D2.2: Research Outcome Mapping Report

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Abstract	This deliverable identifies validated research outcomes from projects involving SynGRID partners and maps them to the Smart Specialisation Strategies of Slovenia, Croatia, and Greece. It supports the strategic alignment of technical results with regional innovation priorities.
Keywords	LV grid, research outcomes, smart specialisation, flexibility, SynGRID

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Executive Summary

This deliverable **maps validated research outcomes** from EU-funded and national projects **to the SynGRID technology domains** and assesses their alig**nment with national Smart Specialisation Strategies (S3)** in Slovenia, Croatia, and Greece. The research outcomes were sourced from projects where SynGRID partners have played a central role in development or deployment.

The identified technologies differ in their level of maturity. Some represent early-stage solutions validated through simulations and lab-scale setups, while others have been demonstrated in real-world conditions through pilot installations. **Following the technology identification phase in Task 2.1**, these outcomes were categorised based on their relevance to SynGRID's core domains.

Each v**alidated outcome was analysed in terms of its potential for exploitation, replication, and future development**. The final step involved assessing how well these outcomes **align with the innovation priorities defined in the S3 strategies** of the participating Widening countries. This mapping highlights where existing technical solutions can contribute to regional innovation ecosystems and where SynGRID partners can provide additional value in future activities.

The results of this deliverable will inform SynGRID's capacity-building and valorisation activities and guide the **preparation of future project proposals under WP3**.

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1 Introduction

1.1 Purpose of the document

The purpose of this deliverable is to **analyse and map validated research outcomes from EU funded and national projects** in which SynGRID partners have been actively involved. The focus is on outcomes relevant to the **management, observability, and controllability of low-voltage (LV) grids**. These outcomes are considered in relation to the **SynGRID project's objectives** and are assessed for their alignment with the **Smart Specialisation Strategies** (S3) of the involved Widening countries: Slovenia, Croatia, and Greece.

This document is primarily linked to WP2, and more specifically to Task 2.2, which focuses on identifying and evaluating validated results from previous projects and aligning them with national innovation strategies. It builds directly on the technology domains identified in Deliverable D2.1 and complements Task 2.1's analysis of regulatory and technological gaps.

1.2 Scope of the document

The document covers three main areas. First, it presents a **selection of EU and national projects involving SynGRID partners**, focusing on **validated research outcomes** relevant to SynGRID's technological scope. Second, it analyses the **national S3 frameworks in Slovenia, Croatia, and Greece**, examining how SynGRID's themes intersect with regional innovation priorities. Finally, it provides a **mapping of validated outcomes to S3 goals**, identifying areas of strong alignment and potential for future exploitation and scaling.

1.3 Structure of the document

The contents of the document are divided into the following chapters:

- **Chapter 2** explains the methodology applied for identifying validated research outcomes and their alignment with SynGRID's technological domains, as well as the connection with D2.1.
- **Chapter 3** presents the selection of projects where SynGRID partners have participated. It outlines the validated research outcomes relevant to LV grid management and assesses their technological maturity, validation context, and exploitation potential.
- **Chapter 4** provides an overview of S3 and focuses on Slovenia, Croatia, and Greece. It includes a mapping of research outcomes to national S3 priorities and identifies areas of alignment.
- **Chapter 5** is dedicated for the conclusions.

2 Methodology and Context

The methodology employed in this deliverable consists of two main parts. Firstly, **validated research outcomes** were **identified and analysed** and secondly, these outcomes were mapped against regional S3s [1] to evaluate their alignment with specific country's innovation priorities. The goal is to identify relevant solutions aligned with D2.1 and with a strong potential for further development, exploitation and capacity-building activities.

2.1 Methodology

The initial step of the methodology involves identifying and analysing the projects that included validated research outcomes from previous national and international funding programmes and frameworks. These projects were specifically selected based on their validated research outcomes and relevance to the technologies identified and described in the SynGRID task T2.1. The selection criteria detailed below:

- **Consortium involvement:** Outcomes were selected only from projects with participation from SynGRID partners, ensuring in-depth project insights.
- **Technology Readiness Level (TRL):** Only the outcomes with at least a TRL 6 were considered, indicating validation through either realistic simulation environments or pilot demonstrations and field trials.
- **Relevance to LV grid management:** Projects needed to be aligned with the SynGRID topics and directly address challenges in management, observability or controllability of LV grids.
- **Documented validation:** Each outcome selected required evidence from structured testing or pilot projects involving relevant stakeholders.

The analysis of each identified project focused on its validated research outputs including the developed technical tools, methodologies and models, as well as frameworks and market designs. The key aspects considered in the analysis included the following aspects, necessary to understand each project's contribution towards SynGRID's domains and potential for further exploitation:

- **Project description:** Brief overview of the project's objectives, scope, current implementation stage, and key stakeholders involved.
- **Solutions developed:** Presentation of relevant validated outcomes (tools, methodologies, software, or hardware solutions) originating from the project, clearly linking them to specific technologies described in D2.1.
- **TRL and validation means:** Assessment of the current technological maturity and specific validation approaches and environments used.
- **Exploitation potential:** Evaluation of the outcomes' potential for broader market implementation, scalability, and adoption by relevant industry stakeholders or future development.

Following the identification phase, **analysis of S3**s at **EU and national levels** clearly defines the regional priorities. It adds context and enables the **mapping of validated research**

outcomes to specific regional innovation needs, which in-turn provides an overview of the **effectiveness of these outcomes in supporting regional innovation** priorities and to identify opportunities for further integration and exploitation within regional and national development frameworks.

2.2 Connection to T2.1

The process of identifying relevant projects connected ran **in parallel with the *Task 2.1:*** *Technology environment analysis and regulatory gap analysis* where the technology identification took place. T2.1 identified the following three domains as **key aspects of SynGRID** and its core topic, the **LV grid management**:

- In the **Energy System Observability & Monitoring** emphasizes the tools and platforms that improve access to data, real-time monitoring and predictive analytics as a prerequisite that enables DSOs to take control of its grid.
- The **Management & Control** focuses on advanced energy management systems, demand-side solutions and optimisation techniques that enable efficient operation of distributed energy resources.
- Finally, the **Community & Market Integration** focuses on solutions that promote citizen engagement and the development of local energy markets.

3 Analysis of Projects and Validated Research Outcomes

In line with SynGRID's overarching objectives, the analysis of research outcomes is structured around the categorisation of tools and technologies into three interconnected domains: **management**, **observability**, and **controllability** of **LV networks**. These domains represent critical aspects of **LV grid management**, where the SynGRID consortium has extensive expertise.

3.1 Project & Research Outcomes Identification

This section introduces the key projects addressing the SynGRID topics. This section, organised per project, dives deeper into relevant validated research outcomes, in-line with the selection criteria.

3.1.1 COMPILE (H2020, 2018 – 2022)

Table 1: Compile project overview

Project name and Logo	**COMPILE** [2]: INTEGRATING COMMUNITY POWER IN ENERGY ISLANDS Compile
About the project	COMPILE aimed to **activate local energy systems** and support energy communities in becoming active participants in energy markets. It focused on decentralised energy production, local energy sharing, and increasing self-consumption and flexibility at the LV grid level. The tools addressed voltage control, peak shaving, and integration of RES through community-centred tools. **Website**: https://main.compile-project.eu/
Pilot site(s)	COMPILE involved multiple pilot sites, two of them relevant for SynGRID. First pilot site, **Luče (Slovenia)**, represented a case of a rural low voltage network with a weak and unstable connection to the MV grid along with a relatively weak local power grid which often encounters power failures and **limits the integration of renewable energy sources** (RES), as the voltage during the day rises above the limits. Outages are most common during times of extreme weather events like storms and thunderstorms. Second pilot site, Rafina (Greece), represented a semi urban coastal area, with a seasonally variable energy demand, driven by tourism. Rafina was chosen to explore the role of energy communities and self-consumption models in managing demand variability and promoting local RES integration. The pilot demonstrated the feasibility of energy communities, peer-to-peer energy sharing, demand response mechanisms, to improve the welfare of citizens.
Project implementation stage	Completed
SynGRID partners involved	IRI UL (coordinator roles, tool developer), ICCS (tool developer), PET (technology provider)

Key technology domains addressed	**GridRule**: Observability and controllability – monitoring of the grid and operation of the energy community, **Value Tool**: Management – Energy community development
Relevance for SynGRID	COMPILE provides **practical, validated experience** in community flexibility and pre-investment analysis. Tools **developed have been replicated** in other H2020/HE projects, but the initial ideas originated from COMPILE. The **lessons learned** from COMPILE **include the whole lifetime of the project and beyond**, which provides unique experience in managing the technology and assets in EU projects, which could serve as valuable input into new proposals and capacity-building activities. Both tools contribute directly to SynGRID's objectives in LV grid management and could inform new proposals and capacity-building efforts.

3.1.1.1 GridRule

Table 2: COMPILE - GridRule analysis

Validated research outcome	GridRULE [3] is a software platform supporting operators (DSOs or aggregators) in planning and operation of energy communities. It **operates energy production on a community level,** designs control strategies and visualises impact on the LV grid. Its functionalities included **community-self consumption** for maximising local energy production, **community island mode**, where the community could disconnect from the grid with the help of community battery and create a microgrid, as well as using community battery for **ancillary services**.
TRL level & Validation	**TRL 8**: Validated in **Luče (Slovenia)** through real-world operation. Assets were physically installed and operated in a real LV grid by the local DSO. Validation included long-term operation where the **community self-consumption ranged from 58-75%** and enabled operation of the community in **island mode for up to 16 days**, depending on the season, and enabling the additional installation of **100 kW of PV**, compared to just 10 kW without the COMPILE (incl. GridRULE) approach.
Potential for exploitation, replication or future development	Useful for DSOs and aggregators needing decision-support for local energy communities. Scalable to any context involving decentralised generation and flexibility. Potential integration into broader flexibility platforms. Tool was replicated in other EU projects, such as X-FLEX and STREAM, where the functionalities were expanded. The level of demonstration offers insights into installation and operation of local energy systems and therefore, experience from GridRULE is **highly useful for future proposals** and **capacity building activities**.

3.1.1.2 Value Tool

Table 3: COMPILE – Value Tool analysis

Validated research outcome	The Value Tool [4] is a web-based calculator for **evaluating the financial feasibility of rooftop PV installation as households or a part of an energy community**. It estimates investment costs, energy savings, and financial viability using local input parameters life tariff design. It is designed to support citizen engagement and pre-implementation planning.

TRL level & Validation	**TRL 7:** Used in COMPILE for engagement and planning sessions with citizens, cooperatives, and NGOs. Focused on planning stage rather than technical deployment, but the tool included the latest tariff design, energy prices, PV installation prices in different regions, etc.
Potential for exploitation, replication or future development	**Highly accessible** tool intended for anyone interested in the business side of the PV installation. It is **suitable for municipalities, cooperatives, and NGOs** and can be used to promote energy community development of RES integration. It is simple to replicate or update with the latest data. It **complements technical tools** by supporting awareness, engagement, and **bottom-up initiative design**, all valuable for SynGRID's capacity-building goals.

3.1.2 X-FLEX (H2020, 2019 – 2023)

Table 4: X-FLEX project overview

Project name and Logo	X-FLEX [5]: Integrated energy solutions and new market mechanisms for an extended flexibility of the European grid
About the project	X-FLEX project aimed to create and integrate synergies related to the exploitation of energy flexibility sources and technologies, promoting cooperation among all the actors of the smart grid and energy market, in an efficient and cost-effective manner. Through a holistic approach, X-FLEX focus was to ensure the optimal utilization of decentralised flexibility assets, providing benefits to all the actors of the smart grid, energy retail and wholesale market. In X-FLEX project 4 complementary products [6] offering services to all the energy stakeholders, from network operators (TSO, DSO, microgrid operators) to final consumers/prosumers and flexibility providers, including other intermediate players, such as retailers and aggregators were developed: SERVIFLEX tool: Integrated flexibility management tool GRIDFLEX tool: Advanced tools for automatic control and observability MARKETFLEX tool: Market platform and new market mechanisms X-FLEX platform: Flexible and scalable integrated platform connecting all the above-mentioned tools
Pilot site(s)	In 3 EU Member states: Bulgaria (Albena), Slovenia (Luče and Ravne na Koroškem), Greece (Xanthi)
Project implementation stage	Completed
SynGRID partners involved	ICCS (project partner, tool developer), PET (technology provider, Slovenian pilot site leader), IRI UL (associated entity)
Key technology domains addressed	MARKETFLEX tool: **Community & Market Integration** – Local Flexibility Markets

	GRIDFLEX tool: **Energy System Observability & Monitoring** – Grid Monitoring & Predictive Analytics Grid Planning tool: **Management & Control** – Long-term planning
Relevance for SynGRID	In 3 EU Member states: Bulgaria (Albena), Slovenia (Luče and Ravne na Koroškem), Greece (Xanthi)

3.1.2.1 MarketFLEX

Table 5: MarketFLEX – tool analysis

Validated research outcome	MarketFLEX tool enables final consumers and prosumers to access and participate, individually or through an intermediate party (e.g. aggregators), on different energy markets, such as wholesale market, local energy market or ancillary services market for TSO or DSO. Tool itself is as web-based service with an integrated connection to other wholesale trading platforms such as M7-ComTrader Trading Platform. In addition to the connection to the external trading platforms where the market clearing is done, MarketFLEX also provides algorithms for market clearing, especially suitable for clearing the local flexibility market.
TRL level & Validation	**TRL 7**: In the scope of the X-FLEX project, MarketFLEX tool was tested in different pilot sites covering wide range of use cases from local to wholesale electricity markets. Where possible, actual physical activations of devices were also carried out based on market results.
Potential for exploitation, replication or future development	A tool like MarketFLEX has great potential for use, especially in emerging local flexibility markets. The main advantage of the tool compared to other similar tools, which mainly allow peer-to-peer trading, is the possibility to allocate network capacity on a market basis. This opens new possibilities for its use and implies a wider range of users, which are not only market operators but also network operators.

3.1.2.2 Grid Planning Tool

Table 6: Grid Planning tool – tool analysis

Validated research outcome	The Grid Planning tool is intended for distribution system operators (DSO) and its purpose is to evaluate the impact of the integration of flexible assets into the grid, test long-term scenarios of network need to evaluate the capability of the grid to support such scenarios and to identify the weakest parts of the grid and propose the upgrades. The tool is designed as a standalone tool to be used locally.
TRL level & Validation	**TRL 7**: The Grid Planning tool was tested by the two involved DSOs in two pilot sites. Both involved DSOs have recognised the importance of the tool and its functionalities especially relevant for future grid planning with the emphasize on the use of flexibility. Gird Planning tool can also be expanded to be used in the networks not related to the project or in the project involved DSOs.
Potential for exploitation, replication or future development	As mentioned above, the tool can also be used to analyse other networks, subject only to an adequate network model corresponding to the structure used in the project. In addition to using the whole tool, the individual parts of the tool can also be used separately in similar tools, as in the case of the STREAM project and sPLAN tool.

3.1.2.3 GridFLEX

Table 7: GridFLEX – tool analysis

Validated research outcome	The GridFLEX tool, intended for grid and microgrid operators, aims to prevents congestion (voltage and current issues) and power quality problems related to the increasing share of intermittent RES, giving special attention to the potential grid problems due to the impact of extreme climate events. The tool considers flexibility as an alternative to network reinforcement when it is more cost-efficient than traditional reinforcement of the network. Tool is as web-based service, supporting multiple users.
TRL level & Validation	**TRL 7:** Similar as the MarketFLEX, also in the scope of the X-FLEX project, GridFLEX tool was tested in different pilot sites covering wide range of use cases. The tool was tested and validated by the DSOs involved in the project.
Potential for exploitation, replication or future development	The GridFLEX tool provides functionalities that help to accurately estimate the network conditions, improving the operation of distribution grid, which can greatly improve efficiency, technical and economical, of DSOs. The above thus represents a great potential for exploitation and future development of the tools and its functionalities, due to the wide pool of the potential users.

3.1.3 STREAM (HE, 2022 – 2026)

Table 8: STREAM project overview

Project name and Logo	STREAM [7]: Streaming flexibility to the power system STREAM
About the project	STREAM project aims to create an innovative and robust flexibility ecosystem ("STREAM Ecosystem") on the LV grid side of existing power markets connecting data, technologies, stakeholders and markets, thus facilitating the flexibility provision. Its relevance to LV grid management lies in unlocking the small-scale flexibility by enabling its utilisation in a local flexibility market, designed to manage congestion in an economically efficient way. Additionally, it aims to increase LV grid observability by pairing the measurements from smart meters and transformer stations with the grid model to accurately forecast congestion. Website: https://stream-he-project.eu/
Pilot site(s)	Four STREAM pilot sites were chosen to present the diversity in geographical, economic, size and type of the consumers. All the **pilots focus on a specific part of STREAM Ecosystem but complement each other to form a comprehensive testing ground** of all the elements of STREAM Ecosystem. **Finish pilot** focus is on data gathering and data-based flexibility utilization, **Italian pilot** the focus is on open data platform and multi vector flexibility utilization, **Spanish pilot** focuses on local market design on LV networks and

	Slovenian pilot focuses on coordination of the whole STREAM ecosystem, especially device register, pre-qualification and validation.
Project implementation stage	Validation phase
SynGRID partners involved	IRI as a part of the coordinator's team & tool developers
Key technology domains addressed	sPLAN [8]: **Management & Control** – Long-term planning sGRID [9]: **Energy System Observability & Monitoring –** Grid Monitoring & Predictive Analytics sMART [10]: **Community & Market Integration –** Local Flexibility Markets
Relevance for SynGRID	Significance of the project and its outcomes for the objectives, methods, and impact pathways within SynGRID.

3.1.3.1 sPLAN

Table 9: STREAM – sPLAN analysis

Validated research outcome	sPLAN is a planning and decision-support tool developed within STREAM to support DSOs in evaluating long-term scenarios involving the integration of flexibility resources into LV distribution grids. The tool enables the simulation of various grid expansion and flexibility deployment strategies, helping operators assess investment deferral options, network resilience, and congestion risk reduction through flexibility.
TRL level & Validation	TRL 7. The tool is undergoing validation in the Slovenian pilot site, where different grid configurations and flexibility mechanisms are modelled and tested in cooperation with DSOs. The validation process includes comparison against historical network data and stress testing future scenarios.
Potential for exploitation, replication or future development	sPLAN addresses a significant planning gap in LV networks where flexibility is not yet considered. Its ability to quantify long-term impacts of flexibility based strategies makes it highly relevant for DSOs, especially those under pressure to delay costly grid reinforcements. The tool can be further developed as a module integrated into digital twin environments or regulatory planning workflows.

3.1.3.2 sGRID

Table 10: sGRID – tool analysis

Validated research outcome	sGRID enhances observability of LV networks by combining smart meter data and grid topology models with predictive algorithms. It allows DSOs to detect potential overloads, forecast voltage and current issues, and identify localised grid constraints in advance.
TRL level & Validation	TRL 7-8. The tool is validated through real-time data from Slovenian and Spanish pilot sites, using measurements from transformer stations and smart meters. Validation focuses on its forecasting accuracy, response time, and integration with DSO monitoring tools.
Potential for exploitation, replication or future development	As LV grids often lack observability infrastructure, sGRID offers a scalable and low-cost solution to address this gap. It is applicable in both urban and rural settings and can be replicated in any region with available smart meter infrastructure. The

	tool is suitable for integration with flexibility activation platforms or used independently for operational monitoring.

3.1.3.3 sMART

Table 11: sMART – tool analysis

Validated research outcome	sMART is a local flexibility market design and trading tool that enables the participation of small-scale flexibility providers (e.g., households, SMEs) in DSO-led congestion management schemes. It includes modules for prequalification, bidding, and settlement, ensuring that local assets can be aggregated and activated in response to local grid needs.
TRL level & Validation	TRL 7-8. The tool is validated in the Slovenian, Spanish and Italian pilot sites, where local market operation is tested in live environments. Testing involves real or simulated asset activations and interaction with market actors under predefined rules.
Potential for exploitation, replication or future development	The tool is highly relevant for DSOs seeking to establish or test local flexibility markets. Its modular architecture and compliance with evolving market designs make it adaptable to different regulatory environments. Future development could link the tool with national market platforms or incorporate standardised protocols for interoperability with aggregators.

3.1.4 OPENTUNITY (HE, 2023 – 2027)

Table 12: OPENTUNITY project overview

Project name and Logo	OPENTUNITY [11]: OPENing the electricity ecosystem to multiple actors in order to have a real decarbonization opportunity opentunity
About the project	OPENTUNITY aims to create a flexibility ecosystem by reducing interoperability barriers and promoting the use of open standards to support the decarbonization of EU power grids—while placing the end user at the center of the transition. The project supports a wide range of energy stakeholders, including grid operators, consumers, and aggregators, through the development of innovative technologies powered by advanced and interoperable software modules. The innovations in OPENTUNITY are organized into two main groups [12]: • Technologies to boost flexibility in the prosumer environment • Technologies for grid operators to improve grid management These core innovations are further supported by the development of energy data space solutions and additional tools designed to enhance interoperability. The OPENTUNITY project is relevant to the topic of LV grid management through several of its core innovations developed under Work Package 5. These include a state estimation solution tailored for low-voltage networks

	to improve grid observability, a real-time thermal rating approach to dynamically assess the capacity of grid components, and a grid planning tool that integrates flexibility as a means to defer traditional grid investments. Website: https://opentunityproject.eu/
Pilot site(s)	OPENTUNITY innovations will be demonstrated across four pilot sites in four different countries, with the aim of testing the same solutions in diverse grid environments, each with its own characteristics and challenges: In **Slovenia**, the pilot involves sections of the grid operated by two DSOs: Elektro Ljubljana and Elektro Primorska. The Elektro Ljubljana area includes the rural municipality of Grosuplje, which was selected due to its higher-than-average frequency of outages. Elektro Primorska's pilot area focuses on an industrial zone in Ajdovščina, chosen for its rapidly increasing energy demand driven by fast-paced development. In **Greece**, the pilot is located in the Mesogia region, southeast of Athens in Attica. The focus here is on improving grid observability and enhancing coordination between the DSO and TSO. In **Spain**, the pilot covers areas within the Osona and Vallès Oriental regions in Catalonia, characterized by high penetration of photovoltaic systems. The aim is to facilitate better integration of these renewable sources and enable the use of local flexibility markets. In **Switzerland**, the pilot takes place in the Via Motta urban district of Massagno, near Lugano in southern Switzerland. This site focuses on the interaction between energy communities and citizens, with the goal of establishing a local flexibility market and fostering citizen engagement.
Project implementation stage	Development phase
SynGRID partners involved	IRI UL, ICCS
Key technology domains addressed	**Topology identification and state estimation** – Energy system observability and monitoring: grid monitoring **Low-Cost Real-Time Thermal Rating** - Energy system observability and monitoring: Grid Monitoring & Predictive Analytics **Advanced Asset Management** - Management & Control: Predictive maintenance **Grid Planning Optimization** - Energy System Observability & Monitoring: Energy Planning Tools
Relevance for SynGRID	Significance of the project and its outcomes for the objectives, methods, and impact pathways within SynGRID.

3.1.4.1 Topology identification and state estimation

Table 13: OPENTUNITY– Topology identification and state estimation analysis

Validated research outcome	A machine learning-based software module for distribution networks is being developed in OPENTUNITY to enable automated topology identification and state estimation. The tool uses deep learning techniques to track voltage and current profiles in distribution feeders, identify switch statuses, and reconstruct grid topology with high accuracy. This allows DSOs to overcome the limitations of

	manual inspection methods and low measurement availability, especially in LV networks.
TRL level & Validation	The tool will be validated through **field-level demonstrations** in OPENTUNITY pilot sites. Validation involves using **historical and real-time measurement data** from selected grid areas to train and test the model under realistic operational conditions. Stakeholders involved include local DSOs and research partners, who will support the testing with relevant datasets and system configurations. **TRL level: 7**
Potential for exploitation, replication or future development	The developed tool is particularly relevant for **small and medium-sized DSOs lacking advanced monitoring infrastructure**. It offers a sca**lable and sensor-light solution** that can be deployed across LV grids to improve observability and enable more advanced grid management functionalities such as congestion detection, fault restoration, and flexibility activation. The modularity of the algorithm allows for **integration into existing DSO IT systems** or as part of future smart grid platforms.

3.1.4.2 Low-Cost Real-Time Thermal Rating

Table 14: OPENTUNITY– Low-Cost Real-Time Thermal Rating analysis

Validated research outcome	OPENTUNITY is developing a cost-effective methodology for Real-Time Thermal Rating (RTTR) of distribution and transmission lines. Unlike traditional approaches requiring extensive and expensive sensor deployments along the lines, this solution leverages numerical weather prediction models (such as GFS and ECMWF) enhanced with available environmental data from nearby connected assets. These include Home Energy Management Systems (HEMS), building management systems (BMS) and charging stations. By combining these diverse data sources with machine learning and big data analytics, the tool provides accurate real-time estimations of line capacity without the need for direct line-mounted sensors.
TRL level & Validation	The methodology will be validated **through simulations and pilot testing** within OPENTUNITY demonstration sites. Real-world weather and asset sensor data are collected and integrated with numerical weather prediction outputs to train and test the RTTR model. Validation includes comparisons against traditional static line ratings and estimation accuracy assessments. Involved stakeholders include DSOs and TSOs, who will assess the usability and scalability of the tool within their operational environments. **TRL level: 7**
Potential for exploitation, replication or future development	The innovation offers a cost-effective alternative to traditional RTTR methods, reducing the need for expensive sensor deployments while still providing accurate and dynamic line capacity estimates. It is highly scalable and particularly valuable for DSOs operating MV networks and TSOs managing large grid areas. The approach can be replicated in other regions by integrating locally available weather and sensor data, and further developments could include real-time integration with grid operation tools for congestion management or market-based flexibility procurement.

3.1.4.3 Advanced Asset Management

Table 15: OPENTUNITY– Advanced Asset Management analysis

Validated research outcome	OPENTUNITY is developing a data-driven asset management solution aimed at modernizing both traditional and electronic components of the distribution grid. By leveraging sensor data from electronic meters and other monitoring infrastructure, the tool applies machine learning techniques to assess equipment aging, estimate non-technical losses, and support predictive maintenance planning.
TRL level & Validation	The solution will be validated in pilot environments through the analysis of real measurement data from DSOs. Focus will be placed on evaluating the feasibility of predictive analytics and risk-based maintenance strategies for both conventional infrastructure (e.g., transformers and lines) and newer electronic equipment. This will demonstrate the potential for improved risk assessment, maintenance scheduling, and loss detection using real-world data sets. DSOs were the main stakeholders involved in testing and assessment activities. **TRL level: 6**
Potential for exploitation, replication or future development	This innovation holds strong potential for adoption by DSOs and TSOs aiming to optimize grid maintenance while minimizing operational risk and investment needs. Its flexible design allows integration into existing grid monitoring systems without major infrastructure upgrades. As the penetration of smart grid technologies increases, the value of data-driven asset management will grow, opening up opportunities for further development and integration with digital twin environments or grid investment planning tools. The methodology can be replicated across different types of grids and regulatory frameworks.

3.1.4.4 Grid Planning Optimization

Table 16: OPENTUNITY– Grid Planning Optimization analysis

Validated research outcome	OPENTUNITY is developing a new grid planning methodology tailored to support the goals of the EU Green Deal and Fit for 55, with a strong focus on cross-sector integration. The approach will move beyond traditional, single-carrier planning by identifying dependencies with other energy sectors and incorporating them into the grid planning process. It will define new risk indices and planning variables that better reflect the evolving energy landscape and apply advanced optimization techniques to deliver cost-effective and future-proof infrastructure plans. The solution aims to help grid operators make informed investment decisions while managing trade-offs between cost, reliability, and decarbonization.
TRL level & Validation	The approach will be tested in selected OPENTUNITY pilot sites, where different planning scenarios were analyzed to assess the impact of emerging technologies and evolving energy demands. The validation process includes simulation-based evaluations using real grid data, forecasting of new technology adoption (e.g., EVs and PVs), and assessment of resulting grid performance. **TRL level: 7**
Potential for exploitation, replication or future development	This methodology is highly relevant for DSOs and TSOs looking to modernize their grid planning strategies and integrate sector coupling considerations. It is particularly suited for regulatory environments where alignment with

	decarbonization policies is a priority. The flexible and modular nature of the planning framework makes it adaptable to various geographic and regulatory contexts. With further development, it could be integrated into digital twin platforms or used as a decision-support tool for long-term infrastructure investment and policy design.

3.1.5 SEEDS (HE, 2024- 2027)

Table 17: SEEDS project overview

Project name and Logo	**SEEDS** [13]**:** Cost-effective and replicable RES-integrated electrified heating and cooling systems for improved energy efficiency and demand response SEEDS
About the project	The SEEDS project is co-funded by the European Commission and aims to boost the **electrification of thermal systems in buildings** through an integrated approach leveraging **energy efficient renovation** and **smartification of HVAC systems**. The SEEDS project solutions aim to **reduce the thermal energy demand** of buildings and enable the **deployment of energy flexibility to increase the RES share** (in particular, locally produced) thereby enhancing grid stability in a cost-effective way and with low life cycle environmental impact. This strategy will be tested in six pilot sites throughout Europe: Denmark (CDK), Belgium (SWECO), Hungary (EMI), Slovenia (Petrol) and Greece. The SEEDS project is centered around 3 key themes: 1. Cost efficiency through optimization, 2. System integration through holistic design and control, 3. Replication through configuration modularity and scalable building types. These are addressed in 7 focus areas: 1. Iterative design of the component and integrated system, 2. Secure and interoperable data platforms and IoT, 3. Integrated system optimization for energy efficiency and flexibility, 4. Deploying energy flexibility to enhance grid stability, 5. Replication strategies, exploitation, and business models, 6. Decision making support framework for replication, 7. Dissemination, communication, and stakeholder outreach. Website: SEEDS Project: Electrification of Thermal Systems in Buildings
Pilot site(s)	Six pilot sites throughout Europe: Denmark (CDK), Belgium (SWECO), Hungary (EMI), Slovenia (Petrol) and Greece. Slovenian pilot consists of 5 gas stations, namely gas station Izola-Industrijska, Bled-Seliška, Čatež-Grič, Velenje-Celjska V and Celje-Mariborska.
Project implementation stage	Development phase

SynGRID partners involved	Petrol d.d., Ljubljana / carrier of the Slovenian Pilot
Key technology domains addressed	Reference to the relevant technologies as (will be) identified in deliverable D2.1.
Relevance for SynGRID	The Slovenian pilot consists of 5 gas stations, namely Gas station Izola, Bled, Čatež, Velenje and Celje. Three gas stations out of five are located on the area of Elektro Celje (DSO and consortium partner in SEEDS) and the two of them are spread at the different parts of Slovenia. The core project activities are focused on the remote management of the energy flexibility for the needs of further optimization of the energy consumption and in addition to that, our goal is also to offer flexibility services to the DSOs and TSO. Gas stations are often seen as sources of emissions, but by adopting flexibility services like the integration of renewable energy and electric vehicle charging stations, we can significantly reduce our environmental footprint. **Slovenian pilot as part of the SEEDS project can be an important model for other community flexibility projects, especially in the context of energy management and sustainability.**

3.1.5.1 SEEDS - Validated Research Outcome 1 (Tool, methodology, model, ...)

Table 18: SEEDS – tool analysis

Validated research outcome	Petrol will implement public procurement schemes for purchasing the appropriate equipment for near real time data acquisition and automation control of micro energy sources. Petrol and IJS (Institut Jožefa Štefana) collaborate on upgrading Petrol's existing IoT platform to integrate the newly installed sensing and control equipment, and develop and API that will enable seamless integration with the DSS for flexibility services. Petrol and IJS will focus on forecasting energy demands within the time horizon of market bidding (day-ahead). Local (building level) models for each energy source will be based on relevant public or locally collected data.
TRL level & Validation	The overall project envisages achieving the **TRL 6-8**. Slovenian pilot is a field pilot and currently we're in the middle of operational deployment (preparation of project documentation for electrical and mechanical works). First data should be available in the summer 2025.
Potential for exploitation, replication or future development	Petrol, ELCE (Elektro Celje) and IJS will evaluate the system for market bidding of electricity balancing services performed on real-world day-ahead market data for tertiary, secondary and local level services. If the project results will be positive, there is a huge potential for scalability within the network of Petrol's gas stations.

3.1.6 RE-EMPOWERED (H2020, 2020 – 2024)

Table 19: RE-EMPOWERED project overview

Project name and Logo	RE-EMPOWERED [14] (Renewable Energy EMPOWERing European & InDian Communities)

	RE-EMPOWERED Renewable Energy EMPOWERing European & InDian Communities
About the project	RE-EMPOWERED aimed to develop and demonstrate comprehensive, renewable-based energy solutions for islanded and isolated communities with limited or no access to stable grid infrastructure. The project focused on co-optimizing multiple energy vectors—electricity, heating, cooling, water, and e-mobility—while enhancing system flexibility through advanced energy management and demand-side tools. Solutions were tailored to maximize energy autonomy, reliability, and cost-effectiveness in weak-grid or off-grid contexts. Key components included energy planning, dynamic energy management systems, behavioral demand response, and community engagement tools, all integrated under a holistic, multi-vector energy platform [15]. Website: https://reempowered-h2020.com/
Pilot site(s)	**Kythnos Island, Greece**: A non-interconnected island in the Aegean Sea with a history of pioneering renewable energy projects. The pilot focused on upgrading existing microgrid infrastructure, integrating additional RES, and implementing advanced energy management and community engagement tools. **Bornholm Island, Denmark**: A grid-connected island aiming to optimize the use of local renewable energy sources. The pilot implemented tools for co-optimization of electricity and district heating networks, enhancing system flexibility and reliability. **Ghoramara Island, India**: A remote island facing challenges due to rising sea levels and limited energy access. The pilot established a microgrid integrating solar PV, battery storage, and energy management systems to provide reliable and sustainable electricity to the community. **Keonjhar District, India**: A rural area with limited grid access. The pilot developed a microgrid incorporating solar PV, biomass, e-mobility solutions, and water treatment systems, aiming to improve energy access and quality of life for the local population.
Project implementation stage	Complete
SynGRID partners involved	ICCS/NTUA
Key technology domains addressed	Energy Planning: Designing microgrids from scratch and upgrading existing installations to high-RES systems. Energy Management: Implementing advanced control systems for optimal operation of multi-energy systems. Demand Side Management (DSM): Enhancing flexibility through customer engagement and behavioral demand response. Community Engagement: Fostering active energy communities via sustainable business models and investments.
Relevance for SynGRID	RE-EMPOWERED provides validated experience in deploying comprehensive energy solutions in diverse contexts, from islanded European regions to rural Indian communities. The project's tools and methodologies offer valuable insights for SynGRID's objectives in flexibility, LV grid observability, and

	consumer engagement. The lessons learned, particularly in behavioral demand response, local system optimization, and multi-vector integration, can directly inform new project proposals, tool development, and training activities.

3.1.6.1 ecoMicrogrid

Table 20: ecoMicrogrid – tool analysis

Validated research outcome	ecoMicrogrid is a modular energy management and control platform designed for the operation of microgrids in both grid-connected and islanded modes. It enables real-time coordination of distributed energy resources (DERs), including PV, batteries, diesel generators, and flexible loads. The system balances generation and demand while optimizing energy flows at the local level. Key functionalities include load forecasting, state-of-charge (SoC) optimization for batteries, black-start support, and seamless mode switching (grid-connected ↔ islanded).
TRL level & Validation	**TRL 7-8**: Validated in real-world settings across Kythnos (Greece) and Ghoramara (India), where ecoMicrogrid was deployed to operate hybrid systems integrating PV, battery storage, and conventional generators. The tool successfully demonstrated autonomous control and stability, enabling island operation for extended periods (up to several days), peak load management, and improved energy quality. It supported energy access for previously underserved areas while reducing reliance on diesel.
Potential for exploitation, replication or future development	ecoMicrogrid can be replicated in remote, weak-grid, and off-grid communities where stable operation of hybrid systems is critical. The tool is compatible with existing and emerging DER assets, making it suitable for a broad range of geographies. It is especially relevant for DSOs, microgrid developers, and rural electrification initiatives, and is being considered for further development and integration in follow-up EU-India collaborative projects.

3.1.6.2 ecoEMS

Table 21: ecoEMS – tool analysis

Validated research outcome	ecoEMS (Energy Management System) is a supervisory control platform that enables real-time energy optimization across multiple energy carriers—electricity, heating, cooling, water, and e-mobility. Designed for multi-vector systems, it uses advanced algorithms to schedule energy usage, reduce operational costs, and increase system flexibility. It integrates with field devices and other ecoTools (like ecoPlanning and ecoDR) to coordinate distributed assets, manage grid constraints, and ensure reliability.
TRL level & Validation	**TRL 7-8**: Validated at the Bornholm (Denmark) and Keonjhar (India) pilot sites. In Denmark, ecoEMS was used to co-optimize electricity and district heating, while in India it coordinated solar PV, biomass CHP, EV charging, and water pumping systems. It delivered significant improvements in cost efficiency, renewable penetration, and reduced fossil fuel use.
Potential for exploitation, replication or future development	ecoEMS is highly adaptable to both urban and rural energy systems, particularly where multi-energy vectors interact. It is well suited for municipalities, industrial parks, and community-scale energy systems aiming to improve resource

	utilization. The modular structure allows further development for climate resilience planning and integration into virtual power plant (VPP) architectures.

3.1.6.3 ecoDR

Table 22: ecoDR – tool analysis

Validated research outcome	ecoDR is a behavioral and automated demand response platform aimed at increasing system flexibility and engaging end-users in energy system optimization. It includes load forecasting, automated response to grid signals, and consumer engagement modules to shift energy usage patterns based on pricing signals or grid needs. Behavioral pilots used real-time feedback and gamified platforms to incentivize participation, targeting residential, commercial, and institutional users.
TRL level & Validation	**TRL 6-7**: Demonstrated at Kythnos and Ghoramara pilot sites, where users were engaged through dashboards, training programs, and incentives. Automated load control was implemented for lighting, HVAC, and water pumps, achieving measurable load shifting and improved grid stability. The tool proved valuable in peak shaving and maintaining voltage stability in microgrids with high RES penetration.
Potential for exploitation, replication or future development	ecoDR is ideal for local energy communities, microgrids, and aggregators aiming to harness consumer-side flexibility. It complements energy management systems and can be integrated into broader DSM strategies.

3.1.7 ProPowerNet (National - HRZZ, 2020 – 2025)

Table 23: ProPowerNet project overview

Project name and Logo	ProPowerNet [16]: Prosumer-rich distribution power network
About the project	The main objective of the project is to establish a new research group focused on investigating the operation management of prosumer power systems and distribution networks. Additional objectives include developing simulation models to analyse the interaction between prosumers and the distribution network, as well as creating optimization algorithms to determine the optimal operation of prosumer devices and the distribution grid under various observation scenarios. Website: https://propowernet.ferit.hr/
Pilot site(s)	Developed models for optimizing the operation of prosumers in distribution networks, considering various observation scenarios.
Project implementation stage	Last year of the project
SynGRID partners involved	FERIT
Key technology domains addressed	**Energy Management:** Developing optimization algorithms for efficient operation of distribution grids with integrated prosumers.

	Community & Market Integration: Developing optimization-based software tools enabling prosumers to participate in electricity markets and provide ancillary services within the power system.
Relevance for SynGRID	The project offers valuable expertise in managing the operation of prosumer power systems, with direct relevance to SynGRID's goals in distribution grid optimization and flexibility. By addressing four key areas: market-based profit maximization for prosumers, loss minimization and voltage/load regulation in distribution networks, mitigation of power quality issues, and stability of voltage and frequency under high prosumer penetration the project provides practical methodologies and insights that align with SynGRID's focus on LV grid observability, control strategies, and resilient grid operation. These findings can support future tool development, scenario validation, and capacity-building efforts within SynGRID.

3.1.7.1 Simulation models for prosumer-rich distribution network

Table 24: TEMPLATE – tool analysis

Validated research outcome	This suite of validated research outcomes provides a comprehensive set of tools for optimizing the operation of prosumers within distribution networks. It includes software codes for prosumer bidding strategies in electricity and ancillary service markets, as well as algorithms for optimizing distribution grid operation with a focus on loss minimization and voltage control. Models have been developed for assessing voltage and frequency stability in grids with high prosumer penetration, along with optimization tools for determining optimal placement of active filters to enhance power quality. Additionally, a detailed simulation model enables analysis of grid–prosumer interactions from the perspective of power quality, supporting robust planning and operational strategies.
TRL level & Validation	**TRL 6:** The developed models were validated based on actual measurements of electrical quantities from prosumers.
Potential for exploitation, replication or future development	The developed tools and models offer strong potential for exploitation by DSOs, energy service providers, and aggregators to optimize prosumer participation, grid operation, and power quality.

3.1.8 USBSE (ERDF, 2020 – 2023)

Table 25:USBSE project overview

Project name and Logo	USBSE [17] - Connected Stationary Battery Energy Storage USBSE
About the project	The project focuses on the development of two prototypes of energy storage batteries as modular products, which will be connected to a software application for aggregators. The goal is to increase market-oriented research activities through the development of innovative energy storage solutions and create new value through collaboration with scientific organizations. This project contributes to enhancing energy efficiency and flexibility in

	distribution systems, enabling better energy management in the context of market and technological challenges. Website: https://usbse.eu/
Pilot site(s)	Developed two battery energy storage prototypes as modular products, connected to aggregator software applications.
Project implementation stage	Completed
SynGRID partners involved	FER, FERIT
Key technology domains addressed	**Community & Market Integration:** Enabling cost-efficient energy management by shifting electricity consumption from high-price to low-price periods through optimized battery storage usage. This approach not only reduces energy costs by charging during off-peak times and discharging during peak periods but also facilitates participation in auxiliary services, empowering prosumers to contribute to grid stability through aggregators of distributed flexibility sources.
Relevance for SynGRID	USBSE project aligns with the SynGRID initiative by contributing to the integration of distributed flexibility sources, enhancing the participation of end customers in grid operations. By developing a connected stationary battery energy storage system, it supports the objectives of increasing grid flexibility, reducing electricity costs, and improving system stability. The focus on active customer involvement through aggregators strengthens SynGRID's goals of optimizing low-voltage grid management and fostering a more resilient, consumer-oriented energy system.

3.1.8.1 Battery energy storage prototypes as modular products

Table 26: Battery energy storage prototypes – tool analysis

Validated research outcome	Developed two battery energy storage prototypes as modular products, connected to aggregator software applications.
TRL level & Validation	TRL 4: The developed prototypes were validated in the laboratory environment
Potential for exploitation, replication or future development	The developed battery storage prototypes offer strong potential for exploitation by aggregators and energy service providers to optimize end-user participation in energy markets and improve grid flexibility and stability.

3.1.9 REANIMATION (National Recovery and Resilience Plan, 2023-2025)

Table 27: REANIMATION project overview

Project name and Logo	REANIMATION: A System for Coordinated Provision of Flexibility to the Power Grid Using Advanced Households
About the project	REANIMATION enables households to participate in electricity markets by adjusting appliance use without compromising comfort or wasting time. Two main products are developed: an automated system that connects households with an aggregator to provide flexibility on energy and reserve markets, and a virtual simulator to test large-scale coordination before real-world implementation. The solution consists of algorithms for appliance

	scheduling based on forecasts, real-time control signal sending, flexibility calculation and aggregation, and optimal electricity market participation. It also includes tools for the aggregator to monitor its flexibility providers' fleet and for households to track their energy performance.
Pilot site(s)	Three energy-poor households in Zagreb, Croatia, have been selected for the integration of smart devices and testing of the solution. Each household will receive one device: an air conditioner, refrigerator, and dishwasher. The scheduling, as well as the sending and receiving of control signals, will be tested on these devices. The remaining households will be simulated using a virtual simulator to test the scalability of the solution.
Project implementation stage	Last quarter of the project
SynGRID partners involved	UNIZG (project coordinator, tool developer)
Key technology domains addressed	**Households-Aggregator Platform:** AI-based Forecasting Models, Optimization Algorithms, Distributed Control, Demand Response, Smart Home Integration, Electricity Markets Participation, and Flexibility Provision **Household Virtual Simulator Environment**: Demand Response, Digital Twin
Relevance for SynGRID	The project algins with the goals of the SynGRID projects since it investigates possibilities of flexibility provision by final customers connected to an LV network. Furthermore, the focus of the project is also developing the platform that can be used by aggregators who will exploit demand side flexibility and offer services to a DSO. Finally, the project REANIMATION creates a set of measurements that can be used in different joint research activities that will be conducted as a part of SynGRID.

3.1.9.1 Household-Aggregator Platform

Table 28: REANIMATION – Household-Aggregator Platform analysis

Validated research outcome	The main product combines **forecasting** of appliance demand and **smart control** with real-time signal exchange between the household and the aggregator, and within the household. It includes a home controller that learns from household data and schedules appliances based on electricity prices. The goal is to enable automated and coordinated participation of a large number of households in **energy and reserve markets** through the **aggregator**, without burdening the end users.
TRL level & Validation	**TRL 4 (going to TRL 8)**: The solution, including the software for household energy management and the aggregation optimization algorithm, has been developed and successfully tested in a laboratory environment that simulated a single household. While Further development, testing and scaling to real-world conditions are currently in progress, which will allow for its potential commercialization.
Potential for exploitation, replication or future development	This tool can be used for smart building integration into power systems as an active part-taker. It can be used for aggregation and simultaneous control of multiple households for **flexibility provision** to power system operators. The software is suitable for **aggregators** and **flexibility providers**.

3.1.9.2 Household Virtual Simulator Environment

Table 29 REANIMATION – Household Virtual Simulator Environment analysis

Validated research outcome	The Household Virtual Simulator is a tool for testing **residential flexibility solutions at scale** without needing access to thousands of real households. It allows users to simulate the behaviour of tens or hundreds of thousands of virtual households based on real measurements and configurable scenarios.
TRL level & Validation	**TRL 4 (going to TRL 8)**: The virtual household simulator is developed using artificially generated data to simulate the operation of various households. Currently, it is designed for use in our specific project and laboratory setting. As the project progresses, the simulator will be adapted to handle any household and be ready for commercial use.
Potential for exploitation, replication or future development	The virtual simulator for households is particularly valuable in the **residential sector**, where a large number of users is needed to observe system-level effects. Since gathering a large number of real households may not always be feasible, the simulator enables scalable and controlled testing of various actions or services, such as flexibility provision algorithms.

3.1.10 WeForming (HE, 2023-2026)

Table 30: WeForming project overview

Project name and Logo	WeForming [18]: Empowering Buildings, Energizing the Future.
About the project	WeForming is developing a new generation of smart buildings (iGFBs) that actively participate in the energy system through flexible consumption management and cooperation with other buildings. The focus is on interoperable digital architectures, AI models and digital twins that enable predictive management and exchange of energy services. The project tests technical and business solutions for buildings that communicate, respond to market signals and contribute to a sustainable energy transition. Website: https://weforming.eu/
Project implementation stage	The WeForming project is being demonstrated in six pilot areas across Europe. In Luxembourg, a grid-interactive district with multiple energy sources and a large number of electric vehicles is being tested. In Portugal, a shopping mall with its own generation and energy storage is being developed. In Croatia, a renewables-based system is being tested on an island in an environment with pronounced seasonal consumption fluctuations. In Belgium, a residential area is being managed with integrated energy conversion systems and thermal storage. In Spain, a rural energy community based on collaborative energy exchange is being developed. In Germany, a smart district that responds to signals from the energy market in real time is being tested.

Pilot site(s)	Ongoing (half of the project)
SynGRID partners involved	UNIZG (tool developer)
Key technology domains addressed	WeForming Reference Architecture (RA):
Relevance for SynGRID	Significance of the project and its outcomes for the objectives, methods, and impact pathways within SynGRID.

3.1.10.1 WeForming Reference Architecture

Table 31: WeForming Reference Architecture – tool analysis

Validated research outcome	The WeForming Reference Architecture (RA) is a modular and interoperable framework that supports the management and connectivity of intelligent, grid-forming buildings (iGFB). It includes building-level energy management, AI-based prediction and optimization, and communication with the power grid, all connected through a middleware layer that ensures secure data exchange, identity management, and real-time operation. The system is adaptable and scalable, in line with European standards, and forms the basis for advanced analytics, service exchange, and the development of shared business models within energy communities.
TRL level & Validation	TRL 2-3 (going to TRL 6-7): The WeForming Reference Architecture (W-IBRA) is currently in its early development as a hybrid of reference and technical architecture. In this phase, the project combines a top-down and bottom-up approach to provide a clear overview of the system, but also a detailed insight into individual components. Functional requirements are defined through an analysis of user and system needs, all with the aim of creating a tool that is scalable and applicable beyond the scope of the project. Further development and validation of W-IBRA are planned through pilot testing in Croatia, Portugal, Germany, Belgium, Spain and Luxembourg, thus moving from TRL 2-3 to TRL 6-7.
Potential for exploitation, replication or future development	Useful for developers and integrators of smart building systems, energy communities, and digital platforms. Supports interoperability and modular service integration in line with EU data governance frameworks. Applicable to projects aiming to enable intelligent, coordinated energy management across multiple buildings or districts.

3.1.11 DINGO (ERDF, 2020-2023)

Table 32: DINGO project overview

Project name and Logo	DIstributioN Grid Optimization (DINGO) [19]

About the project	The project aims to develop a system for continuous analysis of technical parameters within the distribution network, which, through the application of machine learning, would assess and predict both technical and non-technical losses. The system includes measuring equipment for installation in the secondary distribution network, as well as a software platform for data acquisition, processing, and analysis. The expected outcome of the established system is to provide a concrete insight into the secondary distribution in order to enable informed optimization of the electrical energy distribution network, through more precise geographic localization and the assessment and prediction of losses on transformer station lines. Website: https://www.helb.hr/hr/eu-projekti/povecanje-razvoja-novih-proizvoda-iz-aktivnosti-istrazivanja-i-razvoja/
Pilot site(s)	21 LV networks in Croatia
Project implementation stage	Complete
SynGRID partners involved	FER (tool developer)
Key technology domains addressed	Digital Twins – Grid Monitoring – Grid Planning and Operation – RES integration
Relevance for SynGRID	The focus of the DINGO project was to increase the LV networks observability, to analyse the potential of metering devices in distribution networks and to create a set of tools that will maximize the use of existing LV networks data and measurements. Such tools help DSOs to enhance grid planning and operation and can also be used in SynGRID activities.

3.1.11.1 GIS Data Processing

Table 33: GIS Data Processing – tool analysis

Validated research outcome	GIS Data Processing tools takes the initial LV network data as an input, processes it and through identified errors such as connectivity issues edits data, removes errors and prepares it for further use in LV network analyses.
TRL level & Validation	**TRL 7:** The tool was tested on the real-world LV network data collected from 21 pilot sites during the DINGO project. The solution was validated through integration with professional network simulation software and conducting different analyses which accuracy was approved by a DSO.
Potential for exploitation, replication or future development	The tool is expected to be mostly used by DSOs or research institutions who require errorless data for network analyses. Even though the tool is focused on LV network data it can be easily modified and replicated to process MV or HV network data or roads and traffic data in e-mobility analyses.

3.1.11.2 ML-based Phase Detection and Phase Consumption Identification

Table 34: ML-based Phase Detection and Phase Consumption Identification – tool analysis

Validated research outcome	Two ML-based tools take initial measurements collected from smart meters and prepares them for future calculations. The first tool identifies the phase connectivity of single-phase end-users and correct schedule of phase voltage

	measurements of three phase end-users. Based on these results, the second tool distributes aggregated measured consumption amongst three phases.
TRL level & Validation	**TRL 7:** Phase detection algorithm was firstly tested on synthetic data and then the solution was validated on one of the pilot locations by the DSO, who confirmed the results of the algorithm by visiting all households in the pilot site. **TRL 5:** Phase Consumption Identification was validated using real-world topology data but synthetic measurements since phase demand was not measured by devices installed in pilot locations.
Potential for exploitation, replication or future development	The solutions are relevant for DSOs since they can enable use of additional data and not only the one measured at the end-user's location. Also, it is interesting for research institutions due to an increase in the LV network's observability that solution presents. The tool is scalable since it can easily be implemented in different LV networks but also, its application on a substation level can also be ensured. Future development includes the increase of TRL of Phase Consumption Identification tool by verifying it on a real-world data.

3.1.11.3 LV Network Losses Forecast

Table 35: LV Network Losses Forecast – tool analysis

Validated research outcome	The tool is used to forecast network losses in LV distribution networks. Two different approaches are adopted. One solution relies on forecasting aggregated electricity consumption in substation and electricity consumption of end-users and calculates the difference of these two values which can be considered network losses. The second approach forecasts only electricity consumption of end-users and calculates network losses by performing three-phase power flow calculations.
TRL level & Validation	**TRL 5:** The solution was tested using real-world data, including network topology and electricity consumption measurements and the results of forecast were compared and verified against simulation results. DSO do not directly measure network losses on a single-network level so the accuracy of the algorithm could not be tested in an operational environment.
Potential for exploitation, replication or future development	The solution is mostly expected to be used by a DSO since it ensures more precise forecast of network losses which is important for the market and technical aspects of a DSO's business, allowing them to better plan the purchase of losses. The solution can be modified and used in forecasting of other quantities, such as RES generation. Future development includes the consideration of additional parameters in the training process, making the forecast result more precise. Also, the future development includes the development of the algorithm that might be able to separate technical from non-technical losses in an LV network.

3.1.12 FLEXIGRID (H2020, 2019-2023)

Table 36: FLEXIGRID project overview

Project name and Logo	**Interoperable solutions for implementing holistic FLEXIbility services in the distribution GRID (FLEXIGRID)** [20]

About the project	The FLEXIGRID project addressed the challenges posed by the increasing integration of renewable energy sources (RES) into distribution networks by developing innovative hardware and software solutions. It focused on enhancing grid flexibility, observability, and automation to support energy decarbonization and improve overall system resilience. Through real-life demonstrations in four pilot sites, the project validated its technologies in diverse environments, highlighting their effectiveness and replicability. Key outcomes included the creation of the open-source FUSE platform for interoperability, as well as tailored algorithms to tackle grid congestion efficiently. Beyond technical achievements, FLEXIGRID also worked to remove innovation barriers, engage stakeholders, and promote a low-carbon transition through targeted communication and strategic dissemination efforts. As part of its broader impact, the project actively contributed to the BRIDGE initiative, fostering collaboration and knowledge exchange across EU smart grid and energy storage projects. Website: https://www.flexigrid-h2020.eu/
Pilot site(s)	Spain, Greece, Croatia, Italy
Project implementation stage	Completed
SynGRID partners involved	FER (tools developer, WP leader)
Key technology domains addressed	Demand Side Management – RES integration – Observability, controllability and automation, Congestion Management
Relevance for SynGRID	The focus of the FLEXIGRID project was to find solutions for distribution networks with a high share of RES. The solutions were separated into ones oriented on the installation of hardware and ones oriented on the development of software. The part of solutions [21] was mainly focused on the increase of LV networks observability and their automation and controllability. Achieving the goals of these goals are in line with the ones defined by the SynGRID project. Other part of the solutions was not specifically focused on LV networks but distribution networks in general. However, these solutions can be replicated to an LV level and can be exploited in achieving SynGRID goals.

3.1.12.1 Virtual thermal energy storage module

Table 37: Virtual thermal energy storage module – tool analysis

Validated research outcome	The module relies on installing IoT devices in a household, i.e., temperature sensors and communication infrastructure. Based on the historical measurements and preferences of the end-user, developed software is used to control the HVAC system installed in a household, i.e., to increase or decrease the temperature, based on the service end-user provide.

TRL level & Validation	**TRL 7:** All hardware was installed in a pilot location and developed software module was tested to control the air conditioner in a household. The conducted tests were successful, and the air conditioner adequately reacted to sent control commands.
Potential for exploitation, replication or future development	The developed module was tested on a single household as a proof-of-concept. However, the same solution can be implemented in many different households or other commercial or industrial consumers. That way, the flexibility of a system can be significantly increased and consumers can provide ancillary services to a DSO or TSO. They cannot do it on their own but need to be aggregated. Therefore, this solution is of an interest for aggregators but it can also be investigated in terms of local flexibility markets.

4 Mapping of Research Outcomes to Smart Specialisation Strategies in the EU

4.1 Smart Specialisation Strategies in general

S3 is an EU policy framework designed to foster innovation-driven regional development. The core idea behind S3 is to **identify and capitalise on a region's unique strengths, resources, and capabilities to achieve sustainable economic growth and innovation.** By implementing S3, each EU country **channels resources into areas of competitive advantage**, fostering collaboration between businesses, research institutions, and public authorities, with an overarching goal to make EU regions more competitive, resilient and adaptable to global challenges.

The concept of S3 originated in the early 2000s as a response to the need for a more targeted and **place-based innovation strategy**, motivated by the productivity gap between the United States and Europe [22].

While not completely new, S3 represented a refinement and update of the existing methodology for Structural Funds programming [23]. It officially became part of EU policies in 2010, while the **first generation of S3 was implemented as a part of 2014 – 2020 EU Cohesion Policy** to encourage collaboration and investments in joint projects between industry and research & development institutions. As a precondition for accessing **European Structural and Investment Funds (ESIF)**, all EU Member States and regions were required to develop a **Research and Innovation Strategy for Smart Specialisation (RIS3)**. The **European Regional Development Fund (ERDF)** served as the primary funding instrument within ESIF to support S3 implementation

During this period, S3 helped regions tailor their innovation policies to their strengths, ensuring that EU funding was directed towards transformative projects rather than being spread too thinly across multiple areas [24]. Additionally, S3 has become a **major driver for energy innovation and smart grid development** in Europe by concentrating funding, fostering networks, and **aligning R&D with energy policy needs**. With smart specialisation strategies in the implementation phase, **clean energy is one of the main priorities for most EU regions**.

However, challenges emerged in implementation, particularly in aligning strategies with national priorities, governance structures, and funding absorption capacities. As identified in [25], over 25% of S3 did not align well with their region's innovation potential which could have led to challenges in absorbing allocated funds. Additionally, as stated in [26]X, challenges included establishing a **sound monitoring system** to evaluate the impact of S3 and its necessity for continuous improvement and ensuring that S3 frameworks are flexible enough to **adapt to rapid technological advancements**. Moreover, a challenge of involving a **diverse range of stakeholders** and ensuring their active participation while balancing their interests and **better communication and dissemination** to the general public were identified as shortcomings.

Recognising these challenges, **the 2021-2027 programming period of S3** has continued to build on the three pillars of S3 [1]:

1. **Localisation**: This pillar emphasizes building on the assets and resources available within a territory, aligning with the goal of identifying regional strengths.
2. **Prioritisation**: Investments should focus on a limited number of key areas where a region has competitive advantages, thereby avoiding duplication of efforts and maximising impact.
3. **Participation**: The strategy promotes collaboration among regional stakeholders, including policymakers, businesses, researchers, and civil society, to create strong innovation ecosystems and support inclusive growth.

The S3 have been refined to overcome previous limitations, placing **increasing attention on governance structures** and introducing a thematic enabling condition on "*good governance of national or regional smart specialisation strategy*" made up of seven fulfilment criteria. These include maintaining an up-to-date analysis of innovation and digitalisation challenges, establishing a competent managing authority, and developing monitoring and evaluation tools. Additionally, the strategy requires active stakeholder engagement and the implementation of targeted actions to strengthen research and innovation systems [1].

A crucial cultural shift is also required to improve the effectiveness of S3. As highlighted in the literature, the adoption of S3 represents not just a policy instrument but a **fundamental shift in how regional innovation is approached**. This shift must begin with policymakers, who should seek evaluation studies as a tool for informed decision-making rather than to comply with administrative requirements [27].

4.2 S3 in Widening countries

Widening countries refer to **EU Member States that have historically lagged behind in research and innovation performance and participation in Horizon Europe (HE) and its predecessor programmes (Horizon 2020, FP7)**. These are primarily nations that joined the EU during the **2004, 2007, and 2013 enlargements**, along with older EU members Greece and Portugal, due to their lower R&D performance. All of SynGRID's partner countries: Croatia, Greece and Slovenia are Widening countries.

While the core principles of **Localisation, Prioritisation, and Participation** remain central to all S3 strategies, their **implementation in Widening countries is distinct** due to additional EU policies, funding mechanisms, and capacity-building initiatives designed to bridge the innovation gap. These countries often face **structural barriers** such as **weaker institutional frameworks, limited research infrastructure, low private-sector R&D investment, and fragmented innovation ecosystems**.

To address disparities in research and innovation capacities, Widening countries benefit from **higher allocations from the ESIF** and the **ERDF**, as well as through programs like the **Widening Participation and Spreading Excellence** initiative under Horizon Europe. These additional resources help Widening countries develop and implement S3 strategies more effectively.

SynGRID is actively contributing to this effort through its participation in the Pathways to Synergies call (under the **Widening Participation and Spreading Excellence** programme) which emphasised stronger regional cooperation, capacity building and focuses on emerging sector related to increased renewable energy integration.

4.2.1 S3 in Slovenia

The **Slovenian Smart Specialisation Strategy (S4)**, adopted in 2015 for the **2014–2020 programming period**, was Slovenia's first formal smart specialisation strategy focused on two fundamental EU policy goals: transitioning to a green and digital society. Its core objectives were to drive Slovenia's **green transition** towards a low-carbon, sustainable economy and to promote **digitalisation** by integrating advanced ICT solutions across industries and public services. Additionally, S4 aimed to strengthen **research, development, and innovation (RDI), enhance entrepreneurial capacities, support SME competitiveness, and promote internationalisation** [28].

A key feature of S4 was the establishment of **Strategic Research and Innovation Partnerships (SRIPs)**, which brought together **industry stakeholders, research institutions, and public authorities** to drive collaborative innovation. This approach followed the **quadruple helix model**, which fosters interactions among government, academia, industry, and civil society to create dynamic innovation ecosystems. While it is difficult to isolate S3's contribution to quantitative outcomes, the SRIP framework proved to be highly effective in structuring Slovenia's innovation ecosystem, with **over 59% of all co-financed R&D projects in Slovenia involving SRIP members**, significantly increasing **knowledge transfer and innovation output** [29].

Beyond governance mechanisms, S4 identified **nine priority domains** where Slovenia had a competitive advantage: **Smart Cities and Communities, Smart Buildings and Homes (including the wood value chain), Sustainable Food Production, Factories of the Future (Industry 4.0), Mobility, Sustainable Tourism, Health & Medicine, Advanced Materials, and Networks for a Circular Economy** [30]. In addition to the greening of the economy, Digitalisation was likewise threaded throughout S4, with ICT designated as a key enabling technology across domains (e.g. supporting smart grids, IoT, big data, etc., in sectors from manufacturi [31]ng to energy).

For the second programming period (2021–2027), Slovenia refined its smart specialisation strategy, rebranding it as **Slovenia's Sustainable Smart Specialisation Strategy (S5)** to better align with evolving EU priorities. As part of the strategy update, which involved various stakeholders, including ministries, research organisations, businesses, NGOs, and local/regional actors, Slovenia explicitly **re-oriented S5 around the green transition**, **incorporating sustainability as a fundamental principle** [32]. The adopted S5 is now the guiding framework through 2030 and an enabling condition for accessing approx. 707 million € of Cohesion Policy funding for Slovenia.

Building on the collaborative framework established under S4, **S5 continues to rely on SRIPs as key facilitators** of innovation and policy coordination. While maintaining S4's original domains, **S5 introduces a more integrated approach**, prioritising **cross-sectoral collaboration**, digitalisation, and enhanced stakeholder engagement. Additionally, S5 strengthens the role of horizontal networks and key enabling technologies such as artificial intelligence, automation, and digital twins. Many of S4's priority domains remain, such as Smart Cities, Sustainable Food, Health, etc., but **new emphasis is placed on climate and environmental aspects** within each. **Digitalisation is a central theme in S5**, particularly for businesses and public services. Citizen science and engagement are actively promoted, encouraging public participation in addressing challenges related to green and digital transitions. Regional sectors are encouraged to create ecosystems offering smart, mobile, and digital public services for citizens, businesses, and public institutions.

4.2.1.1 SynGRID's alignment with Slovenia's S5

As described above, besides the general priority of green transition, 10 additional priorities were determined by S5. SynGRID's topic of research, aims and goals can be effectively placed in many of the defined priority areas, but areas that align mostly with the project are **Smart Cities and Communities** [33] (PMiS), **Horizontal Network of Information and Communication Technologies** [34] (ICT Horizontal Network), **Networks for the Transition to a Circular Economy** [35] and to some degree also **Mobility** [36].

Smart Cities and Communities is one of S5's central pillars, addressing the digitalisation of urban infrastructure and sustainable energy management. The strategy explicitly prioritises technologies such as **demand response (DR), DSM, energy management systems (EMS), and distribution management systems (DMS)** and **energy storage** all of which are within SynGRID's technological scope. Through its work on **optimising LV networks, enabling greater RES penetration**, and advancing **flexible demand-side solutions**, SynGRID supports the decarbonisation of cities and the development of intelligent energy systems. These objectives also directly align with the EU Mission: **Climate-Neutral and Smart Cities**. These are precisely the technological areas SynGRID is concerned with.

The **ICT Horizontal Network**, belonging under Smart Cities and Communities, focuses on advancing Slovenia's digital transformation through key enabling technologies (IoT, Cybersecurity, digital transformation, AI and big data), all of which are important for the transition to a real-time or near real-time grid operation. Therefore, the SynGRID's content addresses this priority area well.

In terms of **Networks for the Transition to a Circular Economy**, S5 highlights the integration of green technologies and processes, encouraging industry and research projects that would enable the efficient and sustainable transition of Slovenia towards net-zero goals. SynGRID and its connection to enabling the higher integration of RES can also address this priority area.

Mobility is also tackled in S5 and while it is not SynGRID's primary domain, indirect synergies exist. The S5 details topics that include transforming transport systems, including **electrification, charging infrastructure, and smart mobility services**. The **inclusion of RES** technologies in charging infrastructure, increasing number of EVs and charging infrastructure will not be possible without **advanced LV management**, meaning that SynGRID's work presents potential applications in support of e-mobility and smart energy-transport integration.

In addition, Slovenia is highly promoting international cooperation and explicitly supports **transnational R&D projects**, **participation in Horizon Europe**, and **positioning within European value chains**. SynGRID, funded under Horizon's **Widening Participation and Spreading Excellence programme**, is well-placed to benefit from this policy environment. Furthermore, one of SynGRID's specific objectives ***increasing the participation of SMEs in Horizon Europe*** is also an implicit goal within S5 as it aims to strengthen international R&D cooperation and increase the competitiveness and internationalisation of SMEs.

By analysing the S5, we can claim that EU projects such as SynGRID can **count on national level support, integration, and promotion of the final solutions** to the public and market. The

S5's vision and the goals align perfectly with some of the SynGRID goals, showing the perfect **geographical placement and timing of the project**, creating a sustainable environment where solutions and designs are highly relevant. By collaborating with city authorities, SynGRID can pilot advanced grid schemes knowing it aligns with national strategy.

4.2.2 S3 in Croatia

The first cycle of implementing Croatia's S3 for 2016–2020 was adopted in March 2016 [37]. The strategy was aligned with the EU's 2014–2020 financial framework and served as an ex-ante conditionality for accessing EU funds for research, development, and innovation (RDI). Its goal was to concentrate resources on selected innovation priorities to stimulate private investment, build comparative advantages, and avoid fragmentation of efforts.

The initial S3 focused on targeted support for national priorities, fostering technological and practice-based innovation, encouraging synergy between public R&D, industrial development, and human capital, and engaging stakeholders through the Entrepreneurial Discovery Process (EDP). While many measures are underway, results remain to be fully assessed as most projects are still in progress. Preliminary findings indicate that Croatia continues to lag in competitiveness and innovation despite some improvements.

The new S3 for 2021–2029 builds on lessons learned and aims to contribute to the EU Cohesion Policy objective of "A Smarter Europe." It supports economic modernization and industrial transition, aligned with Croatia's National Development Strategy 2030. The approach considers the real economic context, including the impact of COVID-19, and calls for more precise (granular) interventions, stronger EDP, and flexible implementation.

The S3 marked a new direction within Croatia's innovation policy framework but encountered significant challenges and delays during its rollout [38]. As a concept, smart specialization involves defining national or regional innovation priorities by aligning research and innovation capacities with business needs to foster competitive advantage. In Croatia, the S3 introduced a sector-oriented approach that focused policy interventions around defined thematic and sub-thematic priority areas (TPAs and STPAs). However, the process of adopting the strategy was protracted, with the final document being approved more than two years into the EU's 2014–2020 financial period. This delay postponed access to approximately HRK 6.74 billion in European Structural and Investment Funds earmarked for research, development, and innovation, as adoption of the S3 was a prerequisite for funding. Furthermore, the strategy's intended bottom-up prioritization process struggled to gain traction due to setbacks in establishing the necessary sectoral governance structures.

The integration of sector-specific priorities into Croatia's S3 has been limited, primarily due to delays in establishing sectoral governance structures. While the S3 intervention logic combines broad, horizontal policies with targeted, vertical investments in specific sectors, the links between strategic goals, instruments, and identified sectoral priorities (TPAs) remain unclear. Objectives are often vague, using terms like "quality of life" or "competitiveness" without measurable indicators, making it difficult to assess policy effectiveness. Although the structure of implementation instruments was streamlined during rollout, inconsistencies remain. Many instruments are not clearly linked to objectives or outcomes, and 85% of funding is concentrated on just two of six strategic objectives, raising concerns about achieving the rest. The monitoring framework was revised during implementation but still lacks crucial elements such as targets, milestones, and comprehensive data at the TPA level. This hampers the ability to track progress and address implementation issues effectively.

As per recommendations, Croatia's S3 requires a clearer and more coherent intervention logic that fully integrates its sectoral priorities. The complexity of combining horizontal and vertical RDI policies, alongside both top-down and bottom-up approaches, calls for a more structured and explicit framework. A theory of change should be developed both at the strategy level and for each individual sectoral priority area (TPA), making clear how objectives, instruments, and inputs interconnect. Clarifying the vision and strategic objectives through precise definitions and measurable indicators would enhance the strategy's evaluability. Furthermore, the S3 should better align with other national and sectoral strategies to ensure policy coherence.

The current policy mix and instruments also need refinement. Instruments should be consistently defined, clearly categorized, and aligned with both strategic goals and sector-specific needs identified through the entrepreneurial discovery process (EDP). Institutional support tools should be distinct from those aimed at businesses and researchers, and any changes to instruments must be justified and documented. Stronger connections between instruments and TPA goals would improve policy responsiveness and effectiveness.

The monitoring and evaluation framework must be strengthened to support adaptive implementation. A more consistent system with better-aligned indicators, the inclusion of milestones and process indicators, and plans for quantitative impact evaluations would enable timely adjustments. Moreover, TPA-level indicators should be expanded and standardized, enabling disaggregation across relevant dimensions to better identify implementation gaps and sector-specific challenges.

4.2.2.1 SynGRID's alignment with Croatia's S3

The **SynGRID project** and **Croatia's S3** share a strong thematic alignment, particularly in the areas of energy transition, digitalization, and innovation. Below is an overview of how SynGRID's goals support and complement the strategic priorities outlined in Croatia's S3:

1. **Priority Area: Energy and Sustainable Environment:**
    - **S3** focuses on the development of smart grids, integration of renewable energy sources (RES), and digital transformation of the energy sector.
    - **SynGRID** aims to enhance the controllability and flexibility of low-voltage distribution networks, while promoting better integration of RES and digital tools.
    - Both emphasize transforming energy systems toward sustainable and tech-driven solutions.
2. **Digital Transition and Smart Technologies**
    - S3 direction is to focus on the implementation of advanced ICT solutions and automation in public infrastructure and industry.
    - **SynGRID** focuses on digitizing energy grids using monitoring systems, sensors, and control algorithms and contributes directly to digitalizing one of the most critical infrastructure sectors in Croatia.
3. **Research, Development and Innovation (RDI)**
    - **S3** objective is to strengthen cooperation between universities, research institutions, and the business sector.

- One of **SynGRID** activities is to connect FER and FERIT with other research institutions like IRI UL and ICCS and industry players like Petrol through summer schools, workshops, and joint R&D. The project exemplifies the S3 “triple helix” model (academia–industry–government collaboration).

4. **Smart and Sustainable Infrastructure**
    - **S3** promotes infrastructure that enables higher energy efficiency and flexibility.
    - **SynGRID** delivers real-time management solutions for low-voltage grids, enabling smart local energy systems.
    - Both support the shift toward cleaner, more efficient, and resilient energy infrastructures.

As can be seen, the SynGRID project is **well-aligned with Croatia’s Smart Specialization Strategy**, as it advances innovative and sustainable technologies, strengthens research and innovation ecosystems and operates in a sector strategically identified for national growth and competitiveness.

4.2.3 S3 in Greece

Greece’s Smart Specialisation Strategy (RIS3), initially developed for the 2014–2020 programming period, was designed to enhance the country's innovation ecosystem by focusing investments in areas of competitive advantage. Greece’s RIS3 aimed to shift the economy towards a knowledge-based and innovation-driven model, prioritizing sustainable growth, regional development, and digital transformation. As a Widening country with historically lower R&D performance and participation in EU research programs, Greece was encouraged to focus on targeted investments in key domains where innovation could have the most transformative impact.

The Greek RIS3 framework was structured across national and regional levels, with 13 Regional Operational Programmes (ROPs) complemented by a National RIS3. This dual-level structure enabled both localised tailoring of priorities and alignment with overarching national and EU innovation agendas. The RIS3 identified eight priority sectors: agro-food, energy, environment and sustainable development, transport and logistics, health and pharmaceuticals, ICT, materials and construction, and tourism, culture and creative industries.

The energy sector featured prominently in Greece’s S3, with a strong emphasis on renewable energy technologies (solar, wind, hydro), smart grids, energy storage, and energy efficiency. The strategy recognized the potential of decentralised energy systems and innovation in energy management, particularly given Greece’s geographic characteristics—including its many non-interconnected islands—which pose unique challenges for energy security and integration of renewables.

Smart grids, in particular, were identified as a priority area, with funding allocated to support pilot projects, digital infrastructure development, and the modernisation of distribution networks. The emphasis was on improving grid resilience, reducing energy losses, enabling DSM, and integrating DERs. These goals aligned well with national energy transition policies and the European Green Deal.

For the 2021–2027 programming period, Greece developed a new Smart Specialisation Strategy in line with updated EU Cohesion Policy objectives and the European Commission’s thematic enabling conditions. This new strategy places a stronger emphasis on green transition, digitalisation, and resilience, incorporating lessons learned from the previous programming cycle. A key feature of the updated RIS3 is the increased focus on applied research, industrial modernisation, and the scaling of successful pilot initiatives. In addition, stakeholder engagement mechanisms have been strengthened, aiming for more inclusive governance and enhanced public-private collaboration through innovation clusters and Living Labs.

The revised strategy maintains the energy sector as a pillar of smart specialisation, now embedded more deeply in cross-cutting themes such as climate adaptation, smart mobility, circular economy, and digital twins for energy infrastructure. The RIS3 now also promotes investment in AI, big data, and IoT technologies for smart energy applications, opening new opportunities for interoperability and real-time control across networks.

4.2.3.1 SynGRID's alignment with Greece's RIS3

SynGRID's technological scope and objectives are well aligned with the national RIS3 priorities of Greece, particularly in the domains of energy innovation, smart grids, and digitalisation. The project contributes directly to RIS3 goals related to:

- **Smart Grids and RES Integration**: SynGRID focuses on improving LV grid management, facilitating higher penetration of renewables, and increasing system flexibility—core challenges identified in Greece's S3, especially in remote or weak-grid areas such as non-interconnected islands.
- **Digitalisation of Energy Systems**: Through tools for real-time grid monitoring, demand-side management, and predictive analytics, SynGRID supports Greece's RIS3 push for digital transformation in energy. Technologies such as DR, energy management systems (EMS), and data-driven decision-making platforms are priorities for both SynGRID and RIS3.
- **Support for Regional Development and Islands**: SynGRID's relevance to regional innovation is high, particularly considering the Greek context of decentralised islands and rural areas. These areas face specific energy challenges, and SynGRID's focus on community-based flexibility and grid resilience can be leveraged to support local S3 actions.
- **Capacity Building and Stakeholder Involvement**: As a Horizon Europe project under the Widening Participation and Spreading Excellence programme, SynGRID contributes to capacity-building and cross-border collaboration—both key elements in the new RIS3 framework. The project's emphasis on pilot site demonstrations, SME involvement, and knowledge transfer aligns with Greece's goals of boosting regional R&I ecosystems and fostering inclusive innovation.
- **Circular Economy and Smart Mobility Synergies**: While not a primary focus, SynGRID's work indirectly supports RIS3 domains such as smart mobility and circular economy by enabling smart charging infrastructure for e-mobility and supporting flexible, sustainable energy use across sectors.

By aligning with Greece's S3 objectives, particularly in smart grid development, digital transformation, and regional resilience, SynGRID is well-positioned to **support national innovation policy and contribute to Greece's broader energy transition**. The project also offers a **valuable model for replication and scale-up** in other parts of the country, particularly in island or semi-urban contexts where grid modernization and community engagement are critical.

4.3 Key Findings: How Research Outcomes Support National S3 Strategies

The analysis conducted demonstrates clear alignment between validated research outcomes and the priorities set in the S3 of Slovenia, Croatia, and Greece. These outcomes significantly contribute to innovation objectives defined by each country, particularly regarding the management and flexibility of LV grids, renewable energy integration, and digitalisation of energy systems.

Slovenian partners (IRI, PET) contributed significantly through projects such as **COMPILE**, **X-FLEX**, **STREAM**, and **OPENTUNITY**. Outcomes such as **GridRule** (COMPILE), **MarketFLEX** and **GridFLEX** (X-FLEX), and solutions like **sGRID** and **sPLAN** (STREAM) strongly support Slovenia's Sustainable Smart Specialisation Strategy (S5). These outcomes directly target the "Smart Cities and Communities," the "ICT Horizontal Network," and the "Networks for the Transition to a Circular Economy" priorities outlined in S5. Specifically, these validated solutions enhance local energy management capabilities, facilitate the creation of community-based energy markets, and improve observability and control of LV grids, fulfilling S5's objectives of digital transformation and green transition.

Croatian partners (FER and FERIT) were involved in projects such as **FLEXIGRID**, **DINGO**, **USBSE**, **ProPowerNet**, and **REANIMATION**. Key outcomes include the **Virtual Thermal Energy Storage Module** from FLEXIGRID, the **GIS Data Processing and ML-based Phase Detection tools** from DINGO, and advanced simulation models from ProPowerNet for optimising prosumer-rich distribution networks. Additionally, battery storage prototypes from USBSE align closely with Croatia's S3 goals. These outcomes support the national S3 areas of "Energy and Sustainable Environment" and "Digital Transition and Smart Technologies" by enabling advanced monitoring, flexibility provision, and improved LV grid management, which are critical for Croatia's energy transition and infrastructure modernisation efforts.

Greek partner ICCS actively contributed to projects such as **COMPILE**, **X-FLEX**, **RE-EMPOWERED**, and **OPENTUNITY**. Notable validated outcomes include **ecoMicrogrid** and **ecoDR** from RE-EMPOWERED, focusing on community-scale energy management. Additionally, ICCS contributed to the **MarketFLEX** platform within X-FLEX, piloted notably in Greek contexts. These outcomes align explicitly with Greece's RIS3 focus on decentralised smart grid management, digital innovation, and renewable integration. Given Greece's particular focus on island and semi-urban contexts, these tools directly contribute to the regional development goals set within the RIS3 framework.

5 Conclusions

This deliverable first identified relevant research outcomes from EU funded and national projects involving SynGRID partners, specifically focusing on their relevance to the management of LV grids. These projects addressed key domains previously identified in **Deliverable D2.1**. The next step involved a thorough analysis of **S3s in Slovenia, Croatia, and Greece**, as well as the alignment of SynGRID's activities and goals with these national strategies. Finally, the deliverable aligned the validated research outcomes with the identified objectives and focus areas of the S3s.

The key achievements from this analysis include the identification of advanced methods and tools that improve management of LV grids, renewable energy integration, flexibility services, and the digitalisation of energy systems. It was confirmed that these validated research outcomes closely align with national and regional **S3 priorities**, thus strengthening local innovation efforts.

Insights from these research outcomes and the analysis will guide SynGRID's future activities by informing the identification of **funding opportunities in Task 2.3**. These insights are valuable as they highlight specific areas where the SynGRID project can provide **significant value**. They also help identify domains that have previously benefited from research and development efforts by SynGRID partners, suggesting opportunities for **further expansion** and bringing these solutions **closer to market maturity**, especially in WP3 where the insights will support the preparation of new project proposals.

Despite considerable progress, several key challenges remain, as previously identified in **Deliverable D2.1**. There is still **limited deployment and scalability** of advanced LV management solutions across various regional contexts. **Regulatory and market barriers** continue to hinder widespread adoption of flexibility solutions. Furthermore, innovative digital grid management tools require **extensive validation and testing** in real-world environments to ensure reliability, security, and cost-effectiveness.

Moving forward, SynGRID will specifically target these challenges, enhancing the **scalability, adaptability, and market-readiness** of validated research outcomes to maximise their impact at both regional and EU-wide levels.

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6.2 Acronyms

Acronyms list	
ACER	Agency for Cooperation of Energy Regulators
BMS	Building Management Systems
DER	Distributed Energy Resources
DMS	Distribution Management System
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
EC	European Commission
EMS	Energy Management System
ERDF	European Regional Development Fund
ESIF	European Structural and Investment Funds
HE	Horizon Europe
HEMS	Home Energy Management System
ICT	Information and Communication Technology
IoT	Internet of Things
JRC	Joint Research Centre
LV	Low voltage
LV	Low Voltage
MV	Medium voltage
MV	Medium Voltage
PV	Photovoltaic
RDI	Research, Development, and Innovation
RES	Renewable Energy Sources
RIS3	Research and Innovation Strategies for Smart Specialisation
RTTR	Real-Time Thermal Rating
S3	Smart Specialisation Strategy

S4	Slovenia’s Smart Specialisation Strategy
S5	Slovenia’s Sustainable Smart Specialisation Strategy
SRIP	Strategic Research and Innovation Partnerships
TRL	Technology Readiness Level
TSO	Transmission System Operator