# D1.7: Final Project Report 2

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**Abstract:** This deliverable includes a publishable summary of the most important results and lessons learnt from the INTERRFACE project

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# EXECUTIVE SUMMARY

The future of the European energy system has embarked into ambitious energy transition targets towards Net-Zero carbon emissions by 2050. Targets that are ratified by several initiatives such as Fit for 55[1] and REPowerEU[2], and oncoming Network Codes and Guidelines on Demand-side Flexibility[3]. This journey has far-reaching implications for the evolution of electricity systems, having at its core the integration of significant shares of renewable energy sources and the decarbonisation of various sectors through sector coupling initiatives.

In this journey, system operators will face new challenges requiring greater coordination and collaboration in the procurement of ancillary services for an effective and reliable operation of the electricity network. Striving for an optimal TSO-DSO coordination, the INTERRFACE project plays an important role aiming to improve cooperation among system operators providing access to services which are commonly beneficial for the secure operation of their systems.

This document includes a short summary of the most important results and lessons learnt from the INTERRFACE project and revolves around 3 main pillars: (i) the demonstrators of INTERRFACE, (ii) the scalability and replicability considerations of the IEGSA platform and (iii) the recommendations towards policy makers and suggestions for the upgrade of European Network Codes.

[1] Fit for 55 - The EU's plan for a green transition Fit for 55 | Consilium (europa.eu)
[2] REPowerEU: affordable, secure and sustainable energy for Europe REPowerEU | European Commission
[3] Network Codes (entsoe.eu): https://www.entsoe.eu/network_codes/

# 1 INTRODUCTION

With the growth of renewables, the increased interconnection of European grids, the development of local energy initiatives, and the specific requirements on TSO – DSO cooperation as set forth in the different Network Codes and Guidelines, TSOs and DSOs face new challenges that will require greater coordination. The European Commission adopted legislative proposals on the energy market that promote cooperation among network operators as they procure balancing, congestion management and ancillary services. The measures encourage procurement of services at both the transmission and distribution level, recognizing that this will enable more efficient and effective network management, will increase the level of demand response and the capacity of renewable generation. TSOs and DSOs must now define the services they want to procure in collaboration with market participants, and must set up ways to procure them in a coordinated manner. Digitalisation is a key driver for coordination and active system management in the electricity grid, enabling TSOs and DSOs to optimise the use of distributed resources and ensure a cost-effective and secure supply of electricity but also empowers end-users to become active market participants, supporting self-generation and providing demand flexibility. To support the transformation, the INTERRFACE project will design, develop and exploit an Interoperable pan-European Grid Services Architecture to act as the interface between the power system (TSO and DSO) and the customers and allow the seamless and coordinated operation of all stakeholders to use and procure common services. State-of-the-art digital tools will provide new opportunities for electricity market participation and thus engage consumers into the INTERRFACE proposed market structures that will be designed to exploit Distributed Energy Resources.

A key principle of INTERRFACE is to "remove barriers" to unleash the potential of the existing and future energy resources to be active in the power system for the benefit of the customers and grid operators. It will demonstrate new concepts by deploying pan-EU markets that provide services for congestion management and flexibility, by using micro-grids and peer-to-peer transactions to engage consumers, and by creating a platform for further research.

INTERRFACE will provide: (a) *new services,* market rules and coordination functions for pooling and allocating distributed flexibility, (b) innovative digital *technologies* to facilitate the transition to the next generation grid services in a cost-effective and coordinated manner; (c) *advanced information and communication technologies* to support the plug-and-play integration of different services and tools (existing and newly developed within the project) into an IT platform that will enable the utilization of IEGSA; (d) *data models* to support the data governance structure and confidentiality, thus ensuring and enabling the secure exchange of heterogeneous data generated by different actors, in a unified way; (e) *changes and evolution of roles* within the energy value chain, in particular upscaling the role of customers, taking into consideration the actors' and markets' needs and capabilities.

## 1.1 Purpose and Scope

This document includes a short summary of the most important results and lessons learnt from the INTERRFACE project and revolves around 3 main pillars: **(i) the demonstrators of INTERRFACE, (ii) the scalability and replicability considerations of the IEGSA platform and (iii) the recommendations towards policy makers and suggestions for the upgrade of European Network Codes.**

INTERRFACE featured 7 large scale demonstrators in 9 European Countries, namely: Estonia, Finland, Latvia, Italy, Bulgaria, Slovenia, Hungary, Greece and Romania. The demos are divided into three Demo Areas: Congestion Management and Balancing Issues, Peer-to-Peer trading and Pan-EU clearing Market.

This is presented in Figure 1 below.

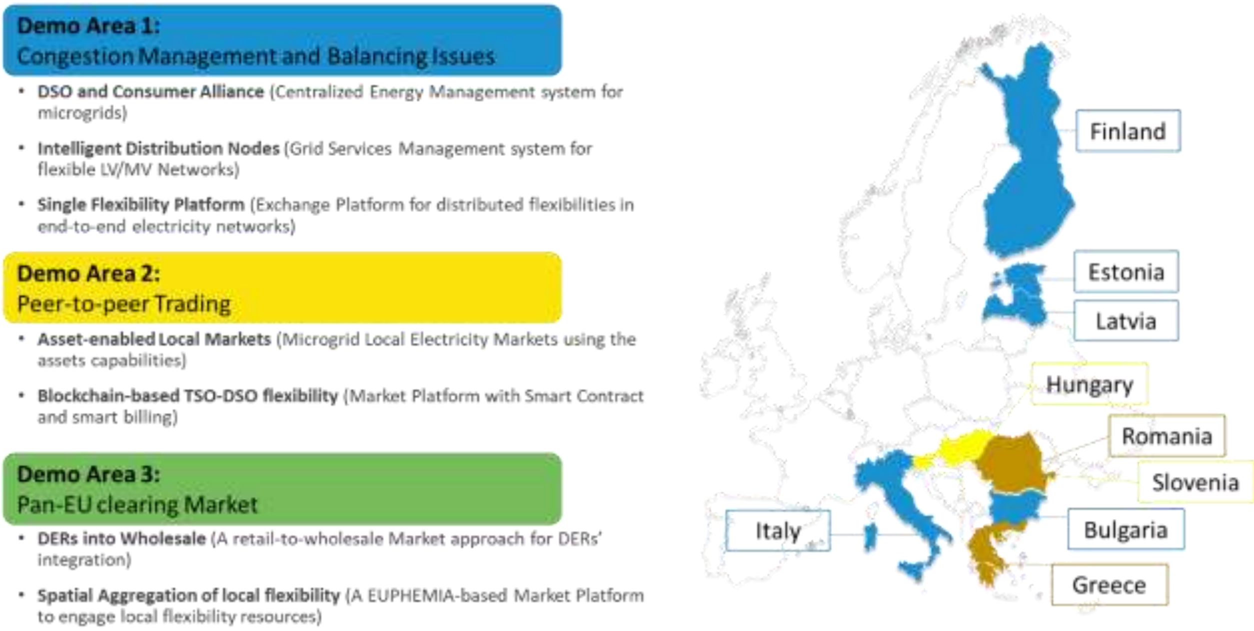


Figure 1 INTERRFACE Demo Areas and Demonstrators

Towards the end of the project, the main results that were identified from each one of the 7 demonstrators were evaluated and lessons learnt were extracted. These were presented in dedicated deliverables, one for each demo Area[4]. Moreover, a detailed scalability and replicability analysis for the IEGSA platform was performed addressing the gaps that currently exist and the barriers that IEGSA needs to overcome in order to achieve commercialization[5]. Finally, based on the experience gained through the activities of INTERRFACE recommendations were provided towards regulators and policy makers and proposals for the update of the network codes mostly focusing on demand-side flexibility and interoperability and data access[6].

## 1.2 Structure of the Document

Chapter 2 provides the main lessons learnt from the 3 Demo Areas. Chapter 3 deals with the replicability and scalability considerations of IEGSA and provides the main conclusions that were extracted. Finally, Chapter 4 provides the recommendations to policy makers and regulators and proposed updates for network codes.

[4] INTERRFACE Deliverables (D5.6, D6.5, D7.4)
[5] INTERRFACE Deliverable D9.13
[6] INTERRFACE Deliverable 9.14

# 2 Lessons Learnt from the Demonstrators of INTERRFACE

## 2.1 Demo Area 1: Congestion Management and Balancing Issues

The three demonstrators under this demo thematic area, which were piloted in a total of five countries, allowed the evaluation of a diverse set of business use cases centred on the overall theme of congestion management. Moreover, additional streams to extract the value of flexibility while using IEGSA and other bespoke technologies and approaches developed within the project were explored.

While there were some technical issues encountered during the piloting activities, the business use case validation was deemed as successful. It was shown how congestion management could be provided efficiently and innovatively, combining it with other services (i.e., allowing the resources not to be locked in solely for one service provision, but enabling their participation in several). Moreover, a level of coordination between marketplaces was achieved, and an efficient pre-qualification algorithm was implemented for improved TSO and DSO coordination.

The most important technical innovations achieved during the project are related to IEGSA and its components, especially the Flexibility Register, TSO-DSO Coordination, and the Single Interface to Market. While the SFP demonstration was most closely integrated with IEGSA and consequently could provide the most thorough testing of its processes, there were also innovative solutions developed to address the specific needs of other demos, such as the Information Hub for the IDN or the SW platform for the DSO and Consumers Alliance demo.

When looking at the demo results individually, some of the most important outcomes are as follows:

- DSO and Consumers Alliance demo validated short-term congestion management using distributed generation; namely, a CHP plant (with a TES system), low-voltage power quality improvement using a battery aggregator and demand response as well as renewable energy-producing local energy community smart coordination to reduce the reverse power flows into the TSO network.
- The Intelligent Distribution Nodes demo validated the IDN concept, which enabled its users to achieve efficient energy use while minimizing its costs. Additionally, it demonstrated how the IDN could be used for the operational CM service in two different ways – automatically and manually. Similarly, it was shown how the same resources (IDN and the BESS within it) could also be exploited for TSO needs, i.e., for the balancing (frequency restoration) service. In general, the IDN management system developed allows for diverse flexibility value extraction and also provides valuable additional tools for its users.
- The Single Flexibility Platform demo validated the use of existing mFRR and intraday marketplaces to provide also bids for novel congestion management services, both within the short-term and operational framework. It was found that minimum additional technical developments are needed to enable such a functionality (mostly related to additional locational properties for bids and bid forwarding). The SFP also showed how IEGSA and its processes could be used to perform resource and bid grid qualification to ensure that, for instance, TSO balancing market bid activations from resources connected to the distribution grid does not cause infeasible conditions within the DSO network.

A common takeaway of the aforementioned demos is that IEGSA can facilitate the uptake of flexibility resources. Moreover, flexibility utilization is enhanced when the same resource can be used for several services (e.g., for both congestion management and balancing).

While the current need for flexibility is varied across the regions, the future development trajectory of the European energy system does indicate that flexibility of all types will become increasingly required. To this end, the INTERRFACE project has provided an excellent starting point.

## 2.2 Demo Area 2: Peer-to-Peer Trading

The two demonstrators under this demo thematic area, which were piloted in a total of two countries, allowed the evaluation of a diverse set of business use cases centred on the overall theme of peer-to-peer trading. Moreover, additional streams to extract the value of flexibility while using IEGSA and other bespoke technologies and approaches developed within the project were explored.

Regarding Demo "Asset Enabled Local Markets", the aim of this demo is to create an asset-enabled local electricity market which considers distribution grid's state during the trading process and facilitates transactions beneficial for the reliability and security of supply. To this end, a simulated local Peer-to-Peer (p2p) market operating on real metering and grid data enables consumers to buy electricity from other local parties regardless their local utilities/supplier. Also supporting the exchange of energy of grid users having small RES-production units with other parties in their local network. Local market aims at minimizing undesired effects of local grid transactions by the application of Dynamic Network Usage Tariff (DNUT). Congestion management through DNUT reduces tariff on local transactions to solve congestions locally in benefit of network flows.
In addition, the pilot uses additional grid information from an Integrated Asset Condition Management System (IACMS) which constantly monitors critical network elements and provides real-time estimations about their actual loading levels. This approach helps both solving congestions and reducing network losses while contributing to the voltage stability of the distribution grid.

The following are main lessons learned out of this pilot demonstrator:

- The provision of data, particularly network data is fundamental for system operators to control and coordinate their actions. At European level, it is conceived that in the future, several local P2P markets will be established and therefore, system operators (TSOs and DSOs) will require a single interface (IEGSA) for the optimal exchange of grid information, and towards other market parties as well. Network data exchanges not only for the efficient allocation of market exchanges but also related to topological changes in the grid, should automatically be handled by IEGSA.
- Currently, several DSOs have their own "sign-in" web-based solutions. This helps to the effective communication between grid users and local DSOs. Simulated P2P market also employs user interface where the local market platform acknowledges or refuses user registration. Registered users are recognized through their grid connection point and other data. The verification process is based on a database provided by the DSO as part of the initialization step listing grid users with connection points and other parameters stored in the flexibility register of the IEGSA platform. On a larger scale, flexibility register should be capable to handle significant amount of grid users with sufficient efficiency and security levels.
- Distribution system operator will also share metering data through IEGSA within which historical metering data should remain available for post-operational evaluation. In addition, market results shall also be forwarded to IEGSA, and stored in the flexibility register for the settlement process as well.
- There should be a level of communication of real-time data implemented by IACMS between IEGSA towards relevant distribution system operators. This ensures the automatic and proper representation of the network condition in the marketplace.
- In the following paragraphs some key-takeaways are summarized:

Regarding the Demo "Blockchain-based TSO-DSO flexibility":
i. As power flows become more intermittent and more unpredictable, networks will have to tackle congestion related issues such as feeder overload management and voltage management. If 100 MW of balancing power is requested today, it might be distributed across 5-10 medium-sized generators. If the same volume will be requested in 5 years´ time, it might be distributed across 100-1000 small generators,

including batteries operated by households. **With flexibility control in hand of multiple owners, documentation, transparency and automation are of crucial importance**. Here, Blockchain-based TSO-DSO congestion management at the grid level **supports the complex communication and cooperation of many stakeholders or assets avoiding bottlenecks** at the distribution grid level.

ii. There is a strong need to empower small and medium players to participate in the marketplace through the provision of flexibility services. Here, the automated storage of transactions on Blockchain enables simple billing, which otherwise would be complex to achieve manually. Payment to small/medium sized generators or load centers for their services in the form of tokens increases overall market efficiency. Tokens stimulate behavior beneficial to the grid in the form of flexibility and allows it to be quantified and billed at the same time. **Additionally, the involvement of prosumers opens up the value of their assets, thus reducing intrinsic market entry barriers.**

iii. Finally, the marketplace (EFLEX) **digitizes the procurement process** to make it easier for aggregators and flexibility providers to view the **local opportunities** and to participate in the procurement process. There are several aspects of trading process that brings efficiency (e.g., asset registration, validating assets' metering data and settling the associated financial operations is performed end to end using Blockchain based smart contracts and distributed ledger technology)

The main lessons learned out of the "Blockchain-based TSO-DSO flexibility" pilot demonstrator are:

- With the increasing climate risk and higher electricity cost people are transitioning to renewables and clean local energy. To meet the demand for renewable energy there is a need to accommodate decentralized energy system which comprises the energy produced from DER's. To support such a system and improve the coordination between the actors involved, a platform like EFLEX plays a crucial part in helping achieve this transition.
- Flexibility marketplace like EFLEX digitizes the procurement process to make it easier for aggregators and flexibility providers to view the local opportunities and to participate in the procurement process.
- P2P trading is expected to give multiple benefits to the grid in minimizing the peak load demand, energy consumption costs, and eliminating network losses. However, installing P2P energy trading on a broader level in electrical-based networks presents a number of modeling problems in physical and virtual network layers.
- To achieve an integrated European market, and to reduce market-entry barriers for suppliers, aggregators, prosumers and SOs, the platform should integrate interoperability both regarding data formats and functionalities.
- With the arrival of renewables and smart grid technologies additional functionalities are added to DSO's role. First, they have to manage local markets in the distribution system level and second, handle the data received from smart meters and utilize them for the purpose of forecasting, risk management, scheduling and planning of distribution systems. DSO's will benefit with the successful deployment of EFLEX interface which encompasses the above-mentioned features.
- Coordination between SO's is necessary to efficiently deal with the interaction between different use options for flexibility, to ensure the optimal utilization of flexibility services and to avoid counterproductive behavior.
- The technology platforms need to be updated regularly with every new change or release. It is necessary to keep up with the rolling changes since they come up with performance improvements and bug fixes. EFLEX has multiple modules with its own technology stack and the modular approach helps for seamless upgrades. The modular architecture not just helps with efficient updates but plays a major role in scaling.
- On a bigger scale, when there are more users and thousands of transactions happen, the platform should be capable of handling significant amount of grid users with sufficient efficiency and security levels.

- For a P2P platform to be successful, it is crucial that people must be educated and their awareness on new technologies must be increased, providing incentives to accommodate devices such as smart meters.

## 2.3 Demo Area 3: Pan-EU Clearing Market

In this demo area there were some key findings regarding the integration of the markets that could become the basis for the design of future markets. Both demos that were involved in this thematic area and run in three countries in total resulted in the following key lessons learned and recommendations.

i. The preferred method to include spatial dimension and its resolution: Zonal representation is favoured to align the local flexibility and DER focused markets' algorithm to the existing, single day-ahead market auction framework (EUPHEMIA-type market optimization).
ii. The resulting single market framework is sensible and intelligible for all market players and includes the DSO specific congestion management services with well-known energy trading auctions.
iii. Consideration of congestion management services as additional market product, compatible with a multitude of use cases: single product – multiple (grid) services
iv. Increased DERs participation at a pan-European level requires the harmonisation of product definitions and effective interoperability among different markets to unlock DERs full flexibility potential
v. Market algorithm scalability: leverage on existing auction platforms – additional technical constraints can be introduced
vi. IEGSA scalability: increased computational performance and data handling capabilities; operational processes will compute significant amount of data; suitable data plaforms are critical elements of energy markets.

Main Considerations of "DERs into Wholesale" Demo:
In this demonstrator, the experience gained during the demonstration period has been reviewed and evaluated to provide recommendations for improving the pan-European electricity market. The market effects from the active participation of DERs in the market operation are presented and evaluated. The evaluation in this task has been conducted in coordination with WP3 on market design to provide a detailed roadmap of how the demo benefits satisfy the customer needs and will be channeled into a future pan-EU market evolution plan.
Based on the results obtained, there is significant potential for DERs' market penetration. Apart from their participation in the balancing market by providing upward and/or downward through the charging-discharging cycle of both ESSs and EVs, their role is also important in the coverage of operational congestion management capacity services at both TSO and DSO levels. Depending on the net demand level of each system having an impact on the number and the operational capacity level of the online nuclear and hydrothermal power units, the amount of CO2 emission and natural gas fuel price affecting the economic competitiveness of the thermal power units, as well as the level of interconnection capacities providing flexibility for increased cross-border trading, DERs can play a decisive role on the coverage of the congestion management capacity services which can reach 100% of the total in several cases. In addition, in the absence of significant hydropower resources, the market participation of DERs is of paramount importance for the procurement of congestion management capacity services in future power systems with a high percentage of RES. Under cases of significant RES availability leading to days of very low net demand, the market participation of DERs is considered necessary for the full satisfaction of downward congestion management capacity services. In addition, when the interconnection capacities with the neighboring power systems are not very extensive, the participation of DERs in the TSO-based services creates the need for additional DERs' utilization at a DSO level in order to meet the congestion management requirements. Another important aspect concerns the value of CO2 emission and natural gas fuel price, which has an impact on the relevant economic competitiveness of thermal power units.

This can result in either setting all these units offline, creating additional market space for DERs' penetration, or making those units operational at very low levels, close to their technical minimums, leading to increased downward services requirements to be supplied by DERs.
Last but not least, the operational mode of nuclear power units is of great significance to the power systems operation. If they continue to operate only for energy needs at their total capacity, as is currently the case in the SEE power system, they run the risk of getting offline in the balancing market of high RES power systems due to the high requirements for ancillary services. This includes even more opportunities for DERs' participation in the relevant markets.
To sum up, each EU country must carefully design its own energy mix based on the available resources and interconnection capabilities. However, it is important to stress that under the market coupling concept, more systematic coordination of the overall EU electricity supply security must be executed through more systematic EU monitoring of the National Energy and Climate Plans' design to form complementary energy mixes to maximize the overall welfare. In addition, the increasing electrification of other complementary energy sectors (e.g., heating and transport) creates additional needs for significant RES investments, which go in line with the increased market participation of DERs.

Main Considerations of “Spatial Aggregation of local flexibility” Demo:
As far as this dmeonstrator is concerned, the zonal approach is the preferred way on the European markets, as the **spatial aggregation of local flexibility shall considers this method even in the case of DSO constraints**, as a possible, manageable, gradual development of the wholesale market – moving away from the disincentivizing copper-plate approach. With the spread of distributed energy sources, this uniform pricing approach does not lead to the desired, market-based functioning of short-term trading, as the socialization of the network constraints through system usage tariffs lead to inefficient incentives in market prices. Exact congestion locations do vary frequently, thus the applied zonal configuration shall be carefully considered. The advantage of using a single market platform for different spatial dimensions is to have a unique and liquid trading platform.
Zonal congestion management with PUN-like pricing has been demonstrated to provide a solution to system operators solving the local congestion issues and providing a way to participate in the wholesale market, simultaneously. **The connection of both the global-TSO and the local-DSO dimension and the joint allocation of energy and local flexibility provides proper price incentives through coupling different slices of marketing platforms and electricity products.**
The actual benefits are shown in the demonstration and further analysed to provide input of the concluding Deliverable D7.3. Also, market description has been elaborated to facilitate the documentation of the detailing work on the demonstration development. **Additional market design features, such as linked optimization of capacity and energy bids have been investigated, and considered and demonstrated to be readily implementable despite the algorithm complexity, in an exclusive linked order type.** This feature however can be further progressed from this substitution model to a full co-optimization.
Demonstration objectives addressed the key drawbacks that are yet to be overcome in the current, wholesale focused and energy-only market design. Too much complexity would have resulted in infeasible requirements for the animating algorithm and IT platform. New technology and power system specific constraints however are proved to be readiliy introduced to the almost decade-old integrated implicit cross-border auction based market coupling solution, the EUPHEMIA. Holistic mathematical formulation for optimal market outcomes, linking consumers – DSOs – TSOs is possible. The resulting market algorithm is demonstrated to be feasible and computationally tractable, with the added complexity, on real scale (~100.000 bids / auction), market, based on the liquid Romanian DAM, IDM and BAM markets’ depth of order books.

# 3 Main Conclusions of the IEGSA Roadmap

The Roadmap of INTERRFACE on the scalability and replicability of the IEGSA platform, supports the large-scale integration of flexibility resources considered from the viewpoint of IEGSA. It includes an overview of INTERRFACE pilot demonstrators and relevant EU projects where other IT architectures were envisaged to unlock the flexibility potential across Europe. Thus, pathway recommendations serve as a guideline to the deployment of a pan-European IT architecture which combines and considers all local specificities with the aim of an efficient and coordinated procurement of flexibility services. Each national power system has its own distinct characteristics, such as flexibility portfolio, ancillary services and markets maturity, grid interconnections and constrains, etc. It is therefore necessary to implement consistent rules and strategies at the European level in order to maximise the effectiveness of flexibility provision while recognising the local needs and conditions across Europe.

Key messages that are needed to ensure a successful IEGSA Roadmap implementation across Europe are provided below:

1. Role model definition is a crucial aspect for the interoperability of IEGSA. The proper **adoption of role descriptions** defined by HEMRM will allow an efficient interaction and coordination among different actors.
2. Market challenges are inherently tied to the complexity and multiplicity of new and existing products, services, markets, and processes across Europe. While new regulation (e.g., Network Code on DSF) will undoubtedly enable greater compatibility across markets, these new rules may also impose stricter requirements on market platforms. For IEGSA to be scaled up and replicated in the future, a combination of **flexible design, customizability and sufficiently powerful algorithms** will be required to meet these evolving standards.
3. Technical challenges require further alignment and compliance with existing and future **standardisation** activities. Moreover, future IEGSA development should consider alignment with key initiative at EU and International level, such as: DSBA architecture, metadata, IDS information model, etc, to ensure enhanced interoperability.
4. **ICT scalability** aspects are perceived as a natural challenge rather than a limitation. During the implementation phase of IEGSA in a pan-European scale, these aspects will certainly be addressed.
5. **Integration with multiple distributed data exchange platforms** at cross-border or even at cross-sector level. Is also a necessary step for replicability and scalability of IEGSA. The interconnection of such multiple data-exchange platforms and system aims to release data-driven services among the different business actors.
6. **Regulatory compliance** with relevant frameworks is crucial for in replicability and scalability of IEGSA. Regulatory evolutions might also require IEGSA's adaptability when deemed necessary.

To conclude, it is recognised that a successful undertake of the replicability and scalability pathways will require increasing collaborative efforts across member states, national organisations and industry associations which will unlock the full potential of flexibility provisions across Europe, enabling the inclusion of new flexibility products which could be tested and deployed by a future pan-European IEGSA architecture.

# 4 Main Recommendations towards policy makers / proposals for Network Codes Updates

## 4.1 Demand-Side Flexibility

The Clean Energy Package Electricity Directive (EU) 2019/944 called on the Member States to establish regulatory frameworks for the procurement of flexibility by DSOs, including incentives and adequate remuneration to recover reasonable corresponding costs (Art. 32). This aims to improve the efficiency of the operation and development of distribution systems. At the same time, the Electricity Regulation (EU) 2019/943 included demand response, including rules on aggregation, energy storage, and demand curtailment rules as an area for a new network code (or a guideline). This would bring more detailed technical rules to be applied by the Member States in a harmonised way.

An uncoordinated adoption of national rules for flexibility may lead to entry barriers for demand-side flexibility. This report contributes to the debate by addressing the identified issues, following the CEP introduction, based on the developed optimization models and the lessons learnt from the demonstrators of the INTERRFACE project. Our findings are divided into two parts. The first part covers the long-term flexibility use case of network investment deferral, with results coming from our own research and simulation work. The second part covers the short-term flexibility use cases of congestion management and balancing, with results coming from the INTERRFACE demonstrators.

For the long-term use case of flexibility, i.e. network investment deferral, our simulation of the interaction between the DSO and residential consumers showed that there are different regulatory choices that could impact the potential of demand-side flexibility. The key related findings are:

- The cost-reflectivity of distribution network tariffs: We find that introducing explicit demand-side flexibility schemes in combination with cost-reflective capacity-based network tariffs lead to higher welfare gains than when combined with partly cost-reflective demand-side flexibility.
- The compensation levels: The results obtained through the developed models underline that it is difficult for the regulator or the DSO to set the correct level of compensation in the presence of active and passive consumers. For low compensation levels, passive consumers will be only partly compensated for the electricity load curtailment. However, for high levels of compensation, it becomes too attractive for prosumers who will game it and use their DERs against the system needs to increase their individual welfares.
- Voluntary versus mandatory demand-side flexibility: We compared these two schemes based on their potential for realizing welfare gains. The results suggest that regulators and DSOs should consider introducing a mandatory scheme for demand-side flexibility, i.e., mandatory demand-side connection agreements for its customers. The realized welfare gains are higher than when the customers opt voluntarily for such schemes. The applied load reductions take place only during the non-frequent high consumption events and represent a small fraction of the consumers' annual electricity demand.

For the short-term use cases of flexibility, i.e. congestion management, balancing or voltage control purposes, the results of the INTERRFACE demo projects shed the light on some important regulatory aspects to consider:

- Product definition and harmonisation: With the multitude of technologies and their related technical parameters, the experiences from the demos recognise that product definition and harmonisation are difficult tasks, especially when residential users are involved. However, such processes are key to enable the wide participation of actors in flexibility markets.
- The coordination and data exchange between system operators and FSPs: The demos results show that such coordination, which was embedded in grid qualification processes, could help to mitigate

congestion. This aims to ensure operational stability between TSO and DSO networks through evaluating the FSP resources using network information directly from the system operators. On data exchange, the demo results highlight the importance of utilising grid data as part of the flexibility trading to handle network constraints and flexibility needs.

- Flexibility resource register: Such register which collects all the significant data/information of flexibility resource, including spatial information, is crucial to enable TSOs' and DSOs' flexibility procurement from the right locations. The demo results highlight the importance of such register, for example, in the prequalification processes. However, several challenges and open issues have also been identified during the project. These are related to the future scale and functionalities of the register, as well as the proper definition and allocation of related roles and responsibilities.

## 4.2 Interoperability and Data Access

The recast of the Electricity Directive (EU) 2019/944 in the Clean Energy Package entitles the European Commission to adopt implementing acts specifying interoperability requirements and non-discriminatory and transparent procedures for access to metering and consumption data as well as data required for customer switching, demand response and other services. This aims to promote competition in retail markets and to avoid excessive administrative costs for the eligible parties. The development of the first of a series of implementing acts has already started. With the publication of the Fit for 55 Package, the scope of the debate was expanded to increasingly cover cross-sectoral aspects in light of a future energy system integrated with sectors such as buildings or electromobility.

This report contributes to the debate by analysing existing interoperability experiences within and beyond the electricity sector, including in the context of the INTERRFACE demonstrators, and providing a number of policy recommendations.

To contribute to the policy and regulatory debate surrounding the implementing acts on interoperability and data access, we have analysed interoperability frameworks and existing interoperability experiences in the electricity and healthcare sectors. The key findings are:

- The EU implementing acts on interoperability and data access should be ambitious in addressing the multiple dimensions of interoperability. Different multi-dimensional interoperability frameworks exist. While they agree that full interoperability can only be achieved if all dimensions are addressed, they do not agree on either the number of dimensions or on labelling them. We identified commonalities across the frameworks that need to be addressed to achieve full interoperability of energy services within the EU. These are regulation and policy, business processes, information models, data format and communication protocols, use of standards, and interoperability testing.
- Inspiration can be drawn from existing experience with interoperability in the electricity and the healthcare sectors. The experiences of the North American Green Button initiative with utility customer data and of ENTSO-E with network code requirements for the exchange of market and network data show that different use cases can inspire different solutions. Moreover, experience with interoperability in healthcare is very advanced and can serve as an inspiration for energy, especially regarding interoperability testing and governance.
- Governance is a key issue in achieving interoperability. The existing governance mainly covers stakeholder dialogue and European standardisation. We provided ideas on how to use the EU implementing acts on interoperability and data access to step up these efforts. In addition, we think governance should be extended to include formalisation of best practices, implementation monitoring and reporting, and interoperability testing. We reflected that this governance could be taken on by a new EU entity.

To contribute to the policy and regulatory debate around cross-sectoral interoperability in the context of a future energy system integrated with sectors such as buildings and electro mobility, we have analysed experiences in different ecosystems (smart electricity metering, electromobility and buildings), different sectors (smart electricity metering, healthcare and public administration) and at the national level (The Netherlands, and the UK). The key related findings are:

- The definition of interoperability depends on the context and reflects a narrow (at the level od devices and systems) or broad (at the level or organisations) perspective. The elements included in a definition give an indication as to open interoperability issues in a specific sector or ecosystem. We recommend broadening the definition of interoperability that is used for smart electricity metering. The new definition should consider the multiple levels of interoperability and acknowledge the interoperability of devices as prerequisite for the interoperability of organisations.
- Despite differences in the specific interoperability issues a sector faces, the solutions applied at EU level are often similar across various sectors. More advanced sectors such as healthcare and public administration can serve as a basis for the further development of interoperability solutions for smart electricity metering. One example is to set up an EU monitoring and reporting scheme for national interoperability progress in the energy sector, in alignment with the activities conducted under the implementing acts for interoperability and data access. Another example is to create a scheme for different types of interoperability testing. The "interoperability" community created in the framework of Horizon Europe may facilitate the collaboration of relevant initiatives to implement these solutions.
- Synergies between sectors should be better exploited to avoid redundant activities and pool the relevant resources and expertise. Inspiration can be drawn from developments at the national level, especially when it comes to cross-sectoral aspects of interoperability. One example is to set up a governance framework for interoperability that covers cross-sectoral and sector-specific aspects, in line with the ongoing EU activities in the context of the Green Deal. Another example is to enhance sector convergence in standardisation to avoid duplication of efforts, for example in the areas of demand response, EV charging and smart appliances.

Some of the elements that we have discussed in our research have recently been taken up in one way or another at the EU level. The draft implementing acts published by the European Commission in mid-2022 are taking account of the various interoperability layers that exist (EC, 2022a). They also require the establishment of a common repository of national practices to collect information on how the reference model is implemented in the Member States and make it publicly available. It is foreseen that ENTSO-E and the EU DSO Entity take on this task as a shared responsibility and based on the existing responsibilities of the two bodies related to data management and data interoperability.

The Digitalisation of Energy Action Plan published by the European Commission in October 2022 aims to strengthen stakeholder dialogue (EC, 2022b). The action plan foresees that the Smart Grids Task Force will be formally re-established as Smart Energy Expert Group, which will have greater responsibilities and involve all Member States and additional stakeholders. In addition, the European Commission will set up a Data for Energy Working Group to bring together the Commission, the Member States and the relevant public and private stakeholders for contributing to building the European framework for sharing energy-related data. The working group will help strengthen the coordination at EU level on data exchanges for the energy sector, defining the driving principles and ensuring consistency across different data-sharing priorities and initiatives. The working group will focus its work on developing a portfolio of European high-level use cases for data exchanges in energy that are key to deliver on the objectives of the Green Deal and the Digital Decade, including, initially, flexibility services for the energy markets and grids, smart and bi-directional charging of electric vehicles, and smart and energy-efficient buildings.

We also analysed the results of the INTERRFACE demonstrators with regard to insights that may be relevant for the development of the EU implementing acts on interoperability and data access. However, the majority of the demos focuses on the provision of services (i.e. congestion management, frequency and non-frequency ancillary services, network investment deferral) that are not of immanent relevance for the implementing act that is currently under development. The first implementing act centres on the provision of validated historical and non-validated near-real time metering and consumption data in the context of data sharing services (EC, 2022a). Demand-side flexibility is likely the focus of a second implementing act on interoperability to be developed in close alignment with the new network code on demand response. However, several inputs from the demos have been identified as relevant for the overall debate on interoperability in the energy sector.

The results of the Italian pilot “DSO and Consumer Alliance” demonstrate the successful integration of multiple smart meters for the benefit of providing congestion management and balancing services to the system operators. The demo also highlights the potential for smart meters beyond electricity, an area that deserves more attention in research projects as it can support the twin green and digital transition to a future integrated energy system.

The results of the Bulgarian Pilot “Intelligent Distribution Nodes” demonstrate the usage of an intelligent system including an information hub to leverage the flexibility of a multi-storey building. The demo provides insights as to the relevant capabilities of an innovative control system, namely data consolidation, data quality, data integration and data governance. The results of the Bulgarian demo are relevant for the integration of buildings as active participants in the energy system.

The Baltic-Nordic pilot “Single Flexibility Platform” provides insights for a future interoperability implementing act on demand-side flexibility and the implementation of interoperable flexibility market platforms. The pilot relies on the IEGSA / Single Flexibility Platform. The capabilities and governance of IEGSA are relevant for the interoperability discussion around future implementing acts on demand response as well as on a common European common data space for energy. The integration of IEGSA with several other marketplaces and platforms promotes data transparency and flexibility. Its interoperable approach enables the reusing of modules, thus lower costs for its users.

# 5 Conclusions

This documents includes a collection of the most important results and lessons learnt from the INTERRFACE project. This knowledge is divided in three pillars: **(i) the demonstrators of INTERRFACE, (ii) the scalability and replicability considerations of the IEGSA platform and (iii) the recommendations towards policy makers and suggestions for the upgrade of European Network Codes.**

Of course these are only key-highlights; it is not easy to fit all achievements of a project that ran successfully for 4 consecutive years. Detailed analysis of the activities in the 3 pillars mentioned above can be found in the following public deliverables of INTERRFACE:

- D5.6: Congestion Management demonstration - Final Evaluation report and lessons learnt[7]
- D6.5: Peer-to-Peer marketplace Demonstration - Final Evaluation Report and lessons learnt[8]
- D7.4: Pan-EU Clearing market demonstration - Final Evaluation Report, recommendations for European Market Upgrade[9]
- D9.13: Roadmap[10]
- D9.14: Report on the Foundations for the adoption of new Network Codes 2[11]

[7] http://interrface.eu/sites/default/files/publications/INTERRFACE_D5.6_FINAL_PUBLIC.pdf
[8] http://interrface.eu/sites/default/files/publications/INTERRFACE_D6.5_v1.0.pdf
[9] http://interrface.eu/sites/default/files/publications/INTERRFACE_D7.4_v1.0.pdf
[10] http://interrface.eu/sites/default/files/publications/INTERRFACE_D9.13_v1.0.pdf
[11] http://interrface.eu/sites/default/files/publications/INTERRFACE_D9.14_v1.0.pdf