OSMOSE

Executive summary

OSMOSE
OPTIMAL SYSTEM-MIX OF FLEXIBILITY

Project key figures

START DATE

January 2018

END DATE

April 2022

TOTAL BUDGET

27,2 M€

EUROPEAN GRANT

21,2 M€

33 partners

INCLUDING ACADEMICS, TRANSMISSION SYSTEM OPERATORS, EQUIPMENT MANUFACTURERS, RENEWABLE ENERGY PRODUCERS, AGGREGATORS AND IT EXPERTS.

9 countries

COORDINATOR

RTE, France

Figure 1. OSMOSE partners by country.

BELGIUM

FRANCE

ITALY

GERMANY

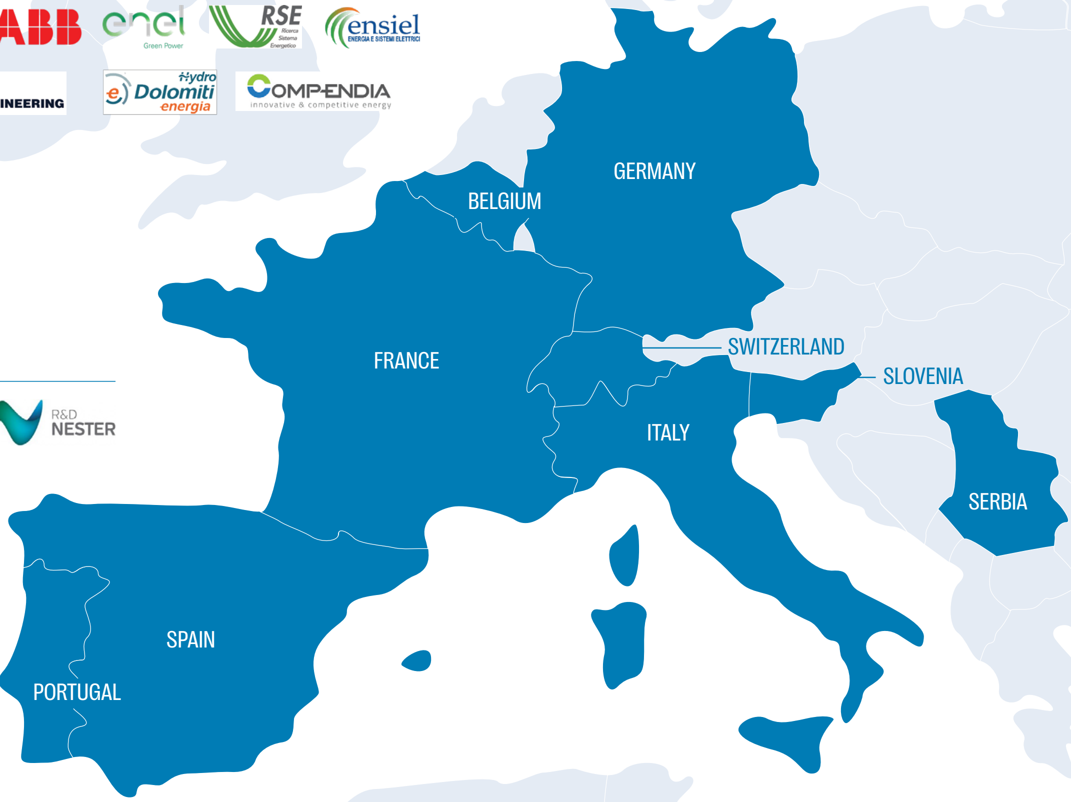
PORTUGAL

SLOVENIA

SERBIA

SPAIN

SWITZERLAND



Executive summary

The OSMOSE project aimed to improve the understanding and consideration of flexibility needs and resources in future power systems. The 33 partners implemented four large-scale demonstrators under the leadership of Transmission System Operators (TSOs). In parallel, they worked on three theoretical Work Packages (WP) dealing with modelling and standardization.

Figure 2. OSMOSE Work packages and demonstrators' main features.

WP1. Optimal mix of flexibilities

System planning models | 2030-2050 scenarios

WP2. Market designs & regulations for optimal development of flexibilities with high RES shares

Forecast errors | Market models

WP7. Scaling up and replication

Interoperability | TSO-DSO coordination | BESS design & data analytics

Demo WP3

Grid forming for the synchronisation of large power systems by multi-service hybrid storage

Supercapacitors 1 MW-10 s

0.5 MVA-60 min Li-ion battery

Ingeteam lab

720 kVA/560 kWh LTO battery

25 kWh LOT battery

EPFL campus

Demo WP6

Near real-time cross-border energy market

Soverzene plant

20 MW

ENEL

Santa Massenza plant 70 MW

HDE

DEM, TES and SENG plants

135 MW

HSE

High voltage grid

TERNA & ELES

Demo WP4

Multiple services provided by the coordinated control of different storage and FACTS devices

STATCOM 4 MVar

Supercapacitors 0.8 MW

1500 V Li-Ion batteries (2 MW/0.5 MWh)

CENER 20 kV grid-connected facilities

Different batteries

Demo WP5

Multiple services provided by grid devices, large demand-response and RES generation coordinated in a smart management system

5 industrial consumers

~120 MW of flexibility

2 wind farms - 53 MW

+1 battery (2 MW - 2 MWh)

ENEL, E2i

7x150 kV lines

Dynamic Thermal Ratings

TERNA

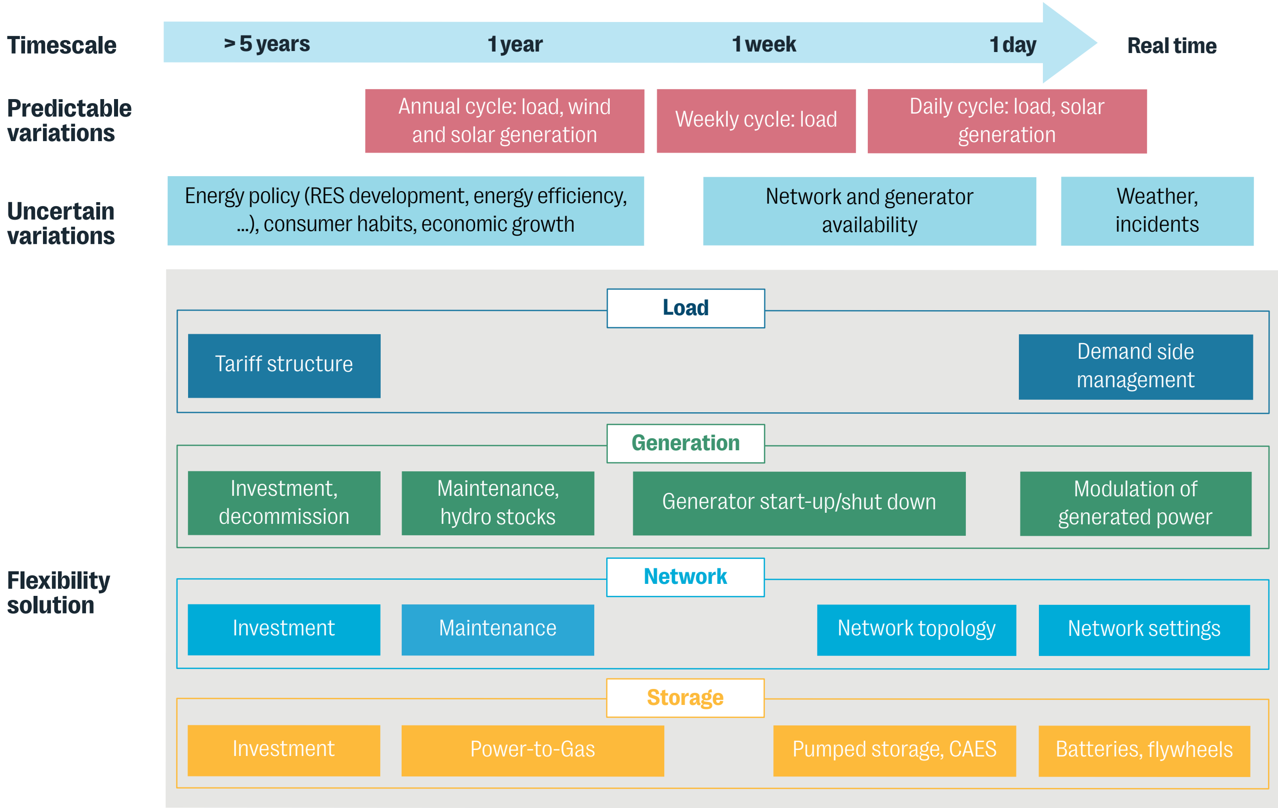
Many definitions of flexibility exist in the literature, some focusing only on short-term issues, others covering only specific flexibility sources like demand. On the contrary, OSMOSE promoted a holistic definition of flexibility: “power system flexibility is understood as its ability to cope with variability and uncertainty in demand, generation and grid, over different timescales.” Indeed, all the time horizons are fundamentally interrelated and all the components of the system can contribute to its flexibility. A global understanding is thus critical to capture synergies.

The power system has always required flexibility to address uncertainty and variability and, in the past, it was mainly provided by thermal and hydro plants. However, the on-going evolutions are triggering both new needs and new sources of flexibility:

- ✓ Renewable Energy Sources (RES) drastically reshape the variability and uncertainty in the system but they can also contribute to its flexibility.
- ✓ Inverter-based generation replace the synchronous generators, challenging system stability but also bringing new opportunities of fast and advanced controls.
- ✓ New electrified end uses - heating, mobility – can create additional load peaks but can also provide flexibility if managed in an intelligent manner.
- ✓ Large storage solutions are becoming more competitive, offering new perspectives for flexibility provision.
- ✓ Advanced automation and control technologies enable smarter and faster activation of flexibility solutions.

The OSMOSE project contributed to shape the future system flexibility by demonstrating some of these new technological solutions and understanding future needs and resources in prospective scenarios.

Figure 4. The flexibility question across time horizons.



Demonstrating Battery Energy Storage System and converters flexibility

Battery Energy Storage System (BESS) are technically very efficient in providing support to the system thanks to their high flexibility. However, their high cost compared to other flexibility solutions remains a barrier to their deployment and some of their capabilities were still to be investigated. In that perspective:

- ✓ WP4 demo developed a **new hybrid flexibility device** integrating a utility-scale lithium-ion battery, supercapacitors and a modular multilevel static compensator. Its architecture used standard components able to reach higher voltages, reducing current and therefore losses, allowing flexibility and compactness.
- ✓ The **lithium-ion battery,** developed within the project, **supplies high-voltage power output** (1260 Vdc), enabling significant cost and power loss reductions, as well as enhanced power quality.
- ✓ **WP4 and WP3 both demonstrated advanced controls for multi-services provision by BESS.** The first one focused on multiple device coordination and ageing limitation. The second addressed the stochastic behaviour of the services and the real time capability curves of the converter.
- ✓ **WP7 investigated methods to optimise the sizing and the control design of BESS.** A database with **new data analytics tools** was also developed to support the sharing of experience between BESS operators.
- ✓ **WP3 investigated how off-the-shelf converters can contribute to the fundamental stability of the system thanks to grid forming controls.** The ability of grid forming to respond to grid disturbance within 5 ms was demonstrated without impacting the converter size and the provision of other services. Methods to certify and assess the grid forming capability were developed and synchronisation services were defined to feed in future grid codes.

Key takeaways

- ✓ Due to their criticality for system stability, the mandatory provision of synchronisation services should be investigated when it implies no additional cost for the providers. Anticipating their implementation on the converters connected to the grid is necessary to prevent scarcity of synchronisation services in the future European system or high retrofit costs.
- ✓ Battery Energy Storage Systems can now compete with other existing flexibility solutions to support system security and stability. Specific designs and controls tailored for system services make them all the more cost-effective in specific situations such as isolated systems.

Demonstrating RES and industrial flexibility

While the flexibility potential of RES and demand sources is acknowledged in the literature, significant implementation gaps still prevented their effective contribution in the daily operation of the power system. To foster this integration, **WP5 demonstrated in Southern Italy:**

- ✓ **The provision of Automatic Voltage Control (AVC) by wind farms.** An upgrade of two plants' controls enabled AVC, however with some delay of up to 60 seconds in the provision, since the control system had not been originally developed for this type of regulation.
- ✓ **The provision of Synthetic Inertia (SI) by two wind farms.** The main innovation laid in the Synthetic Inertia Control Device (SICD) implemented and the measurement and filtering algorithm to provide response within 500 ms. Laboratory test bench simulations on wind turbine components also provided an insight on the possible inertial-like power contribution a wind turbine could provide for frequency support.
- ✓ **The provision of ancillary services by 5 industrial loads.** Although successful, the required plants' retrofitting was complex and the flexibility that could be activated was rather limited.

In WP6, the near real-time potential of flexibility of hydro producers was explored. New tools were developed and live demonstrated to estimate their remaining flexibility 15 min before delivery time.

Key takeaways

- ✓ The provision of ancillary services by wind farms is technically possible but some implementation gaps remain for their daily effective use. TSOs - through grid code evolution - and manufacturers – through industrial development - should accelerate their efforts to avoid scarcity of ancillary services or high retrofit costs in the coming years.
- ✓ Industrial loads can provide flexibility to the system but with a limited potential due to their already optimised industrial processes and with significant retrofitting challenges. Harvesting this flexibility potential for fast regulations should probably not be the priority in the coming years, while they can be counted on for slower regulations.

Demonstrating grid flexibility and efficient coordination

The grid itself can offer significant flexibility to the system through advanced equipment and controls. The proper coordination of the grid and all other flexibility levers in system operation is key to benefiting from their full potential. In that perspective:

- ✓ **WP5** demonstrated the flexibility potential of the grid thanks to the deployment of **Dynamic Thermal Rating (DTR) in seven high Voltage Lines** in Southern Italy, and the installation of **an innovative smart Energy Management System** (EMS) in the TSO control room.
- ✓ **WP6** demonstrated the possibility of **cross-border flexibility activation near-to-real time while respecting grid limitations.** The developed tools and processes resulted in a real cross-border activation thanks to a selection of bids every 5 minutes and an activation signal sent every 10 seconds.
- ✓ WP7 developed a tool to enhance **voltage control by optimising the flexibility levers at the TSO/DSO interface and at distribution level.**
- ✓ WP7 defined and demonstrated **improvements of the IEC 61850 engineering process** for substations. They standardise the exchange of information between the system operators and the equipment vendors.

Key takeaways

- ✓ Advanced sensors and tools like advanced Energy Management System can improve the operation of the grid in congested areas. They are significant opportunities for TSOs to optimize their operational cost, although their deployment induces challenging adaptations in already complex industrial environment and practices
- ✓ Close to real time cross border exchanges are challenging from an IT perspective but technically feasible while complying with grid constraints and thus ensuring system security. However the economic value of the hydro producers' residual flexibility after existing gate closures remains limited in the actual system. A large deployment of this concept should only be considered when higher RES penetration will call for more close to real time flexibility.

Modelling and quantifying future flexibility

The long-term picture of the contribution of each technology in the future electricity mix is difficult to depict as many uncertainties exist on technologies, social and political orientations. However, advanced quantified studies and simulations are crucial to support investment and market design decisions. In that perspective, OSMOSE worked on enhanced studies and modelling of flexibility:

- ✓ WP1 developed new tools and methods to capture the issues of **flexibility in capacity expansion models** since they turned out to be under-evaluated. **Scenarios for the European System until 2050** were created and provided insights on future needs and sources of flexibility.
- ✓ WP2 achieved significant progress in the **modelling of forecast errors, day-ahead and intraday energy market processes. Simulations of 2030 scenarios** showed the growing role of intraday markets and the contribution of the different flexibility sources to addressing forecast errors.

Key takeaways

- ✓ Advanced simulations of the European power system are essential to support decisions on investment plans, incentives schemes and market design with quantified evidence.
- ✓ All flexibility needs and sources are closely interrelated and should be taken into account in long-term studies. The use of various existing simulation tools is necessary to capture the different aspects of flexibility while considering all time scales (from long-term planning to system operation) and sector coupling.
- ✓ Future policies should ensure the best use of the flexibility potential of power to gas, batteries, RES and grid. They all have a critical role to play in the coming power system and their optimal coordination close to real time brings significant value to address increasing variability and uncertainty.

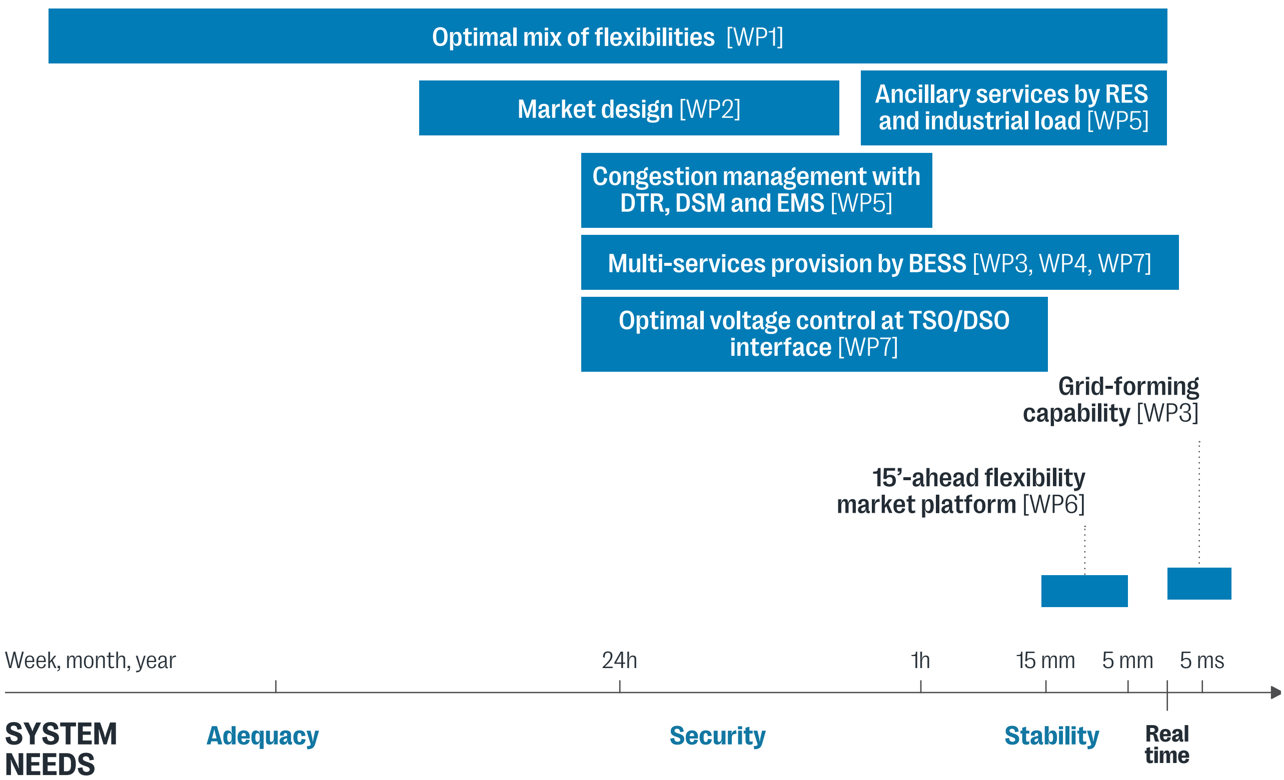
OSMOSE contributed to various and complementary aspects of power system flexibility [Figure 3] showcasing that the decarbonisation of the European power system is at reach: new flexibility challenges are rising but there are many promising options to tackle them. The optimal combination of such options can address the different types of system needs.

Still, the demonstration of some of those innovative solutions highlighted remaining gaps for their effective implementation. They can for sure be solved but TSOs, producers, manufacturers and policy makers need to accelerate their deployment to avoid flexibility scarcity in the coming years and ensure the achievement of EU targets.

The large scale demonstrations also showed that evolutions in the operation of the power system are challenging due to technical complexity, multi-actors involvement and the need of high reliability and security. Efforts should be concentrated on technological or process evolutions that proved the most promising based on quantified impact assessment.

Last but not least, EU projects are a successful example of framework to co-design solutions suitable to address systemic challenges with different actors, each bringing knowledge on its constraints and opportunities.

Figure 3. Summary of the flexibility issues addressed by OSMOSE depending on their time horizon ahead of real-time system operation.



What did you learn? What's your next step?

Partners words

Nathalie Grisey
RTE
Project coordinator

Carmen Cardozo
RTE
WP3 leader

“RTE’s understanding of the possibilities and challenges of providing grid forming capability with inverter-based resources has significantly progressed thanks to the collaboration with the manufacturer Ingeteam and EPFL in OSMOSE. This dialogue is essential to define suitable specifications that lead to a technical feasibility and economic viability of this technology. The results will directly support our discussion with other TSOs and manufacturers regarding future grid codes requirements to ensure power system stability.
On the modelling part, the progress made in OSMOSE for flexibility and market modelling will feed in our current and future tools to analyse the European power system with an improved holistic view.
Finally, the demonstration of a near real-time cross border energy echanges at the Italy -Slovenia border is a great source of inspiration for us to think the future of optimised system operation.”

Miran Kavrečič
HSE
WP6 Task leader

“The possibility to actively participate in OSMOSE gave HSE the opportunity to work with flexibility providers, researchers and TSOs in a different way. The project was an icebreaker in terms of Horizon projects for HSE, enabling the company to put itself on the map of organisations which not only participate in the market but also contribute to rethinking markets of the future. HSE contributed to the pilot test of the near-to-real time cross border FlexEnergy market. Flexibility is one of the future challenges and assessing it near-to-real time on a portfolio of large power plants is both a challenge and an opportunity for us.”

Yves-Marie Bourien
CEA
WP7 leader

“The WP7 activities within OSMOSE confirm that the coordination between the different stakeholders and components of a flexibility device is of major importance to gain time, efficiency and knowledge. It is true for installing intelligent electronic devices from different vendors, for optimally using the flexibilities into the distribution grid, for getting the best operation of the BESS during the longest possible time and for addressing the different services by a BESS with the right sizing and the optimal energy management. OSMOSE enabled to push some developments, and some more will be required in the near future.”

Joaquin Álvarez Agudo
GPTech
WP4 task leader

“In OSMOSE WP4, GPTech has gone through a complete manufacturing process, overcoming most of the scaling up challenges. With the tests on field, connected to a real High Voltage network, GPTech has achieved a high TRL, close to the commercial phase, which is a key milestone on our HV line of innovation.
With OSMOSE and end users, such as REE, GPTech has built a fully functional equipment, capable of integrating multiple energy storage systems and improving electrical grids based on the development of an innovative power electronic architecture focused on network stability.”

Jens Weibezahn
TUB
WP1 leader

❝ The OSMOSE project gave us the opportunity for a very fruitful collaboration between industry and academia. In WP1 we were able to refine methodologies of existing modelling frameworks as well as develop new frameworks -like AnyMOD.jl- to investigate impacts of a high or full share of renewables on energy systems, the interaction of sector integrated systems, and the need for and behaviour of supply side and demand side flexibility. We identified the interplay of long-term investment optimisations and short-term dynamic simulations as a critical factor for a robust system assessment. The exchanges within the team have shown this in data validation loops and regional/local studies. The developed frameworks, data, and results are now provided to the energy research community and industry in an open manner and will be highly valuable for future studies and projects. ❞

Leonardo Petrocchi
Terna
WP5 leader

❝ OSMOSE Italian demonstrator provided a better understanding on what TSOs should expect from future flexibility resources. Tests results will be helpful to update existing grid codes and guide new pilot projects: a smart grid management, supported by capital-light solutions such as Dynamic Thermal Rating and short-term forecasting, is key to the full exploitation of existing assets. This can be of support to the planning of key infrastructures to be realised in the future. Wind farms showed to be a promising addition for future system stability, while industrial DSR should be considered only for slower balancing services: indeed, flexibility needs can be met not by just one technology, but by a well-balanced mix of all. ❞

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