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Innovation Action

flexitranstore

An Integrated Platform for Increased FLEXIbility in smart TRANSmission grids with STORage Entities and large penetration of Renewable Energy Sources

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D2.1 Flexibility challenges in SEE region and worldwide trends

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1.1 Scope of deliverable

The document analyzes the current situation in flexibility assessment studies worldwide and outlines the challenges facing the South East European region. It aims to assist in clarifying debates about flexibility by summarizing the analytic frameworks that have recently emerged to measure operational flexibility, and by clarifying some of the key concerns and misperceptions of the term. An overview on the latest demonstrations, business models and technologies in transmission systems and energy markets is conducted. Special attention is placed on the relative European and international projects, the interactions and the areas of further research pinpointed. It also considers the importance of flexibility, beyond operational reliability, analyzing examples of inflexibility in technical level (i.e., difficulty balancing demand and supply, significant renewable energy curtailments, area balance violations) as well as market level (i.e., negative market prices, price volatility), stressing on the gaps and needs for flexibility assessment.
The material presented in this public document highlights the needs and challenges of the SEE region and summarizes key conclusions of the full deliverable D2.1.

1.2 Concept and methodology

Initial activities of FLEXITRANSTORE WP2 set out the outline of the flexibility assessment topic in Europe and South east area more specifically.

A detailed study in literature for the flexibility concept has been carried out in order to summarize the key concepts and set the basis for future studies.

Several RnD projects dealing with power system flexibility have been revisited in order to summarize the major findings and identify related gaps, especially regarding transmission systems in the SEE area.

A related questionnaire has been devised in order to elicit information from the energy stakeholders regarding their views on flexibility and interest in FLEXITRANSTORE technology. the results were analyzed and commented together with the point of view of industrial partners of FLEXITRANSTORE consortium

1.3 Key activities and results

Through the international review of the latest flexibility related activities, several important remarks were pointed out:

a) Pumping hydro storage and gas operated units play a dominant role in providing flexibility resources in most European countries. Some of the hydro units can be converted to pumping units with reasonable, though site-specific, investment costs. These projects are surely not a 'hands-on' solution while there are usually related with grid reinforcement projects and consequently public acceptance issues.

b) The hydro-pumped storage in Greece "Amfilochia" has been selected as Project of Common Interest and it consists of two separate upper reservoirs and an existing common lower reservoir.

The total installed capacity of the system will be approximately 680 MW (generation) / 730 MW (pumping) and the net annual electricity generation is estimated around 816 GWh. The total budget of the project is expected to exceed the amount of 500M euros. The purpose of the Project is energy storing to assist renewable sources integration by providing the required flexibility. The excess wind, photovoltaic or thermal energy will be hydraulically stored, through water pumping from the lower to the upper reservoirs, during the low load consumption or in renewable overproduction periods. Subsequently, energy will be recovered via turbine mode, during the peak load hours. As most pumped hydro projects, the implementation process is long and difficult, while it is also related with future grid reinforcement projects of the 400kV backbone in the area.

c) Elering, Estonian TSO, has finished the installation of a TSO owned emergency generation plant powered by natural gas connected at the Kiisa substation. The capacity of the plant is 250 MW and will be used as Emergency Reserve and for start-up of grid in no powered situation. The Plant can reach/deliver the Maximum Power (250MW) in less than 10 minutes and it meets the Estonian Grid code requirements including 'Fault Ride Through' capability of 250ms. Furthermore, Elering is doing studies on potential uses of demand response and has established an online platform

d) In most countries, the regulatory framework regarding pumping hydro storage and gas operated units does not provide sufficient motivation for their appropriate exploitation. Especially in Greece, only gas turbine generation units are considered eligible for reimbursement through the Transitory Electricity Flexibility Remuneration Mechanism (TRFM). Thus, the TRFM supports the gas units' viability in Greece, since under the current Greek electricity market framework, it is extremely difficult or even impossible for these units to recover their fixed operating costs and capital costs only through market revenues (including revenues from both energy sales and Ancillary Services). However this regulation is under an update procedure for the finalization of the target model implementation

e) Based on stakeholders' answers, demand side response flexibility is recognised as promising technology with great potential and future perspectives. However, it is not currently considered as a mature flexibility resource, since telemetered consumers are limited and their contribution is also limited (consumers may shed load if necessary, but cannot follow fast ramping needs). Regulation incentives are needed in order to promote end user participation and grid upgrades of smart grid technology that enables demand response**. FLEXITRANSTORE demonstrates such innovative technology of controllers with storage integration on the TSO-DSO border substations**.

f) As indicated by the stakeholders, battery energy storage systems installed together with RES, flexible EV charging stations and demand side management schemes will be available as further flexibility sources. However, the European regulation does not allow TSOs and DSOs to own batteries, since there is a gap in the provided services and monetary value of the stored energy (market interference). In order to bring these distributed sources of flexibility to have scale within the electricity system, aggregation functions may be required as well as a regulatory reform and connection codes update to manage these evolutions.

g) On the two previous subjects, an excellent example is the OFGEM (Office of Gas and Electricity Markets) performance – based regulation in Great Britain (RIIO framework) which approves extra reimbursement for the grid operators for the cost of innovation technology implemented into their grids, additionally to their CAPEX (capital expenditure) and OPEX (operational expenditure) expenses. The mechanisms are called "Innovation Stimulus Packages" and are designed to encourage network companies to consider different ways to achieve greater cost savings or increase the scope of future delivery. Furthermore, they recently introduced the "regulatory sandbox"

program, which allows innovators to trial business propositions that will benefit consumers without incurring all of the usual regulatory requirements.

h) It has been also identified that there is lack of flexibility in the network itself i.e. smart grid technology that improves electricity flows, observability and control. These innovation initiatives would be favoured by regulation reforms.

Stakeholders view on flexibility

I) Massive penetration of renewable generation into the system will accentuate the need for flexible resources to be available to the TSOs, since the drastic ramping downward and upward requirements that are foreseen could put substantial stress into the system, while the daily balancing challenge is becoming increasingly difficult for operators. This applies both when low wind and solar power production coincide with high demand, and when high production coincides with low demand.

II) The majority of answers in the questionnaire stress the need for *new regulatory frameworks*, *market structures* and *business models* that reflect the latest developments in technology and system operation challenges and ease the implementation of clean energy and winter packages mandates. More specifically, there is a lack of *storage related regulation* and *market incentives* to operate such installations to provide flexibility into the grid. **FLEXITRANSTORE proposes and demonstrates specific market and business solutions to promote flexibility services**.

III) Without flexibility services, more capacity investments are needed to aid smooth RES integration alongside with grid reinforcement projects (i.e. new lines, substations) to provide the necessary transmission corridors. These will increase the cost of electricity and limit the overall social welfare. Furthermore, stability and balancing problems will be more often and the risk for a black-out will increase.

IV) Another major concern on these cumbersome transmission projects is the long planning times (up to a decade) for grid enforcements like new power lines and new fossil generation plants. As these constructions are increasingly less accepted by the public, alternative solutions need to be envisioned, in order to bridge the time before a more permanent and viable grid strengthening can take place.

V) With the advent of flexibility services, balancing and stability problems will be overcome since market participants will be incentivised to invest and procure flexibility services: i.e. storage entities will be installed and operated accordingly, smart grid FACTS technology and efficient demand/generation controllers will penetrate the market, new energy services companies and prosumers will be involved into the markets. Possible black-out events can be avoided.

VI) With flexibility services, the active participation of the consumer would contribute to the adoption of a more grid-friendly consumption profile (i.e. alleviate load peaks, mitigate negative-price hours). In other words, there should be incentives for electricity customers to cut down on their electricity use during scarcity situations with high prices and increase their consumption during low price periods, when there is a lot of renewable production in the system. This is very much related with the targets of consumer engagement into the electricity markets set by the Winter Package.

VII) Demand side flexibility is expected to reduce price volatility when it is part of the price formation on the day-ahead market and has the greatest dampening effect on price volatility in a scenario with a lot of wind power.

VIII) According to stakeholders, active congestion management is becoming increasingly important, providing possible low-cost flexibility solutions for operators: In managing network congestion actively, network operators could purchase flexibilities that benefit the network from market players and negotiate the payment. The actors would need to adapt their behaviour in the event of network congestion as instructed by the distribution system operators. The loads or storage facilities under instruction would need to receive financial compensation for any economic loss. A well-ordered procedure before real time and economic balancing of the energy amounts are required for each form of grid flexibility provided so as to keep the influence on the market outcome on the right track.

South East Europe challenges and FLEXITRANSTORE ambitions

Southeast Europe or Southeastern Europe (SEE) is a geographical region of Europe, consisting primarily of the Balkan Peninsula. In the context of ENTSOe, the Balkan Peninsula countries are included in a broader regional group, Continental South East (CSE). The Regional Group CSE comprises the TSOs of Bosnia-Herzegovina (BA), Bulgaria (BG), Croatia (HR), Cyprus (CY), Greece, (GR), Hungary (HU), FYROM (MK), Montenegro (ME), Romania (RO), Serbia (RS) and Slovenia (SI). Albania (AL) recently became a full member of ENTSOe and Turkey is an observer member interconnected with Greece and Bulgaria, so these systems are connected to the Continental Europe Synchronous Area (CESA) system in parallel synchronous operation.

In the context of FLEXITRANSTORE, the challenges of balancing the new generation patterns in Greece, Bulgaria and Cyprus are under study so as to propose flexibility solutions based on grid technology innovation, market structures and business models. It is worth mentioning the following:

a) In Greece, variability in net load and the need for flexibility services have been made apparent in the latest years through the so-called “duck effect”: the PV units’ typical production profile has a notable effect on the net system load curve, which has increased the needs for ramping down during the morning and ramping up during the evening hours. Furthermore, during the noon hours (when the PV solar injections are the maximum) the system may experience over-generation conditions that can negatively impact reliability. With increasing levels of RES injections, the operational challenge of ramping capability becomes even more prominent, as the variable outputs of the RES may increase the magnitude of the 5-minute to 5-minute net load (load minus the renewable resources’ total output) changes.

b) The Greek electricity market has not established any flexibility services so far. In March 2016, the European Commission approved the implementation of a Transitory Electricity Flexibility Remuneration Mechanism. The objective of this measure was to ensure sufficient provision of flexibility services, which would be at risk in case of economic retirement or mothballing of power plants that are able to provide such services. It was deemed absolutely necessary for the economic viability of the Combined Cycle Gas Turbine (CCGTs) units, since it is very difficult for these units to recover their fixed operating costs and capital costs. All the details of this mechanism are presented in Appendix C. However, the mechanism has not been put in operation and an updated mechanism is under discussion among the NRA and stakeholders, in the context of the forthcoming market reform to adopt the target model in Greek electricity sector. **FLEXITRANSTORE will demonstrate flexibility solutions beyond ramping of dispatchable units. Grid storage integration solutions will be demonstrated in TSO-DSO border, wind plant substations and conventional generation plants. FACTS congestion relief technology will be demonstrated to redirect power flows optimally. Furthermore, alternative market structures and business models to**

promote remuneration of flexibility services will be proposed (WP3) and demonstrated (WP9).

c) A mechanism of Demand Side Management has been established lately in Greece, which attributes IPTO the right to temporally interrupt the active power flow to the interruptible consumer (Interruptible Load Service - ILS). The specifics regarding ILS (requirements, technical aspects, compensation) are analysed in Appendix C of the full deliverable. The interruption has pre-specified upper limit, takes place within notice period and the consumer is financially compensated for the provision of this right. This means that the compensation is independent from the actual orders issued by ADMIE and the beneficiaries will receive the same payment regardless if they actually provide the service or not.

d) Greece will harmonize the electricity market structure with the target model, introducing a forward, intraday, and balancing market over a transition period, to complement the day-ahead market. The new market regime should provide the system flexibility required for cost-effective integration of wind and solar resources in the electrical system. **FLEXITRANSTORE may support this ongoing market reform in Greece with substantial proposals on flexibility services and market demonstration.**

f) Balancing generation and demand is extremely difficult in the periods with very low temperatures in Bulgaria, while the presence of wind and snow leads to icing of power lines. Problematic are also the cases with low temperatures and snow without the presence of wind, because wind plant generation forecasting has a lot of variability. **This is an area where FLEXITRANSTORE will demonstrate Dynamic Line Rating technology to prevent icing phenomena and prevent their terrible consequences i.e. assure reliable transmission of clean energy from wind plants, mitigate the number of weather-related contingencies and improve grid performance in a quantifiable way so as to make cost benefit analysis for further adoption of this new DLR technology.**

g) In the Bulgarian case, ancillary services are negotiated on an annual basis while ESO sets a monthly schedule for every participant including primary, secondary, tertiary regulation reserves, as well as cold reserves (negotiated through auctions, commonly for a period of at least a month or more). The seller cannot sell electrical energy on the free market when ESO relies on him to ensure the cold reserve. However no assessment has been made as to how the capacity of the Bulgarian EES and the opportunities for exchange will change if flexible management measures and provision of ancillary services by a larger number of market participants are introduced. **In FLEXITRANSTORE, a computational platform, for upgrading balancing, planning / adequacy studies with flexibility assessment will be developed, while a respective cost – benefit analysis will explore how FLEXITRANSTORE technology innovations will provide tangible benefits to the Bulgarian transmission system.**

h) By 2017 Bulgaria has accomplished the 2020 RES targets for reaching 16% share in the gross final energy consumption. There is also a significant coal units' phase out program even before 2022. Due to the lack of big industrial loads, it is estimated by the TSO that further future integration of RES will result in balancing problems. Thus, capacity and grid infrastructure projects are planned, such as the renovation of the existing big hydro electrical power plants, the new hydro project Yadenitsa, development of 110kV network and 5 new 400kV lines (among them the second interconnection with Greece). These investments are capital intensive and will have to achieve public acceptance in order to be implemented. **In FLEXITRANSTORE, cost-efficient technology and market innovations will be demonstrated that provide solutions for increasing transmission system robustness and flexibility: congestion relief devices, sensor-based de-**

icing systems, grid storage integration with efficient control units, market remuneration mechanisms for flexibility services.

i) Although the environmental factors and weather conditions in Cyprus favour the high penetration of renewable energy sources (especially solar technologies) the inflexibility signs of the Cyprus power system limit the large percentage of RES in the energy mixture of Cyprus. The isolated nature of Cyprus power system (since Cyprus is an island) is probably the main reason for the power system inflexibility in case of high RES penetration. **FLEXITRANSTORE will develop innovative methodologies for the accurate flexibility assessment of a given system as well as methodologies for strategic decision making based on the physical characteristics of the power system and the potential of installation any ancillary services.**

j) The Cyprus electricity system needs to be rearranged drastically in order to be compliant with the energy legislative packages of the European Commission. Although the Cyprus electricity market has been formally fully liberalized since 2014, the practical implementation of the market liberalization was not implemented since EAC is still the sole supplier of power to the customers. The monopoly in the electricity market in combination with the absence of market incentives to improve the flexibility of thermal plants and ancillary services (that must be also integrated to the market), limit the Cyprus power system flexibility and consequently the high penetration of RES. **FLEXITRANSTORE aims to design an enhanced market and novel business model for increasing the flexibility of the power system.**

Energy stakeholders set the future priorities

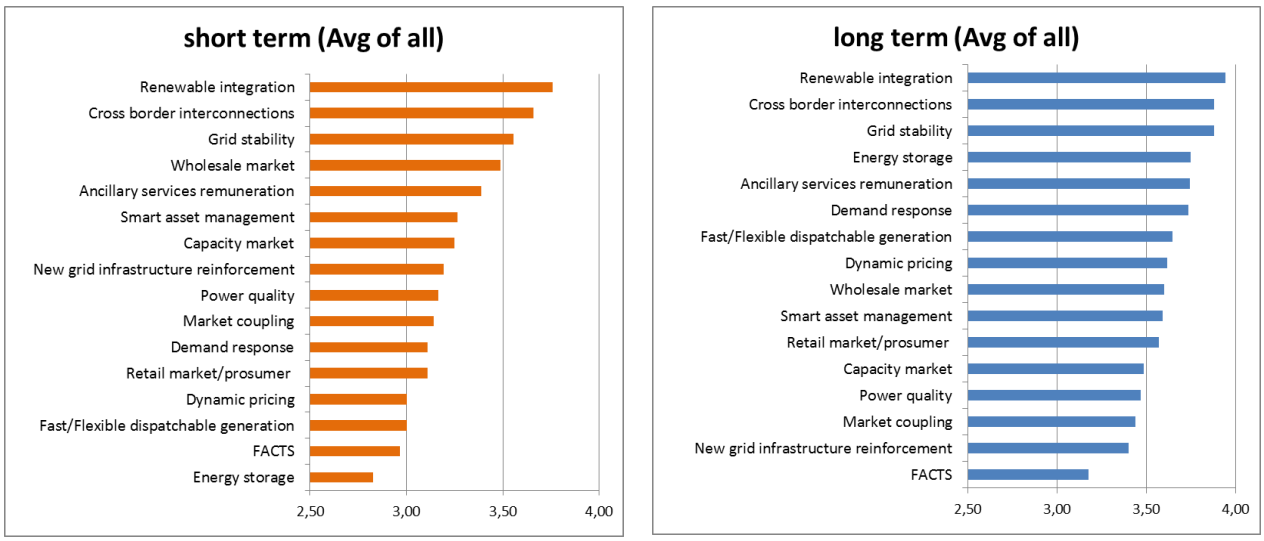
According to stakeholders, highest priorities for the electricity networks in their country are *renewable energy integration*, *cross border interconnections*, *grid stability* in short and long term horizon. RES integration and cross border interconnections answers could be also linked with the European targets:

(i) EU countries have already agreed on a new renewable energy target of at least 27% of final energy consumption in the EU as a whole by 2030 as part of the EU's energy and climate goals for 2030.

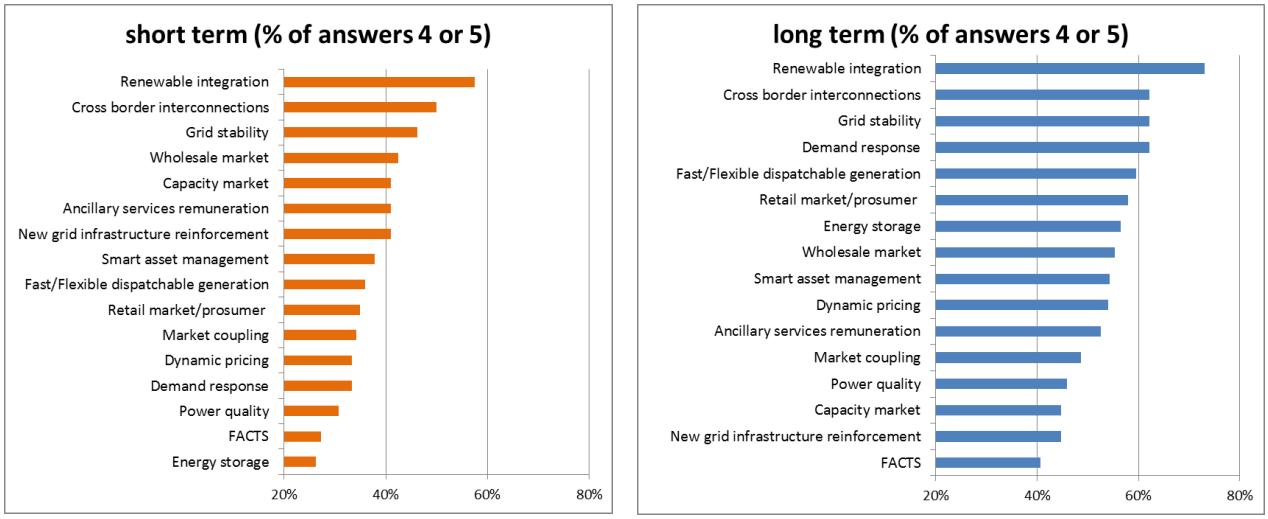
(ii) The October 2014 European Council called for interconnection of at least 10 % of installed electricity production in the Member States by 2020, endorsed the 15 % target by 2030 and underlined that they will be both attained via implementation of Projects of Common Interest in energy infrastructure.

Moreover, in short term horizon (up to 5 years) the *wholesale markets* and the *ancillary services remuneration* (market –related) are highly prioritized as critical topics. In the long term horizon (more than 5 years), *energy storage* and *demand response* are rising higher to the prioritization list of critical topics, since they are currently considered rather immature in Europe. Therefore, R&D projects are needed on these topics.

In other dimension, stakeholders were asked how relevant the different FLEXITRANSTORE demos are to their company and their country.



Average value of relevance, according to stakeholders, on critical topics related to flexibility, in short (1-5 years) or long (6-10 years) horizon



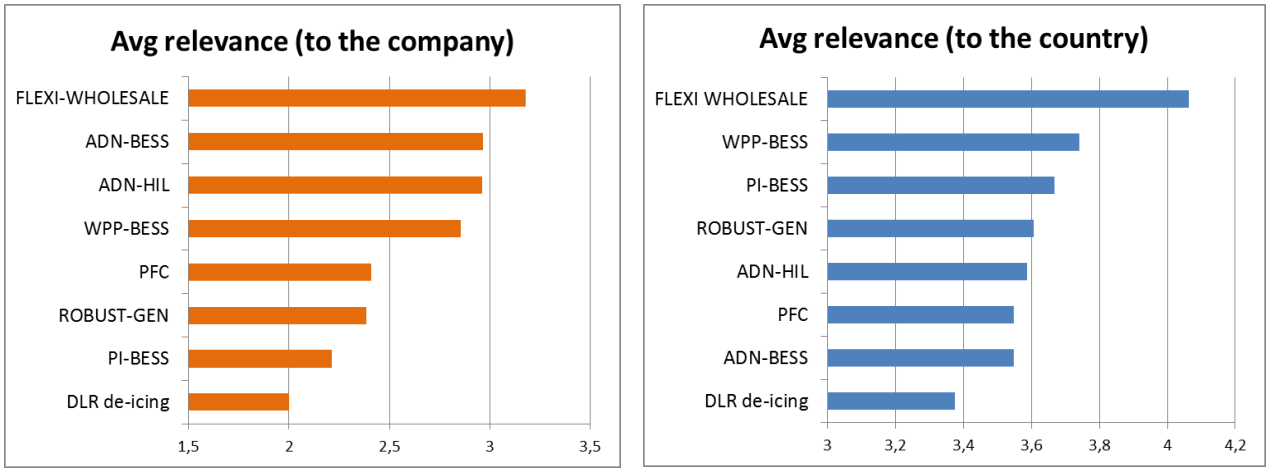
Percentage of number with high relevance, according to stakeholders, over total answers on critical topics related to flexibility, in short (1-5 years) or long (6-10 years) horizon

Eight demos of the FLEXITRANSTORE project

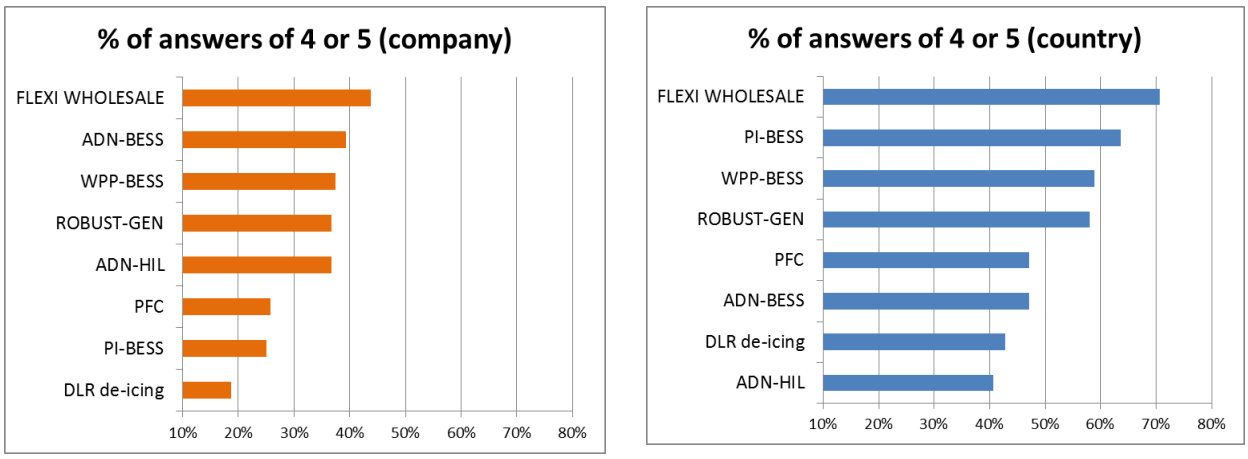
Demo	Description	Acronym

1	Implementation/Development of an Active Distribution Node demonstrator (**controller with battery storage in distribution substation**) for making TSO-DSO interactions flexible (**grid services provision, congestion and voltage control by the distribution side**)	ADN-BESS
2	**Advanced controllers for Wind power plants with battery storage** connected to an active substation **for grid services** (i.e. power oscillation damping, smooth the power fluctuations)	WPP-BESS
3	Increase cross border and transmission line flexibility through improvement of resilience using de-icing solutions	DLR de-icing
4	Improve transmission capacities and control electricity flows through **Power Flow Control Solutions**	PFC
5	Adapting **wholesale market approach allowing flexibility services** to be integrated	FLEXI-WHOLESALE
6	**Advanced controllers for grid services in the HV-MV substations** (linked with 1 and 2 demonstrations)	ADN-HIL
7	**Battery storage system for combined cycle power plant to provide grid services at TSO level (i.e. Faster Frequency Response, Improved ramp-rates, Black-Start capacity)**	PI-BESS
8	Advanced control for **flexible synchronous generation** (**Adaptive models for grid behaviour prediction** i.e. Detect of RoCoF Event early, Avoid combustion blow-out)	ROBUST-GEN

According to stakeholder, among the FLEXITRANSTORE demonstrations, the flexibility services market and storage pilots receive the most attention by the various stakeholders, identified as the most relevant to their company and their country.



Average (Avg) value of relevance according to stakeholders on eight demos of FLEXITRANSTORE



Percentage of number with high relevance according to stakeholders over total answers on eight demos of FLEXITRANSTORE

1.4 Conclusions

As conclusion to this deliverable, it is worth mentioning the following:

a) Flexibility has not been globally defined and it has been approached differently in several studies. It has been distinguished in two main categories namely, planning and operational flexibility with the latter being in the scope of most studies.

b) Expert Group 3 of the Smart Grid Task Force of the European Commission defines the term flexibility in the following way: *"On an individual level, flexibility is the modification of generation injection and/or consumption patterns in reaction to an external (signal or activation) in order to provide services within the energy system"*

c) Among stakeholders, as they expressed their opinion in the FLEXITRANSTORE survey, flexibility has been defined through the effects it has on the power system operation and the resources needed in the transmission system. According to many, flexibility means efficient electricity grid operation without oversizing generation capacity and limited infrastructure investment on the network.

d) Demand side flexibility has a dominant role in the overall power system flexibility, as it has been stressed in many questionnaires, and it results in broader efficient use of resources and contributes to the fulfilment of climate and energy policy goals, consumer engagement into the electricity markets, as these have been set in Clean energy and Winter packages.

e) Massive penetration of renewable generation into the system will accentuate the need for flexible resources to be available to the TSOs. Answers in the questionnaire stress the need for new regulatory frameworks, market structures and business models, in respect with storage and market initiatives. FLEXITRANSTORE will propose and demonstrate specific market and business solutions to promote these flexibility services.

f) It is clear to all stakeholders that without flexibility services, more capacity investments are needed to aid smooth RES integration alongside with grid reinforcement projects, which increase the cost of electricity, public dissent and limit the overall social welfare. FLEXITRANSTORE market and business models framework will provide applicable solutions towards this direction.

g) Pumping hydro storage and gas operated units play a dominant role in providing flexibility resources in most European countries. Emergency reserve units have emerged in some countries (Kiisa in Estonia by Elering TSO), while flexibility remuneration mechanisms are under consultation in European countries (i.e. Greece).

h) Demand side management and grid storage integration to improve RES integration and TSO-DSO coordination have been identified as important flexibility resources, however regulatory reforms are needed to clarify their roles in the energy chain and provide incentives for investment. Smart grid technology innovation on the grid and novel business models have been identified as still missing for achieving the energy targets.

i) To satisfy the above needs, OFGEM NRA in Great Britain has established: (i) the RIIO (Revenue= Incentives + Innovation + Outputs) performance based regulation framework, where innovation investments are funded by "Innovation Stimulus Packages", as well as (ii) the "regulatory sandbox", which allows innovators to trial innovative business products, services and business models that cannot currently operate under the existing regulations

j) Among the various European funded research and innovation projects, significant attention has been given to renewable energy integration and respective grid stability issues, motivated by the high RES targets set in the last decade and so on. Demand response and distributed storage promoting local flexibility in the LV and MV level has been luring significant research attention while providing interesting results. Flexibility has been approached mostly from the distribution side in the various projects; *FLEXITRANSTORE will complete the pieces of the puzzle, approaching flexibility assessment with transmission network innovations, wholesale market reforms and TSO-DSO coordination schemes through efficient control and grid storage*.

k) In the US and internationally by IEA, significant projects have been carried out. Focus has been given by the FLEXITRANSTORE team to EPRI inFLEXion tool and IEA FAST methodology that both propose a complete flexibility assessment methodology for studying transmission systems. Their basic principles will be adopted by the FLEXITRANSTORE methodology. Furthermore, significant pilot projects have been installed and commissioned in the US involving RES-plus-storage configurations, while respective grid services were introduced into the US electricity markets.

l) Based on the survey FLEXITRANSTORE carried out among stakeholders, highest priorities for the electricity networks in EU countries are renewable energy integration, cross border interconnections, grid stability in short and long term horizon. This is very much related with the targets set in the winter package for RES penetration and cross-border trading.

m) The *wholesale markets* and the *ancillary services remuneration* (market –related issue) have been characterized as critical topics in the next 5 years horizon. In longer terms, *energy storage* and *demand response* are also considered critical, since now they are currently considered rather immature in Europe. Therefore, R&D projects are needed on these topics.

n) In the aforementioned survey, FLEXITRANSTORE flexibility services market and storage pilots received the most attention by the various stakeholders, identified as the most relevant to their company and their country.

o) In the SEE, there are several market reforms to adopt the EU target model in the national regulation. The coal power phase-out schedule, RES and interconnection targets have boosted the interest for introducing flexibility remuneration mechanisms (i.e. Greece) and new infrastructure (i.e. PCI projects). However, grid storage integration, active control and smart grid technology are in an immature level in the area while they could provide flexibility resources to the network. Alongside with flexibility market services and business models, FLEXITRANSTORE will promote the

aforementioned technologies and will provide a Flexible Energy Grid (FEG) Architecture for energy studies and cost benefit analysis.

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