and future market specificities for each solution, the value of the solution in the market, the risks in the market value, and specific plans for the potential customers targeted by these solutions identified in the previous section.

This FLEXIGRID solution's the secondary substation of the future advanced features and capabilities create market value by improving efficiency, safety, adaptability, and overall grid performance. It addresses current challenges while establishing a foundation for future energy requirements and innovations in the market. However, this solution is highly vulnerable to critical material shortages, geopolitical issues, and logistic delays, causing project delays and high costs.

The ER new generation smart metering with feeder mapping capabilities consumer-centric approach has significantly considered the increasingly informed and digitally-oriented consumer base by providing real-time information about electricity consumption and costs, supporting data-driven decision-making, and allowing energy users to participate in responsive and load management initiatives. Nonetheless, there are possible market value risks that could negatively affect customer privacy and safety.

The value of solutions focused on providing protections for high Renewable Energy Sources (RES) penetration to customers is substantial, as these solutions address critical concerns and challenges associated with integrating renewable energy into existing energy systems, including ensuring a reliable energy supply, Energy Cost Savings, open to financial incentives and Future-Proofing Investments despite its risks of high cost of investment.

The market value of the Energy Box can be evaluated based on the benefits it provides to its potential customers, which translate into the capability to effectively manage and integrate

DERs, enable demand response strategies, contribute to grid stability and resilience, and extend the lifespan of grid infrastructure without the need for full replacement. However, the affordability of the high initial investment required for production and deployment is a significant concern to potential customers.

The value of an ER-software module for fault location and self-healing in the market can be substantial, both for utility companies operating medium voltage (MV) networks and their customers, including improved Reliability and Reduced Downtime, enhanced operational Efficiency for Utilities, Optimized Resource Allocation: Prevention of Cascading Failures and improve Scalability and Adaptability. However, the FLEXIGRID solution may face regulatory compliance risks.

The economic value proposition of the ER software module for forecasting and grid operation presented by the FLEXIGRID project is poised to make a transformative impact on its targeted customers. The module's accurate forecasting algorithms empowers utility customers to make well-informed decisions, fostering optimized planning, effective resource allocation, and tangible cost savings. However, amidst these promising benefits, it is essential to acknowledge and mitigate the significant market value risk associated with data privacy and cybersecurity.

The software module for congestion management is designed to identify and handle congestion issues in a way that benefits customers in the energy sector. It does this by providing energy efficiency, grid stability, and adaptability, improving operational and cost outcomes for the identified customers. Despite heavily relying on external data sources, there needs to be a need to ensure that disruptions or inaccuracies in these external sources maintain the solution's accuracy and reliability.

Some key market value customers can get from adopting ER virtual thermal energy storage innovative software solutions include optimizing energy consumption, reducing costs, enhancing demand response, and improving grid integration while enhancing occupant comfort and its attractive proposition for a wide range of customers across different market segments. However, the initial investment may deter some potential customers despite its offer of long-term cost savings and energy efficiency benefits.

Finally, the FUSE platform addresses key challenges and provides practical solutions, and its value in the market lies in its capacity to enable efficient data integration, data-driven services, operational optimization, collaboration, and innovation; however, there is a need to navigate the potential risk related to interoperability, standardization, data privacy, and cyber security.

5. REFERENCES

Web pages

EC – European Commission, 2023a. https://energy.ec.europa.eu/topics/markets-and-consumers/smart-grids-and-meters_en

EC – European Commission, 2023c. REPowerEU at a glance. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

EEA – European Environment Agency, 2022b. Use of renewable energy for transport in Europe. https://www.eea.europa.eu/ims/use-of-renewable-energy-for

EEA – European Environment Agency, 2023. Share of energy consumption from renewable sources in Europe. https://www.eea.europa.eu/ims/share-of-energy-consumption-from

IEA – International Energy Agency, 2023b. https://www.iea.org/topics/critical-minerals

IEA (2022), Renewables 2022, IEA, Paris https://www.iea.org/reports/renewables-2022, License: CC BY 4.0

IEA – International Energy Agency, 2023c. How much money are European consumers saving thanks to renewables? https://www.iea.org/reports/renewable-energy-market-update-june-2023/how-much-money-are-european-consumers-saving-thanks-to-renewables

European Environment Agency (2022). Share of energy consumption from renewable sources in Europe. [online] www.eea.europa.eu. Available at: https://www.eea.europa.eu/ims/share-of-energy-consumption-from

Associations (with / without acronyms)

CEDEC – European Federation of Local and Regional Energy Companies, 2014. Smart Grids for Smart Markets.

EC – European Commission, 2019. Benchmarking smart metering deployment in the EU-28. Directorate-General for Energy.

EC – European Commission, 2022a. Zero emission vehicles: first 'Fit for 55' deal will end the sale of new CO2 emitting cars in Europe by 2035. Press release.

EC – European Commission, 2022b. In focus: Employment in EU's renewable energy sector. News Article.

EC – European Commission, 2023b. Pact for Skills: Launch of large-scale renewable energy skills partnership. News.

E.DSO – European Distribution System Operators, 2023. White Paper: A Multi-Scale Approach For A Digitalised Energy System Transformation.

EEA – European Environment Agency, 2022a. Trends and projections in Europe 2022. Report.

ENTSO-E – European Network of Transmission System Operators for Electricity, 2020. Annual Report.

IEA – International Energy Agency, 2022a. Smart Grids.

IEA – International Energy Agency, 2022b. World Energy Outlook.

IEA – International Energy Agency, 2023a. Electricity Market Report 2023.

IEA – International Energy Agency, 2023d. Renewable Energy Market Update - Outlook for 2022 and 2023.

IEA – International Energy Agency, 2023e. World Energy Investment 2023.

IRENA – International Renewable Energy Agency, 2018. Renewable Energy Prospects for the European Union.

IRENA – International Renewable Energy Agency, 2022. Renewable Energy and Jobs. Annual Review 2022.

ISGAN – International Smart Grid Action Network, 2020. ISGAN Annex 6: Power Transmission & Distribution Systems.

ISGAN – International Smart Grid Action Network, 2021. Smart Grid Drivers and Technologies by Country, Economies, and Continent. Analytical Report.

JRC – European Commission, Joint Research Centre, 2016. Assessment of potential bottlenecks along the materials supply chain for the future deployment of low-carbon energy and transport technologies in the EU. Wind power, photovoltaic and electric vehicles technologies, time frame: 2015-2030.

JRC – European Commission, Joint Research Centre, 2017. Smart Grid Projects Outlook 2017 - Facts, Figures and Trends in Europe. JRC Science for Policy Report.

JRC – European Commission, Joint Research Centre, 2022. Clean Energy Technology Observatory: Smart Grids in the European Union. Status Report on Technology Development, Trends, Value Chains and Market.

MarketsandMarkets, 2019. Digital Substation Market Revenue Trends and Growth Drivers.

SolarPower Europe, 2022. EU Market Outlook for Solar Power 2022-2026.

TSG – Think Smartgrids, EY Parthenon, 2022. Le marché français des smart grids en 2030.

Verified Market Research, 2023. Substation Automation Market Size, Analysis, Trends & Forecast.

WindEurope, 2023. Wind energy in Europe – 2022 Statistics and the outlook for 2023-2027.

Scientific papers

Attar M., Repo S. and Mann P., 2022. Congestion management market design- Approach for the Nordics and Central Europe. Applied Energy. Vol. 313.

Barreto R., Faria P. & Vale Z., 2022. Electric Mobility: An Overview of the Main Aspects Related to the Smart Grid. Electronics. Vol. 11. 1-19.

David M., & Koch F., 2019. “Smart Is Not Smart Enough!” Anticipating Critical Raw Material Use in Smart City Concepts: The Example of Smart Grids. Sustainability. Vol. 11. 1-11

Duch-Brown N. and Rossetti F., 2020. Digital platforms across the European regional energy markets. Energy Policy. Vol. 144.

Konrad D., Stifter M. and Zehetbauer P., 2015. Network and feeder assignment of smart meters based on communication and measurement data.

Norouzi F., Hoppe T., Ramirez Elizondo L., & Bauer P., 2022. A review of socio-technical barriers to Smart Microgrid development. Renewable and Sustainable Energy Reviews. Vol. 167. 1-14.

Sarbu I. and Sebarchievici C., 2018. A Comprehensive Review of Thermal Energy Storage. Sustainability, Vol. 10, Issue 2.

Yavuz L., Soran A., Önen A., et al., 2022. Adaptive Fault Detection Scheme Using an Optimized Self-healing Ensemble Machine Learning Algorithm. CSEE Journal of Power and Energy Systems, Vol. 8, Issue 4.