LCE-04-2017

Innovation Action

flexitranstore

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

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774407

D2.3 Strategic decision making for power system flexibility by innovation integration

Report Identifier:	D2.3		
Work-package, Task:	WP2	**Status – Version:**	1.0
Distribution Security:	PU	**Deliverable Type:**	R
Editor:	UCY		
Contributors:	EMAX, ICCS, UCY, IPTO, Smartwires		
Reviewers:			

Quality Reviewer:	Name Surname (Organisation)		
Keywords:			
Project website: www.FLEXITRANSTORE.eu			

Table of Contents

1.1 Scope of deliverable

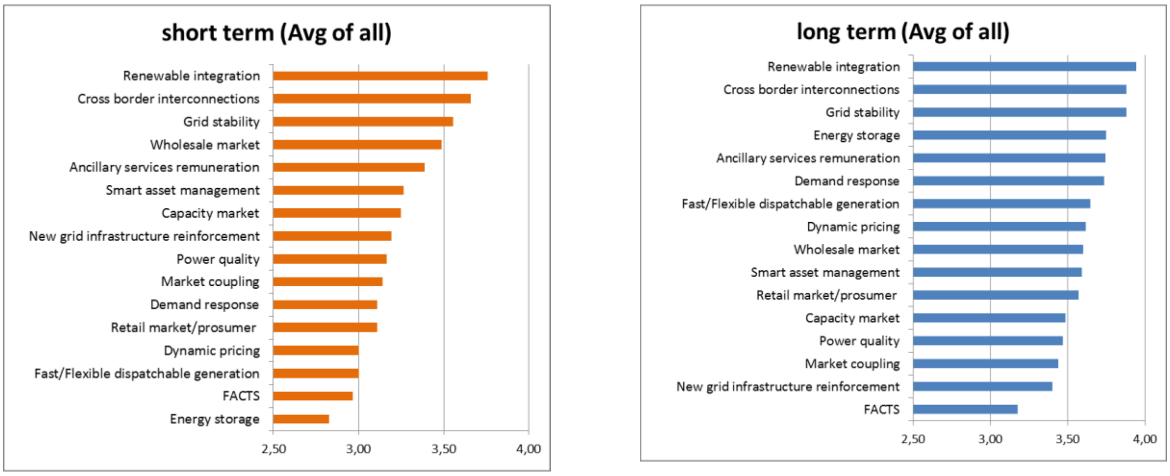
This deliverable provides a *strategic decision-making method* which support the network operators in activating different options to increase system flexibility, as well as highlighting benefits of different innovative technologies demonstrated by the project. The method will be developed in this level that uses identified inflexibilities, the flexibility resources stemming from physical characteristics of the power system, and the market operation characteristics in order to provide power system upgrade solutions that *improve the level of renewable energy share* and *sustain high grid reliability and resilience*. This also provides efficient, controllable, storage-integrated substations in the TSO/DSO interface, reduces congestion, while at the same time allowing new-market players to participate in different electricity markets.

This deliverable is the outcome of Task 2.5 activities, while it is also linked with the activities in all on-going WP2 tasks, as well as with WP3 and demonstration work packages. It also creates a cornerstone to calculate abilities and define methodology of scaling-up and replication of WP13, as well as exploitation of WP14.

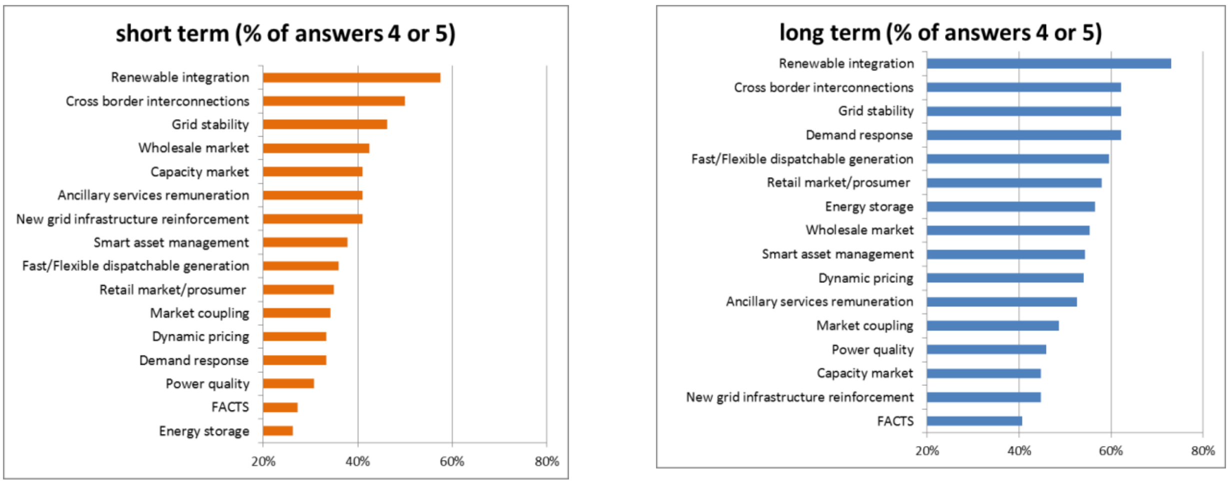
1.2 Concept and methodology

Looking back to the outcome of this FLEXITRANSTORE survey, great feedback is provided on the prioritization of electricity grid and market topics set in various European countries. One interesting remark is that stakeholders rank as **highly relevant certain topics which are actually the result of various reforms, while at the same time these "reforms" are considered as less relevant.** For example**,** '*market coupling'* is considered less relevant than '*cross border interconnections'* while both they are very much related. Accordingly, 'renewable integration' is top–ranked in all time horizons, while '*energy storage'* which assists/promotes greatly RES integration, is ranked much lower.

In this sense, it can be concluded that *the cause-and-effect relation of innovation in grid and market* (i.e. energy storage, FACTS, market coupling, dynamic pricing etc) is not crystal clear to stakeholders with the *profound topics of energy transition* i.e. Renewable Integration, Cross Border Interconnection, Grid Stability. In this report, a strategic decision-making method will be presented to 'channel' the effects of innovation to the power system operation through specific KPIs which are elaborated in section 3, having the common characteristic of flexibility improvement. Thus, the FLEXITRANSTORE approach in task 2.5 comes to relate the cause and effect of innovations presented through the project. It has been 'triggered' by CBA tools for smart grid and energy storage projects, sponsored by the American Recovery and Reinvestment Act, Smart Grid Investment Grant program and Smart Grid Demonstration program. These approaches are developed for the US electricity markets with different reimbursement schemes for grid services depending on the various country regions.



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

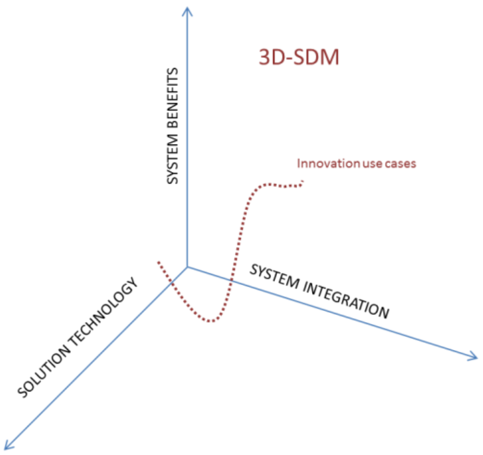


Percentage of number with high relevance, according to stakeholders answers to FLEXITRANSTORE questionnaire, over total answers on critical topics related to flexibility, in short (1-5 years) or long (6-10 years) horizon

Lately TenneT Netherlands introduced a relevant software platform, which models the business case of a grid-connected energy storage projects, taking into account technical characteristics, costs and revenues of a project, and combines them into a business cashflow model [14]. This is an excellent tool for energy stakeholders in their understanding of the business case of an energy storage project.

Standing on the position of the grid operators, FLEXITRANSTORE task 2.5 (a) identified inflexibilities, the flexibility resources stemming from physical characteristics of the power system (b) uses the market operation characteristics (c) evaluates the innovation technology characteristics of the power system upgrade solutions and (d) provides a solution that improves the level of renewable energy share, sustain high grid reliability and resilience, and generally perform high values of a specific set of related KPIs. This approach can be customized for the market characteristics of the SEE countries participating, where flexibility services in electricity markets are still in an infant state. Further elaboration on this will be provided in WP13.

The aforementioned elements (a)-(d) formulate a kind of "3-**D**imensional space" for **S**trategic **D**ecision **M**aking on use-case scenarios of future power systems operation, the **SDM** approach. An illustration of this task 2.5 proposed approach is illustrated in the following figure.



An illustrative representation of the SDM (Strategic Decision Making) approach proposed on FLEXITRANSTORE, showing the various aspects affecting the formulation of innovation use case to be evaluated

The three "degrees of freedom" (DoF) presented in the above-mentioned figure are considered to be:

a) Solution technology

It reflects the selected innovative technologies that may provide alternative solution to conventional grid upgrades i.e. new transformers, OHLs or thermal generation. This DoF expresses "*the innovation technology characteristics of the power system upgrade solutions*" mentioned above. The portfolio of innovations can include energy storage, power flow controllers, power electronics (controllable/regulating inverters), fault current limiters, phase-shift transformers, DLR, PMU-WAMS [11]. This list can be enriched by new technologies by each TSO/DSO in order to include them in their practices, following (a) the evaluation of the maturity of the technology, (b) updating of their asset management practices, and (c) updating of the regulatory framework if needed.

In the context of FLEXITRANSTORE, the demonstrated technology solutions are (i) *Battery Energy Storage Systems*, with various technical characteristics regarding their efficiency for network services, (ii) *Power Flow Controllers*, for congestion relief, increased RES penetration and asset utilization, (iii) *Dynamic Line Rating* (DLR) systems, for increasing grid reliability, weather resilience and asset utilization. These technologies are accompanied with *ICT controllers* and efficient *AI-based software* developed up to a high Technology Readiness Level, for the sake of the demonstrations in FLEXITRANSTORE project.

b) System benefits

It reflects the portfolio of benefits that the innovation technologies identified in (a) above can procure to the power system and the society in general. The scope of the system benefits is mainly driven by the equipment industry and the technology providers, maximizing all the various advantages of their technologies. The benefits are stated in an 'agnostic' way to the technologies i.e. '*increasing line transfer capacities*' benefit can be achieved through Power Flow Controllers, DLRs and maybe other equipment and technologies.

The 'system benefits' as they are perceived in the hereby FLEXITRANSTORE strategic decision making method, cover a wider technology impact, i.e. advantages not directly related with the definition(s) of flexibility as been addressed so far. Flexibility can be perceived in this context as 'ability to adapt' to disruptions. Redeployability, for example, is an excellent merit related with flexibility in this wider sense. In this way, there will be a fair/wider estimation of the overall impact that each innovation has on the power system. Nevertheless, the flexibility improvement of solely operational characteristics is stressed through the flexibility indicators, in order to highlight the added value of the FLEXITRANSTORE technologies comparing to the conventional solutions. The flexibility merits of the technologies are strongly related with the market specificities in each country and the remuneration schemes for the services provided. During the implementation of the hereby strategic decision making , several KPI can be used to evaluate/quantify the improvement provided by examined solution, thus system benefits in the context of FLEXITRANSTORE can be also expressed as ***K****ey* ***P****erformance* ***A****reas (KPAs).* In order to evaluate the performance of each solution technology (DoF (a) above) examined, a set of Key Performance Indicators (KPIs) can be used for each system benefit identified, quantifying the improvement.

c) System Integration

The "degree of freedom" characterized as "system integration" combines all the details of the actual implementation, the 'set-up' of the examined solution let's say. This is actually a descriptive feature including some objective difficulties to be prescribed in advance, with specific terms, since the complexity of electricity networks and the diversification of electricity markets and remuneration schemes are extensive.

In this sense, 'system integration' will include

(i) a '*grid configuration*' part i.e. the network topology and the respective connections of the technologies under study,

(ii) a '*market services*' part, i.e. the services that these technologies will provide via the electricity markets established in the regional context of the network configuration under study. The latter remark brings into the foreground the importance of market and regulatory frameworks that prescribe the operation of electricity networks and the portfolio of flexibility resources for system operators. For example, a specific technology (e.g. BESS) can be operated for specific services in a specific use case (e.g. ancillary services).

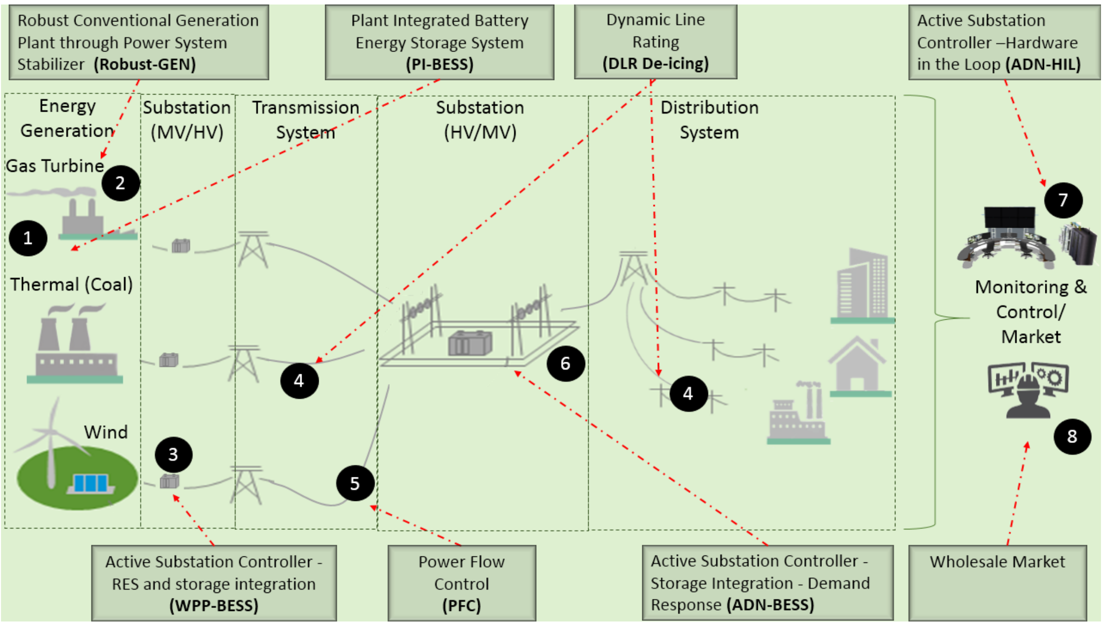
1.3 Key activities

The hereby strategic decision-making method proposed in the FLEXITRANSTORE is applicable by system operators (both TSO and DSO) with a wider scope for planning purposes. In many countries, DSOs operate HV levels 110kV/150kV networks and formulate 5-year planning studies for the complete HV-MV-LV levels (i.e. in Slovenia ELJ, HEDNO in the 150kV networks of Crete. Rhodes, Lesvos islands).

Flexible solutions are often considered to be best suited to managing short-term or real-time issues on power systems, thus their long-term benefits in system planning may be overlooked. One gap of CBAs identified during WP2 activities is that the Cost Benefit Analysis (CBA) approach used by many utilities to support decision making in the long-term investment planning process has gaps which can lead to suboptimum investment decisions. Benefits like redeployability, deferral of investments modularity, scalability are not clearly identified. If these areas are uncovered and an amendment is made to one or more best practice CBA methodologies, then the decision making process will be better overall and lead to better decisions including the possibility of identifying flexible solutions that should be deployed in the long-term process. This will support the achievement of the Energy Union by increasing the efficiency of investments. In the context of FLEXITRANSTORE strategic decision making method and the respective use cases, presented in the full version of deliverable D2.3 Appendices B-F, these benefits are taken under consideration: FLEXITRANSTORE proposes an assessment of costs and benefits for system planners (i.e. system operators in the EU energy context) to assess the impact of innovations on the flexibility and overall improvement of the grid.

The FLEXITRANSTORE area of focus is to enable the testing of flexibility services provided by innovative technologies and market design. FLEXITRANSTORE's approach targets the entire energy industry value chain by focussing on not only a stronger, more flexible infrastructure, but also the capabilities of demand side response, improved operations, more flexible generation and the integration of storage to accelerate RES integration and increase cross border flows from a market and system perspective. Everything is interconnected. Touching each of the flexibility services across the value chain shall result in a big impact on the overall system.

PFC for flow redirections, short term solutions, leasing opportunities for noncapital intensive solutions, while DLRs and battery solutions retain an asset value after the completion of a project.



Different demos with ability to make system more flexibility

In order to quantify such benefits from tested technologies and solution, a set of 'priority' KPAs can be defined. When defining these priority KPAs, we consider these principles for the whole project:

- Strongly highlight benefits of demos of FLEXITRANSTORE project: relevance to the activities we implement within the project
- Compatible and in line with CBA of ENTSO-E and other good practices of CBA calculation: to have common understanding when communication

- Focus on around five essential KPAs: not to have many KPAs so that we lose focus and incur high calculation burden, but not to have few so that we cannot cover the major benefits.

Considering all aspects of KPAs analysis in the section 3 and consultation with different demo leader, as well as TSO/DSO relevant, supporting the European energy targets of renewable energy target, competitiveness and security of supply, we come up with five KPAs:

- *KPA1 - Renewables integration*
- *KPA2 - Congestion reduction*
- *KPA3 - Flexibility indices improvement*
- *KPA4 - Improving Reliability and Stability*
- *KPA5 - Improved competitiveness of the electricity market*

These KPAs can be quantified through specific KPIs, as indicated in the table

Proposed KPIs to be used in the FLEXITRANSTORE project

No	System benefits (KPAs)	Proposed KPIs of FLEXITRANSTORE
1	*Renewables integration*	- Reduction in renewable curtailment on existing generation facilities - Cost of enabling new renewable interconnections relative to conventional solutions - Share of electricity generated from renewable sources - Increased RES and DER hosting capacity - Reduced energy curtailment of RES and DER - Avoid redispatching
2	*Congestion reduction*	- Reduction in redispatching - Increased network capacity - Maximum transfer capacity - RES Energy unleashed - Reduced Congestion Costs
3	*Flexibility indices improvement*	- IRRE, FIX - Capacity of reserves increase - -Maximum hourly ramp of residual load - -Additional capacity (NTC) in relation to existing cross-border capacity - Grid expansion deferral by applying peak-shaving'
4	*Improving Reliability and Quality of Supply*	- LOLE, LORP, -EENS - Additional adequacy margin - VOLL, - Average Hourly Load Not r
5	*Improved competitiveness of the electricity market*	- Type of energy pricing/market products - Market services remuneration - Number of market actors per activity - Concentration ratio (CR)

Mapping of System Benefits with different demonstration and tested technologies of FLEXITRANSTORE

Demo	Technology	Benefits				
		RES integration	*Congestion reduction*	*Flexibility indices improvement*	*Improving Reliability and Stability*	*Improved competitiveness of the electricity market*
1	Active Distribution Node	√		√	√	√
2	Battery Energy Storage at Wind Power Plant	√	√		√	√
3	Dynamic Line Rating			√	√	
4	Power Flow Controller	√	√	√		

5	Adapting wholesale market approach	√		√		√
6	Advanced controllers for grid services				√	
7	BESS for combined cycle power plant	√		√		√
8	Advanced control for flexible synchronous generation				√	

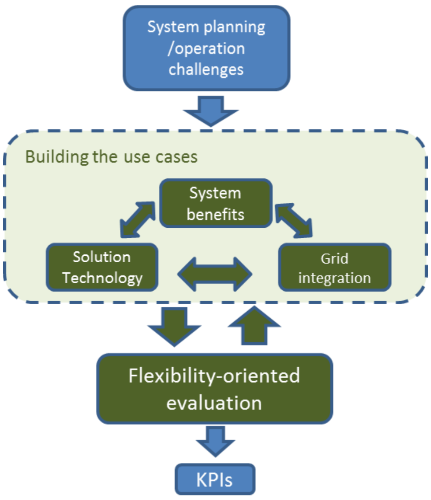
Besides the KPIs list and their mapping in the tables 5 and 6, which are applicable for many technologies and demonstrations, extra set of particular KPIs could be formulated to cover specific aspects, for instance:

Power flow controller

- *Extension of outage windows for construction & maintenance projects*
- *Time required to implement solution*
- *Value of scaling the solution size over time to meet emerging needs.*
- *Value of the PFC assets being highly mobile and ability to be re-deployed to new locations to solve new issues as they emerge.*
- *Flexibility in approach to capital spending (modular design and redeployability means that capital spending can be projected for much shorter time horizons)*

Storage with conventional GT power plant:

- *Primary response – Increase of capacity and response time*
- *Increase of power plant electricity production*
- *EFR – Capacity of response*
- *Black Start – Validation of the service with the storage*
- *LVRT voltage support – quantity and BESS sizing*
- *ROI (Return on Investment)*



Flowchart for strategic decision making through innovation integration

The strategic decision-making method presented in the previous sections has been adapted to cover five specific use cases of the technologies, focusing on various aspects of their impact on the electricity networks. The use cases presented here are aligned with the business use cases explored in the FEG platform and will contribute to the integration of FEG architecture. The basics of these use cases will be presented here while in great detail are analysed on the full deliverable 2.3:

- Use case 1: BESS integration in Cyprus. An evaluation of BESS impact on the Cyprus power system is being conducted for various integration scenarios, building on the flexibility assessment platform of task 2.4 and the strategic decision making method basics and flow presented in the previous paragraphs. Specific services and operational patterns for the BESS have been considered and flexibility and cost KPIs have been calculated to illustrate the optimal scenario, in the system planning horizon of the following 5 years.
- Use case 2: RES integration in Greece: An indicative use case of RES integration challenges with the Greek RES and demand characteristics is being presented e. The BESS integration is been considered for improving the regulating reserves of the network , and KPIs regarding operation cost, reserve requirements, reliability and RES penetration are being calculated, showing the impact of the BESS on system performance
- Use case 3: Congestion relief with power flow controller for facilitating RES project: Alternative innovative solutions to conventional substation upgrade for improving RES integration are being provided in use case 3 through the Power Flow Controllers. The Power Flow Control innovative solutions (namely SmartWires products) is weighed against conventional grid upgrades or a phase shifting transformer in various Key Performance Areas and score as a preferable solution.
- Use case 4: Enabling Challenging Construction & Reduce Generation Costs. The facilitation of the re-conductoring project with low additional capacity needed is being presented in a use case implementing Power Flow Control devices. The alleviation of congestion through alternative routes facilitates the safe implementation of the reconductoring project and security of supply with no additional costly generation.
- Use case 5: Innovation technology as an alternative to conventional transmission upgrade solutions. Another use case of a utility facing a combination of transmission challenges is being presented: new RES capacity to be connected, load growth and phase-out of thermal capacity constitute a difficult situation. Specific strategies of modular deployment are being analysed. It is shown that modular PFC accounts for uncertainty in future grid development as an overall better business case than traditional options like reconductoring. The optionality to augment PFC deployment size at an existing installation in case the needs increase at that location, allows utilities to defer high-cost decisions to a later date.

1.4 Conclusions

The conclusions derived from the activities presented in deliverable 2.3 are the following:

- Looking into the questionnaire results (see D.2.1), stakeholders provide some controversial answers in respect with prioritizing important energy topics, showing that it is not crystal clear to them the 'cause-and-effect' relation of innovations with energy transition.
- In this sense, a method for promoting innovations as alternative solutions by measuring their impact would be very helpful. This decision-making process depends greatly on the '*level of insight*' that network operators have on system operation and assets capability, regulatory framework, the *available solutions* for improving flexibility resources, through market

liquidity and grid technology innovations. Network operators and policy makers need to correlate among these factors.

- The CBA approaches very much differ depending on who is carrying out the CBA: industry and technology providers, energy market actors, or actors involved in regulated activities and government assignments (i.e. network operators, NRAs, policy makers). Their requirements from a CBA method are not the same since their aims are different.
- ENTSO-E is proposing a comprehensive and solid CBA methodology for evaluating new projects impact on the electricity network and it can be used as a guideline for TSO Network Development Plans. However, only in its latest edition, ENTSO-E CBA highlighted flexibility as a benefit to be assessed in future projects, relating it with system security rather than adequacy.
- US DoE through the Smart Grid Computational Tool Architecture promotes a four-stage approach of *Asset-> Function-> Mechanism-> Benefit.* It implements a variety of specificities and remuneration mechanisms existing in the US electricity market, basically for facilitating market participants for investments. The approach followed concerns end-to-end electricity networks.
- US DoE and TenneT NL have developed CBA tools for storage projects, implementing the details of each country's market rules and regulatory framework. They provide an important tool for actors to evaluate the prospective storage projects for the operational characteristics and the various stacked services they aim to provide.
- The technologies demonstrated in FLEXITRANSTORE are very much relevant with most benefits identified in the various CBA approaches and provide multiple drivers for improvement.
- It follows a three dimensional approach of 'Solution Technologies'-'System benefits'-'System Integration' and several Key Performance Areas (KPAs) and respective KPIs have been identified. Among these, five KPAs have been identified as commonly relevant to the FLEXITRANSTORE demonstrated innovations.
- The proposed strategic decision making is designed mainly for system operators and policy makers evaluating the effects of new technologies onto the electricity network. The results of the method dictate solutions to power system challenges and proposals for market/regulation reforms to support any grid resources needed.
- Furthermore, it will set the basis for further elaboration on evaluating the results, the scalability and replicability of the demonstrated solutions during the WP13 activities.

1.5 References

1. "Harnessing variable renewables: a guide to the balancing challenge", International Energy Association, 2011.
2. Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC.
3. Cochran, J., Miller, M., Zinaman, O., Milligan, M., Arent, D., Palmintier, B., O'Malley, M., Mueller, S., Lannoye, E., Tuohy, A., et al. (2014). Flexibility in 21st century power systems. Technical report, National Renewable Energy Laboratory (NREL), Golden, CO.
4. EURELECTRIC (2014). Flexibility and aggregation: Requirements for their interaction in the market. Technical report, The Union of the Electricity Industry.
5. OFGEM, "Innovation Link: Enabling trials through the regulatory sandbox", 2018.

6. Sara Bjørn Aaena, Søren Kerndrup, Ivar Lyhne, “Beyond public acceptance of energy infrastructure: How citizens make sense and form reactions by enacting network of entities in infrastructure development”, Energy Policy 96(2016)576–586.
7. https://tyndp.ENTSO-E.eu/Documents/TYNDP%20documents/Cost%20Benefit%20Analysis/2018-10-11-tyndp-cba-20.pdf
8. EUROPEAN COMMISSION, Directorate-General for Regional and Urban policy “Guide to Cost-Benefit Analysis of Investment Projects”, European Union, 2015.
9. Flego, G., Vitiello, S., Fulli, G., Marretta L., Stromsather J., “Cost Benefit Analysis of Smart Grid Projects: Isernia - - Costs and benefits of Smart Grid pilot installations and scalability options”, JRC, European Union, 2018.
10. “Towards uniform benefit-cost analysis for smart grid projects: an example using the Smart Grid Computational Tool”, Ernest Orlando Lawrence Berkeley National Laboratory Report, 2016
11. “User Guide for the Department Of Energy Smart Grid Computational Tool (SGCT)”, Navigant Consulting prepared for the US DoE, 2011.
12. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC105603/kjna28439enn.pdf
13. “ES Computational Tool (ESCT) Version 1.2 – User Guide” Navigant Consulting prepared for the US DoE, 2012.
14. “TenneT Storage Tool User Guide V1.0”, Ecofys 2018, commissioned by TenneT.
15. Ordoudis, C., Pinson, P., González, J. M. M., & Zugno, M. (2016). An Updated Version of the IEEE RTS 24-Bus System for Electricity Market and Power System Operation Studies.
16. Subcommittee, Probability Methods. "IEEE reliability test system." *IEEE Transactions on power apparatus and systems*6 (1979): 2047-2054.
17. Morales, Juan M., et al. *Integrating renewables in electricity markets: operational problems*. Vol. 205. Springer Science & Business Media, 2013.
18. Löfberg, Johan. "YALMIP: A toolbox for modeling and optimization in MATLAB." *Proceedings of the CACSD Conference*. Vol. 3. 2004.