FlexPlan

Advanced methodology and tools taking advantage of storage and FLEXibility in transmission and distribution grid PLANning

Identified regulatory limitations and opportunities based on the regional cases

D6.2

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About FlexPlan

The FlexPlan project aims at establishing a new grid planning methodology considering the opportunity to introduce new storage and flexibility resources in electricity transmission and distribution grids as an alternative to building new grid elements. This is in line with the goals and principles of the new EC package *Clean Energy for all Europeans,* which emphasizes the potential usage of flexibility sources in the phases of grid planning and operation as alternative to grid expansion. In sight of this, FlexPlan creates a new innovative grid planning tool whose ambition is to go beyond the state of the art of planning methodologies, by including the following innovative features: integrated T&D planning, full inclusion of environmental analysis, probabilistic contingency methodologies replacing the N-1 criterion as well as optimal planning decision over several decades. However, FlexPlan is not limited to building a new tool but it also uses it to analyse six regional cases covering nearly the whole European continent, aimed at demonstrating the application of the tool on real scenarios as well as at casting a view on grid planning in Europe till 2050. In this way, the FlexPlan project tries to answer the question of which role flexibility could play and how its usage can contribute to reduce planning investments yet maintaining (at least) the current system security levels. The project ends up formulating guidelines for regulators and for the planning offices of TSOs and DSOs. The consortium includes three European TSOs, one of the most important European DSO group, several R&D companies and universities from 8 European Countries (among which the Italian RSE acting as project coordinator) and N-SIDE, the developer of the European market coupling platform EUPHEMIA.

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List of Abbreviations and Acronyms

Abbreviation/Acronym	Meaning
aFRR	Automatic Frequency Restoration Reserve
BRP	Balance Responsible Party
CAPEX	Capital Expenditure
CBA	Cost Benefit Analysis
CBCA	Cross-border Cost Allocation
CDSO	Closed Distribution System Operator
DSO	Distribution System Operator
EC	European Commission
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
EV	Electric Vehicle
IEM	Internal Electricity Market
mFRR	Manual Frequency Restoration Reserve
NRA	National Regulating Authority
NTC	Net-transfer capacity
OPEX	Operational Expenditure
RC	Regional Cases
R&D	Research and Development
R&I	Research and Innovation
REN	Redes Energeticas Nacionais (Portuguese TSO)
RES	Renewable Energy Sources
RR	Replacement Reserve
SO	System Operator
SO GL	System Operation (Guideline)
TN	Transmission Network
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
VOLL	Value of Lost Load

Executive Summary

This deliverable is the second of a series of three reports dedicated to the regulatory analysis of topics related to the FlexPlan project.

Firstly, it investigates the results of the six regional cases under a regulatory point of view, trying to highlight the advantages of the use of flexibility resources in the grid expansion process and the barriers that can arise when the European and national regulatory framework are included in the analysis.

Secondly, the replicability and scalability of the project is analysed according to two different points of view:

- The FlexPlan methodology i.e., combination of different methods and techniques assembled in the project, allowing to make estimations of the optimal system expansion considering the use of flexible resources.
- The FlexPlan tool i.e., project-specific implementation of the FlexPlan methodology in a set of software codes and data

The results of the six regional cases show that flexibility resources are used in synergy with conventional grid expansion (reinforcement or installation of AC/DC lines). This synergic behaviour can be observed under different point of views:

- Sometimes, flexibility resources and reinforcement of new lines are employed to solve the same congestion, thus they are connected to the same node and cooperate.
- Sometimes, branches and flexibility resources are used separately, for example in cases where the congestion last long gird reinforcements are preferred.

The advantages coming from the TSO-DSO cooperation can also be highlighted, indeed unnecessary investments are avoided thanks to the possibility of each system operator to use resources connected to the grid on another system operator.

Barriers which could obstacle the deployment of flexibility resource are identified to be:

- Authorization procedures for the development of flexibility resources
- Storage facilities ownership, which is mostly forbidden to system operators with few exceptions.
- Storage and demand response are equally considered to conventional power plants; thus prequalification is not adapted to technical characteristics of these new technologies.
- Privacy policies for data exchange between system operators can create problems during the definition of a coordination.

Finally, average scalability indicators for the FlexPlan methodology and tool show very high scalability level, with some limitations related to computational power, required for upscaled versions of the tool. It can be concluded that the FlexPlan methodology has very high scores related to both replicability and scalability, while the specific implementation into FlexPlan tool has slightly lower scores.

1 Introduction

Nowadays, the Pan-European net-zero emission goal by 2050 is driving the energy transition [1]. The energy production system is moving toward the deployment of a steadily increasing amount of Renewable Energy Sources (RES) as well as the electrification of loads, that up to now have been powered by fossil fuels. These changes create new challenges to be faced by European system operators in order to allow a straightforward transition. RES production is affected by bigger uncertainty with respect to non-renewable sources and many different resources are not able to produce energy on demand (e.g. photovoltaic plants) but are characterized by a variable generation pattern in dependency from the real-time primary energy availability. Single RES plants are generally characterized by small/medium production capacity and are distributed all over a wide area. Furthermore, the increasing energy demand, which was once met by the traditional power plants based on fossil fuels, pollutant sources, now requires in an as much as possible reliable access to renewable and clean energy sources. All these requirements set up the ground for the investigation of new strategies to ensure the safe planning and management of the electricity grid, not only endorsing the transition but also avoiding increase of price volatility, resulting from high demand in periods of small production and inefficiency of congestion management. The use of flexibility resources, such as storage facilities to store energy in periods of overgeneration or demand side management in periods of high demand, has been highlighted in recent European Directives [2] to be an efficient solution. Indeed, in the circumstances of grid planning, flexibility resources are considered of first importance because they can be synergic to grid reinforcement, which leads to big economic investments, long time to obtain building permit, environmental concerns, public opposition, etc.. For that reason, it is important that grid planning methodologies consider also to avail themselves of flexibility resources as an alternative or in addition to traditional grid reinforcements.

The main purpose of FlexPlan is to provide an innovative grid planning tool able to incorporate flexible grid elements in both transmission and distribution systems, meaning that optimizations employ flexibility resources (such as storage and demand management) as well as conventional network assets to find the least cost solution for the system.

The development and testing of the tool involves the collection of datasets about different scenarios for the testing phase and the generation of a comprehensive grid model reproducing every physical and in-force or proposed regulatory limitation. To do so six different regional cases (RC) have been identified which cover almost all Central Europe (Italy; Balkan region and Germany, Switzerland and Austria), Western Europe (Iberian Peninsula and French and Benelux) and Nordic countries (Nordic Region). The testing of the implemented planning tool is carried out by considering different scenarios which are set up for three different target years 2030, 2040 and 2050. The design of the scenarios originates from the European Network of Transmission System Operator for Electricity (ENTSO-E) Ten-Year Network Development Plan (TYNDP) 2020 where three storylines are described for 2030 and 2040. Scenario data for 2050 have been outlined with a smart extrapolation for each storyline of TYNDP 2020. Further information concerning methodologies and processing of data for scenario generation are described in detail in deliverable D4.1 [3].

Regarding the modeling phase, the goal is to create grid models with similar level of details for the different regions. Therefore, the applied approach consisted in looking for existing Pan-EU system models to be used as main datasets so to obtain a coherent grid model of each regional case, respecting different border conditions and including existing and planned interconnections. Given that the scenarios data were taken from TYNDP studies from ENTSO-E, the same data source has been considered and, through the signature of a Non-Disclosure Agreement (NDA) with ENTSO-E, each member of the consortium involved in the regional cases execution received the requested dataset. The extra-high voltage grid model corresponds to a 2025 operational scenario with generation and demand corresponding to market simulations performed by ENTSO-E in TYNDP 2018. If necessary, by means of other analyses, RC models were complemented with additional data sources and reviewed by each regional case leaders for further adaptions. Anyway, the TYNDP 2018 model stops at the 220 kV grid voltage level, so sub-transmission networks have been reconstructed by means of public data and synthetic distribution networks were created to reproduce the distribution grid. Further information concerning the modeling phase can be found in deliverable D5.1 [4]; they will be recalled in the following chapters only whenever needed for explanatory and understanding purposes.

This deliverable includes the first part of the regulatory elaborations that are provided at the end of FlexPlan activities by working on the results of the simulations. This regulatory analysis starts from the analysis of the regulatory drivers to be considered in the development of future network-planning tools; goes on analyzing the results of the regional case studies identifying the main lessons learned and their regulatory implications; and ends up reviewing current regulations and proposing future improvements aimed at reducing the barriers for flexible elements to provide congestion management services. The present deliverable is focused on providing an in-depth analysis of the results obtained from each regional case. The purpose of the assessment is to highlight how national regulatory frameworks enhance or provide constraints on the use of flexible resources to enforce an optimal network plan. The analysis is conducted at regional level but even at pan-European level, observing the differences in regulatory conditions among different nations.

The following chapters are organized as follows:

- Chapters from 2 is dedicated to the six RC and it is structured according to a two-step methodological approach:
  - First, the main results of the regional case will be provided, highlighting the role played by flexibility resources in the optimal solution and analyzing in detail when flexibility was preferred to building new lines and why so.
  - Second, a regulatory assessment will be carried out, critically evaluating the need to modify existing regulations to enforce the optimal solution.
- Chapter 3 analyzes the issue of scalability and replicability of the models. Technical and economic factors will be investigated, as well as regulation and acceptance of stakeholders to understand how and if the current regulatory and social background and foreground are ready to embrace amendments.

- Chapter 4 is dedicated to the final conclusions and observations about gained knowledge and possible steps ahead.

2 Regional cases results: identified opportunities and possible limitations

This chapter analyses the main differences and analogies of the results of the six regional cases. In the first paragraph the opportunities given by the synergic deployment of flexibility resources together with the conventional grid expansion elements are highlighted deepening the simulation results. More detailed description of each specific regional case can be found in Deliverable 5.2 [5], instead the object of this deliverable is a general overview. In the second paragraph an analysis of the barrier and limitations encountered are analysed when the present regulatory framework is taken into consideration so to understand how the FlexPlan methodology could take place in present planning procedures.

2.1 Identified opportunities in flexibility resources

The results of the six regional cases (RC) show a great exploitation of flexibility resources in synergy with conventional expansion approach. Indeed, every RC is characterized by the final selection of the different technologies (AC/DC branches, storage assets and flexible loads). For most of the RC, the investments in storage and demand side management are frequently chosen as cost-effective solutions by the optimization algorithm, thus the potential of flexibility resources in the grid expansion planning is strongly supported by the simulation results.

In all three decades (2030, 2040 and 2050) and for all RC, an overall reduction of the system costs is obtained when comparing costs coming from Optimal Power Flow (OPF) model (which carries out a pre-investment dispatching costs analysis) and the Grid Expansion Planning Tool (GEP) (which selects a subset of the proposed candidates able to minimize total system costs; this subset includes flexibility assets, working in synergy with conventional grid reinforcements). Anyway, it is observed an increase of the overall system costs during the three decades in most of the RC. This increase is linked to two different reasons:

- The awaited increase in consumptions, which often determines an increase of load curtailment.
- The expected increase of RES generation, which often determines an increase of generation curtailment.

Both these contributions are linked to the FlexPlan constraint of limiting the number of candidates to be analysed in the GEP when considering the available hardware resources to run the simulations. The deployment of RES generation, which characterizes the scenarios used as inputs for the FlexPlan tool, shows to be very effective in cost reducing when the resources are geographically well-placed, i.e. installed in the regions where the consumption is high. Indeed, during weeks characterised by high local RES generation, load curtailment is reduced and, thanks to the strategic location (near the locations characterized by the highest consumption), the increase of energy production from RES does not produce additional congestions in the overall network. France and BeNeLux RC represents an example of this, in particular when the results of the decade 2030 are analysed. However, when RES generation deployment occurs in regions where the current grid is not able to back up such increase, the obtained results show that the tool adopts two different approaches:

- the suggested expansion of the grid is not able to transport such a quantity of energy, thus we observe a steep increase of the overall system costs. In these cases, it is not possible to evaluate the outcome of the tool and the efficiency of flexibility resources because of the small number of candidates considered. The limited number of technical resources available for testing the regional cases represent a crucial limitation.
- in the Austrian and Switzerland regions, especially for the decade 2040, it is possible to observe that an increase of RES generation is directly linked with the selection of a high number of flexibility candidates, including storage and flexible loads, so to avoid an increase of generation curtailment when an increase of RES generation is expected.

Furthermore, the great advantages of storing energy coming from RES generation can be observed in the German RC, where a clear example of exercising arbitrage by storage devices can be observed. Overall, flexibility resources prove to be essential for the integration of RES generation.

Flexibility is frequently selected to work in synergy with conventional network reinforcement to solve the same congestion. Balkan and Italy RC show how the use of different technologies to solve the same issue is able to further reduce the overall system costs. Furthermore, in some cases the final solution suggests a synergic operation among different resources but without solving completely the congestion. At first sight, it seems that the non-voluntary load or generation curtailment is more convenient with respect to the installation or reinforcement of lines or the settlement of new flexibility resources. Anyway, further analyses should be conducted when such phenomenon occurs, evaluating if constraints on load interruption should be included rather than disincentivising it with high VOLL penalties.

The results of the simulations show of the importance of a coordinated planning of transmission and distribution networks. This can be seen mainly looking at two different aspects:

- Often the acceptance of a candidate on a specific corridor also suggests the adjustment of close lines. Anyway, when lines at the border between transmission and distribution grids are considered, it is important to develop an integrated planning procedure in order to evaluate if the solution of a congestion on the transmission line determines the occurrence of a new congestion in the distribution network.
- The selection of a candidate on the distribution or transmission network, could be beneficial for a congestion which occurs respectively in the transmission or distribution network. In this case the cooperation during the development of the network expansion is necessary to avoid useless investments.

AC/DC Branches

It has been shown in all scenarios that conventional grid expansion assets (AC/DC lines) are often necessary to ensure that every resource which contribute to the optimization problem (i.e. generation facilities, loads, flexibility assets, etc.) is sufficiently connected with the surrounding resources. Furthermore, they are always used when the congestion last long or in case the connection of two separate nodes can bring great benefits to the overall system planning (German RC). Anyway, this could also be a problem of modelling choices, according to which flexibility candidates are characterized by operation cycles completed in 24 hours (for shiftable demand) or 1 week (for storage).

Storage facilities

From the Austrian and Switzerland RC, storage facilities are mainly deployed when a higher penetration of RES generation occurs, furthermore they are used to increase the efficiency of the energy system in 2040.

Flexible Loads

Flexible loads reveal to be very efficient when selected near RES generation facilities. Locational information is proved to be very importance in the selection of these flexibility assets in order to maximize its potential.

2.2 Identified limitations in the regulatory framework

Section 2.1 summarizes the results of the six RC highlighting that flexibility resources are considerably taken into account when they are included in the grid network development plan. Given the overall reduction of system costs obtained in the simulations, in this section it will be investigated how European and national regulatory framework could affect the exploitation of these resources. By means of a questionnaire directed to each RC leader, which can be found in *Annex I: Questionnaire for RC Leaders*, national regulations have been analysed. Here below, a summary of this analysis.

Firstly, the FlexPlan planning tool does not take into consideration authorization procedures and the time needed for an acceptance for the settlement of storage facilities and reinforcement/construction of transmission and distribution branches. In order to reinforce the network in the Nordic Region (only Norwegian Regulation is considered because accepted candidates are located in that country planning candidates should only be built if they minimize the total socio-economic costs, which means that they are the most socio-economically profitable measure to meet the need and ensure conformity with laws and regulations among the evaluated possibilities.

Furthermore, possible negative impacts on the environment and on the society are taken into account during the authorization procedure. The same goal is met by the FlexPlan planning approach, the target function is indeed based on the minimization of the overall system costs and environmental aspect are monetized directly in the target function. Concerning the construction and exploitation of storage facilities, in Spain the same procedures as any generation facilities must be fulfilled[1]. France and BeNeLux RC highlight instead the necessity of a consultation with transmission and distribution system operators according to their needs of specific assets[2]. Environmental regulations are always taken into account as a common measure in all MS.

Secondly, the possibility of storage facilities and demand response to participate to congestion management and balancing services is included in the regulatory analysis performed by the NRAs. Storage facilities and demand response are currently allowed to participate to electricity market and to provide system services like every kind of generation facility in almost every MS. In Spain, they can specifically

[1] Real Decreto-ley 6/2022, de 29 de marzo, por el que se adoptan medidas urgentes en el marco del Plan Nacional de respuesta a las consecuencias económicas y sociales de la guerra en Ucrania

[2] Code de l'énergie - Article L. 352-1-1n

participate in frequency control services and general conditions for the owners to be considered as Balancing Service Provider (BRP) are already updated establishing the requirements for the participation in each service: aFRR, mFRR and RR [3]. However, the implementation of the Internal ElectricityMarket (IEM) Directive 2019/944 is almost completed in every MS included in the regional case, thus a new implication is introduced: when a storage facility is owned by a SO the flexibility would not be allowed to be offered in the electricity markets. Indeed, art. 36 and 54 of IEM Directive 2019/944 states that transmission and distribution SO are not allowed to own, develop, manage or operate storage facilities and even if there are some exceptions concerning the ownership, in those conditions the installed capacity cannot be used for balancing and congestion services. Furthermore, some differences are found in the national implementations: in Italy, for instance, when no third parties are interested to develop the full request capacity, TSO could be allowed to own the facility but, anyhow, its operation must be assigned to third parties; IEM Directive also foresees the TSO/DSO operation, on the contrary. The FlexPlan planning tool includes the integration of storage assets by means of a market procedure. As, according to the identified regulatory limitations, storage facilities to be developed cannot be owned by system operators, in order to assure an optimal exploitation of the potential of these resources, FlexPlan proposes to attract private investors developing a proper and favourable incentivizing framework. Concerning this topic, more information can be found in Deliverable 6.3 [6].

As mentioned, flexibility assets are currently considered like traditional generation facilities. They are already allowed to participate according to all prequalification procedures developed. However, such procedures were mainly written considering technical characteristics of conventional power plants. Even if not explicitly, the allowance for the participation to electricity market without updating technical and operative parameters included in European and national regulations could create an unfavourable environment which hampers the integration of flexibility resources in the market. According to this, FlexPlan consortium acknowledges that flexibility resources are not completely integrated on a level-playing field and regulations of market participation should be updated to counteract the disadvantageous effects of the current regulatory framework.

Finally, a coordinated approach of transmission and distribution planning processes has proved to be very efficient, thus it is necessary to facilitate access and exchange of all necessary data. All parties performing a regulated task should be able to access data to an appropriate level of detail while respecting data privacy. For example, TSOs might need knowledge about consumption and generation at the point of common coupling between TSO and DSO, sometimes they also need information of the generation technology to understand if flexibility assets respect their obligations. During planning procedures, according to [7], TSOs and DSOs should develop the network expansion plans according to similar assumptions, for instance in terms of generation and consumption forecasts, and common parameters for planning methodology, for example the definition of connection requirements. Both long-term and operational planning should be conducted in coordination and, as long as confidentiality issues are met, even data concerning year ahead-availability plan, outages and emergency plans should be included.

[3] Resolución de 11 de diciembre de 2019, de la Comisión Nacional de los Mercados y la Competencia, por la que se aprueban las condiciones relativas al balance para los proveedores de servicios de balance y los sujetos de liquidación responsables del balance en el sistema eléctrico peninsular español

3 Replicability and Scalability

The present chapter assesses the main outcomes of FlexPlan project, which are distinguished into two parts:

- The FlexPlan methodology i.e., combination of different methods and techniques assembled in the project, allowing to make estimations of the optimal system expansion considering the use of flexible resources.
- The FlexPlan tool i.e., project-specific implementation of the FlexPlan methodology in a set of software codes and data.

3.1 Definitions

The present study refers to scalability and replicability terms and definitions, which were established in the framework of EU project Grid+ specifically for the SmartGrids domain (see [8] and [9]). The terms and definitions are not novel, but based on several technical studies and modified, whenever it was necessary in order to work appropriately within the domain.

- **Scalability** is the ability of a system to maintain its performance (i.e., relative performance) and function, and retain all its desired properties when its scale is increased without having a corresponding increase in the system's complexity.
- **Replicability** denotes the property of a system to be duplicated at another location or time.
- A **system** is understood as a set of interacting elements with similar boundary conditions.

Several other factors should be considered:

- The ability of a system to scale or/and replicate does not necessarily imply that the scaled-up system performs well.
- Scalability is often design-dependent and that it must be tackled from the very beginning.
- Scaling-up and replication might be interlinked, scalability and replicability are independent. The former is rather system dependent, whereas the latter depends on the expected change of the boundary conditions.

Although scalability and replicability of each system depends on specific factors, common and sufficiently generic factors should be sought.

- Technical factors determine whether the solution developed in a particular project is inherently scalable and/or replicable, i.e., whether it is feasible to scale-up and/or to replicate.
- Economic factors reflect whether it is viable to pursue scaling up or replication.
- Regulation and acceptance of stakeholders such as end users, regulators, authorities, etc., reflect the extent to which the current regulatory and social environment is ready to embrace a scaled-up version of a project or whether a new environment is suitable for receiving a project.

Table 3-1: The main factors defining scalability and replicability potential

Area	Scalability	Replicability
Technical	Modularity Technology evolution Interface design Software integration Existing infrastructure	Standardization Interoperability Network configuration
Economic	Economy of scale Profitability	Macroeconomics Market design Business model
Regulatory	Regulation	Regulation
Stakeholder acceptance	Acceptance	Acceptance

Grid+ also developed a workflow for definition of scalability and replicability potential, where the above-mentioned factors were ranked in certain order with pre-domination of the technical part.

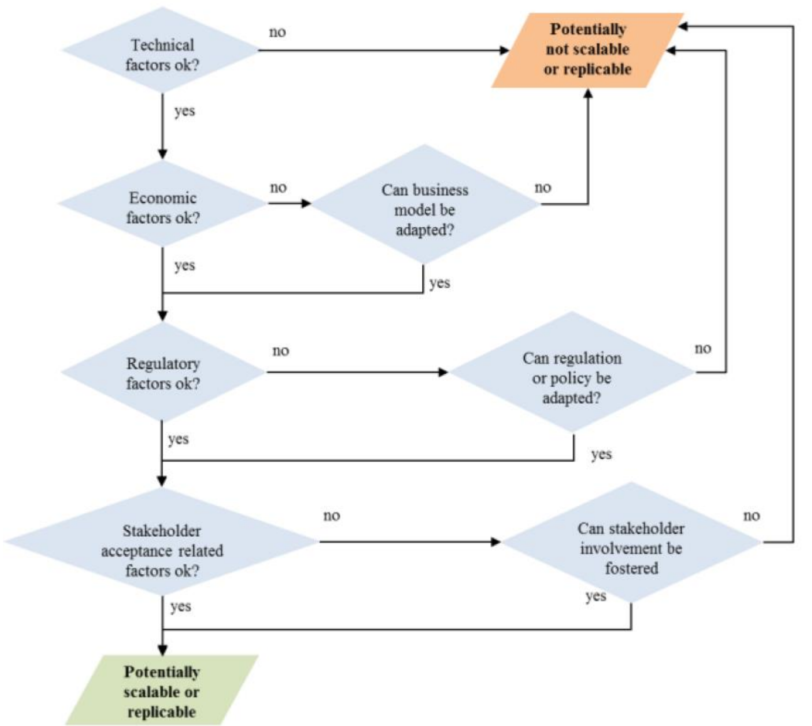

Figure 3-1 Workflow for evaluation of replicability and scalability potential.

3.2 Technical factors for scalability

Following the workflow, the study defined factors for different areas of scalability. They are described in the following and summarized in Table 3-2..

3.2.1 Modularity

Modularity is the basic precondition for scaling-up. It refers to whether a solution can be divided into interdependent components. A monolithic solution will seldom be appropriate for implementation at a larger scale. Clearly defined (and separated) constituent parts, on the other hand, allow for the flexibility needed to transfer the setup to a larger scale.

This factor asks and studies then to what extent a solution is modular (e.g., how easy it is to add new components or whether there are limits on adding components).

3.2.2 Technology evolution

As network projects and their components tend to have a considerable operational lifetime (ranging from years to decades in case of transmission system projects), expected technology evolution is essential. During the time lapse between the roll-out of the original solution and the roll-out of a scaled-up version, the evolving state-of-the-art in underlying technology may turn previously impossible exploits into feasible ones. On the contrary, some projects may reduce their scalability simply because the technology, which they reside on, may become obsolete. The latter is especially relevant for communication protocols.

This factor asks and determines to what extent the expected technological advances allow the solution to increase in size.

3.2.3 Interface design

This factor is complementary to the previously mentioned modularity. The number, complexity and intensity of interactions among the components and with the outside world need to remain manageable. Interface design explicitly addresses the number of interactions among components. If they increase more than linearly with the size, the scaled-up solution may become overly complex and redundant at the desired scale, reducing the performance of the scaled-up solution.

3.2.4 Software integration

Leaving aside the complexity of the solution itself, the software tools (used, for instance to deploy the simulation models, databases, etc.) need to be able to cope with the increased size of the problem. The size of the problem is not only determined according to the number of buses and branches considered but, to a much greater extent, it is characterized considering the number of elements associated to their possible states. Furthermore, it should be considered that this factor can be mitigated by a favourable technological evolution. Existing infrastructure

Demonstrator projects, by definition, take place in realistic settings and are thus bound by pre-existing conditions. Even if the original project is integrated, the current infrastructure may create limits on the maximum scale that can be reached. These limits can range from mild constraints to insurmountable barriers, therefore, the requirements (of the scaled-up solution) on the existing infrastructure have to be analysed.

The factor asks and studies to what extent the current infrastructure creates limits on the maximum size of the solution.

Table 3-2 Summary of the Technical Factors for scalability area.

Scalability		
Factor	**The Methodology**	**The Tool**
Modularity	How easy it is to add new components or whether there are limits on adding components?	Does the tool have a modular architecture?
Technology evolution	Can we expect significant improvement of computational power/time?	Can we expect significant improvement of computational power/time?
	Can we expect significant improvement of the applied mathematical methods and techniques?	Can any residing technology become obsolete?
	Does the methodology depend upon other technologies e.g. telecommunications?	Does the tool depend upon other technologies e.g. telecommunications?
Interface design	Does the interface design e.g. interaction between different components (internal and external) limit upscaling of the methodology?	Does the interface design e.g. interaction between different components (internal and external) limit upscaling of the tool?
Software integration	To what extent the performance of methodology is affected when the solution size increases?	To what extent the performance of software tools is affected when the solution size increases?
Existing infrastructure	Is there any existing infrastructure, which may limit the maximum scale for deployment of the methodology?	Is there any existing infrastructure, which may limit the maximum scale for deployment of the tool?

3.3 Technical factors for replicability

3.3.1 Standardisation

A core requirement for replication in a different environment is that a given solution can interact with other systems. Thus, a solution can be considered replicable if it itself comply with published standards. From the point of view of the grid operator this avoids vendor-specific solutions that may only function well in a given setting.

The indicator asks and determines to what extent the solution is standard compliant and/or whether the solution can be easily made standard compliant.

3.3.2 Interoperability

Standardization itself is not sufficient because the solutions have to be interoperable as well. Given the many standards that exist, it is in principle possible to have something standardized that is not interoperable with a given system/setting (that operates according to different standards). Interoperability refers to the ability of two or more networks, systems, devices, applications, or components to interact, exchange and use information to perform the required functions.

The interoperability indicator asks and determines to what extent solutions and their components/functions are interoperable or even plug-and-play.

3.3.3 Network configuration

The external conditions imposed by the host network configuration need to be defined so to facilitate the integration of the solution in the system. This refers to elements, which are given and cannot be changed within the scope of a project (e.g., climate conditions such as temperature, wind, precipitation levels, terrain conditions, local generation mix, demographics, consumption mix and profiles, etc.) because they can strongly affect the obtained solution. For example, if a project focuses on the joint use of storage systems and solar power plants, the replication of these solutions depends very much on the solar irradiation levels of the new host area.

The network configuration indicator asks and studies to what extent the solution depends on given resources and infrastructures.

Table 3-3 Technical factors for replicability area

Replicability		
Factor	**Methodology**	**The tool**
Standardisation	Are there any country-specific standards, which may create obstacles in deployment of the methodology in another country?	Are there any country-specific standards, which may create obstacles e.g. imbalance settlement periods, grid models etc.?
Interoperability	Are there any limitations on interoperability with methods used in other countries? (e.g. CBA rules)	To what extent are solutions and their components/functions interoperable or even plug-and-play?
Network configuration	Are there any elements which are given and cannot be changed e.g. climate, temperatures, terrain conditions, generation mix) which are limiting for replication of the methodology?	Are there any elements which are given and cannot be changed e.g. climate, temperatures, terrain conditions, generation mix) which are limiting for replication of the tool?

3.4 Economic factors for scalability

3.4.1 Economy of scale

A project will be scaled up in a sustainable manner only if it is viable on the intended scale. This implies that both the cost and revenues need to evolve along with the project scaling process. This essentially means that the marginal cost and revenue functions for a given solution will make scaling-up viable or not. Development of the marginal cost curve according to the number of deployed units is particularly interesting in this context, where increase, decline or stepwise development are the most obvious trends influencing scalability.

The factor asks whether the cost function allows an increase in size or what are the limitations that be imposed.

3.4.2 Profitability

Similarly to the previous factor, the revenues should increase according to an increase of the size of the problem.

The factor asks whether the revenue function allows increase in size and what limitations it can impose.

Table 3-4 Economic factors for scalability

Scalability		
Factor	**Methodology**	**The tool**
Economy of scale	Internal factors	Internal factors: What is the cost function for using the tool e.g. linear or exponential?
	External factors	External factors: What is the cost function for external costs e.g. linear or exponential? (collection of data, updating of grid models)
Profitability	To what extent benefits grow when increasing the solution size? (e.g. increasing size of the system vs. optimal solutions)	To what extent the benefits grow when increasing the solution size?

3.5 Economic factors for replicability

3.5.1 Macroeconomic factors

Different domestic settings can have significant consequences on the economic prospects of a project/solution. Therefore, it necessary to assess whether the solution proposed is (still) profitable in other European countries with regard to the domestic factors as interest and currency rates, local taxes and charges, discount rates etc. This can typically be achieved via a limited scenario analysis on a few selected target countries.

3.5.2 Market design

A domestic market design is another determining factor, mostly because market design means definition of the key roles and responsibilities, including any possible limitations, as for example it is stipulated in the European Internal Electricity Market Directive [2] and the corresponding Regulation [10].

The factor asks then to what extent the solution depends on a given market design.

Table 3-5 Summary of economic factors for replicability area

Replicability		
Factor	**Methodology**	**The tool**
Macroeconomics	To what extent can national taxes, CO2 charges, interest rates, support schemes limit replication of the methodology?	To what extent can national taxes, CO2 charges, interest rates, support schemes influence replication of the tool?
Market design	How dependent is replication of the tool upon national variations of market design (definition of products, services and bids) including roles and responsibilities?	How dependent is replication of the tool upon national variations of market design (definition of products, services and bids) including roles and responsibilities?

3.6 Regulatory factors for scalability and replicability

Regulation is understood here in general terms of roles of agents, rules to provide services, rules on how to remunerate regulated agents and of rules on interaction between agents.

Table 3-6 Summary of regulatory factors for scalability and replicability areas

Scalability			Replicability		
Factor	**Methodology**	**The tool**	**Factor**	**Methodology**	**The tool**
Regulatory	To what extent regulatory factors may influence the size of the deployment? (e.g., limitations on access to data)	To what extent regulatory factors may influence the size of the deployment? (e.g., limitations on access to data)	Regulatory	To what extent regulatory factors may influence replication in another country? (e.g., limitations on access to data, roles and responsibilities)	To what extent regulatory factors may influence replication in another country? (e.g., limitations on access to data, roles and responsibilities)

For scalability area the factor regulation asks and studies whether there are any regulatory barriers with respect to the size and scope of the solution.

For replicability area the factor regulation asks to what extent the solution depends on current national or local regulation in order to be feasible and viable and whether barriers arise from this dependency.

3.7 Stakeholder acceptance factors for scalability and replicability

In case of scalability the factor indicates the extent to which stakeholders like regulators, policy makers and end users are ready to embrace an enlarged project.

The factor asks to what extent stakeholder acceptance has been taken into account and whether any challenges are expected.

Table 3-7 Summary of acceptance factors for scalability and replicability areas.

Scalability			Replicability		
Factor	**Methodology**	**The tool**	**Factor**	**Methodology**	**The tool**
Acceptance	To what extent the methodology supports increased number of users?	Which stakeholders like regulators, policy makers and end users are ready to embrace an enlarged project?	Acceptance	To what extent the user acceptance problems can be expected?	To what extent the user acceptance problems can be expected?
				To what extent the methodology has to be modified to be accepted in a different country?	To what extent the methodology has to be modified to be accepted in a different country?

For replicability the acceptance factor appears for be more important than the one required for scalability, since it indicates the willing from stakeholders in a new target country to embrace something entirely new, which may be more difficult than accepting a larger version of something that already exists.

The factor asks to what extent acceptance problems are expected when exporting the solutions to other countries.

3.8 Assessment of the scalability and replicability factors

The stipulated factors were evaluated separately for the FlexPlan methodology and the FlexPlan tool. In this way the study wanted to assess whether a more refined implementation of the methodology may improve any potential shortcomings identified in the study.

The assessment was made, by using a standard Likert-scale with five alternatives, where high score indicates a better solution or in simple terms: higher score is better:

1. The outcomes have a weak position towards this factor
2. The outcomes have a somewhat weak position towards this factor
3. The outcomes have a neutral position towards this factor
4. The outcomes have a somewhat strong position towards this factor
5. The outcomes have a strong position towards this factor

where having strong position means independence from the analysed factor. The award of these scores considers the learnings coming from the project, in particular the ones coming from implementation of the regional cases. Then the assessment estimated average scores for each factor i.e. technical, economic, regulatory, stakeholder acceptance. Detailed scores for the factors are presented in the Annex, see Table 8.1 and Table 8.2.

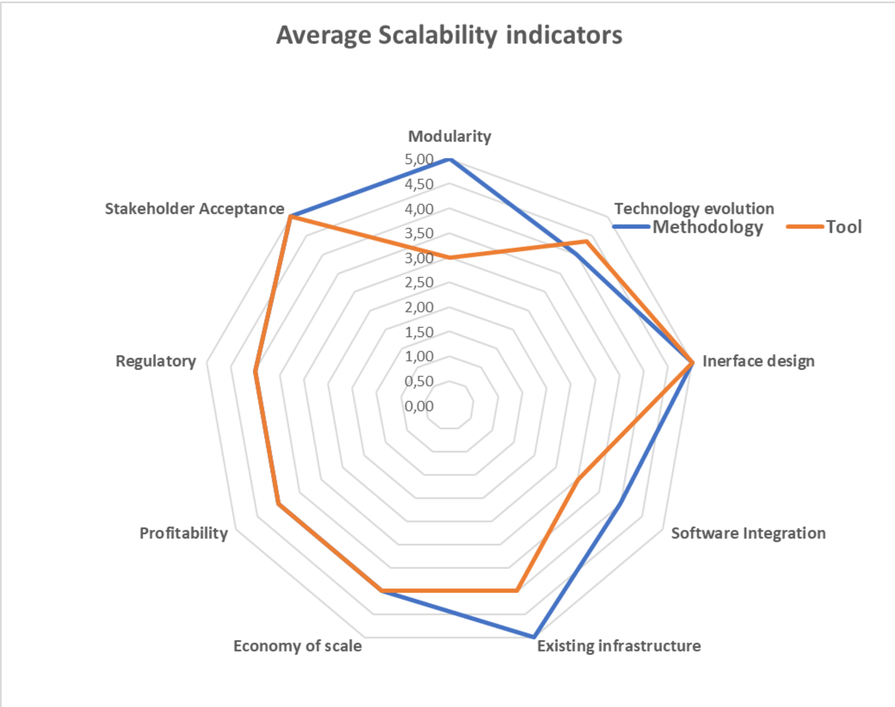

Figure 3-2 Average scalability indicators

Figure 3-2 shows radar diagram with average scalability indicators for the FlexPlan methodology and the tool. In general, it shows very high scalability level, This is the result of deliberate selection of big-scale Regional Cases in the project, where the tool and methodology were thoroughly tested. The learnings were carefully assessed, and new methods were applied for improvement of the methodology as for example implementation of several simplifications, which allowed to run the RCs and achieve sufficient results. In practice this means that both the methodology and the tool have already been applied for scaled-up cases and proved to function satisfactory.

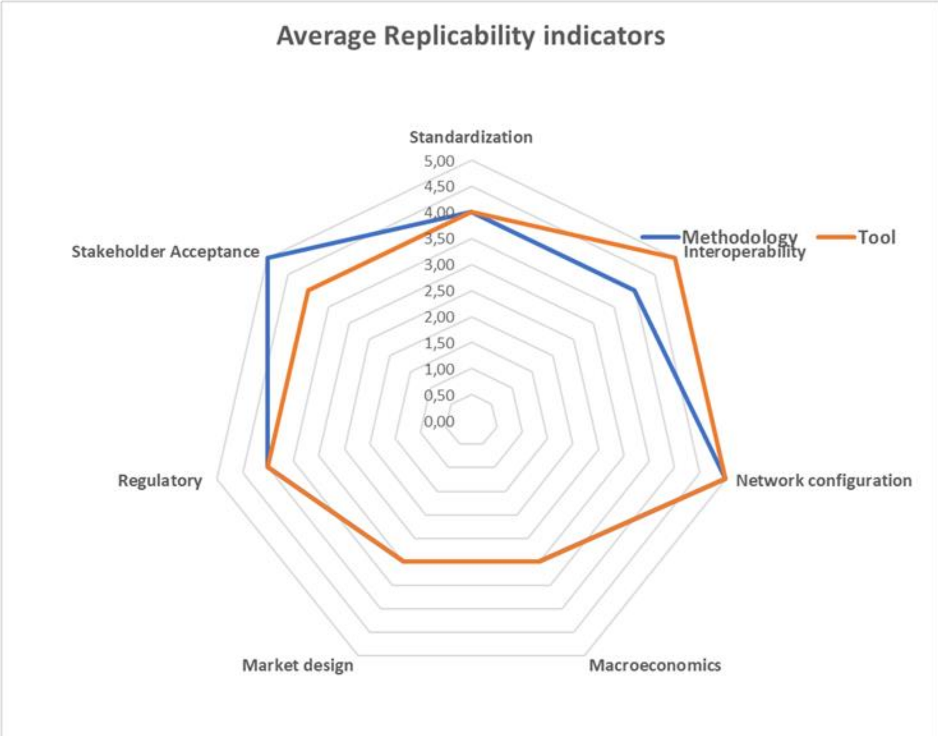

Figure 3-3 Average replicability indicators

In general, it can be concluded that the FlexPlan methodology has very high scores related to both replicability and scalability, while the specific implementation into FlexPlan tool has slightly lower scores.

4 Conclusions

This deliverable identifies the opportunities coming from the deployment of flexibility resources during the expansion planning process and conducts a preliminary analysis of the impact of the regulatory framework in terms of possible barriers and limitations.

Flexibility resources are often used in synergy with conventional grid expansion procedures, which are represented by the construction of new lines or the reinforcement of existing ones. Grid expansion is mainly used when the system shows that a new connection between resources is necessary to bring improvements or in cases where the duration of the congestion is too long to be solved by means of flexibility assets. Many regional cases show how flexibility assets and line reinforcements are often selected simultaneously to act synergically in solving the same congestion. Sometimes they are sized so as to completely solve the congestion and sometimes the tool finds out that the best compromise is a partial resolution of the congestion because load or generation curtailments result allow to achieve a more optimized result on the optic of the overall social welfare. Furthermore, TSO and DSO coordination turned out to be very efficient for avoiding unnecessary investments.

The identified regulatory barriers, which obstacle the development and deployment of flexibility resources can be summarized as follows:

- **Authorization procedures for the development of flexibility resources**
  In this case this limitation is considered in the definition of the target function because it is based on the minimization of the overall societal costs.
- **Storage ownership**
  Storage facilities must not be owned by SOs if they are to participate in the market procedure.
- **Participation of flexibility resources in real time markets**
  Flexibility resources are currently treated like conventional generation facilities, thus the prequalification process is not adapted to the technical peculiarities of these new technologies.
- **Data exchange between SOs**
  Privacy policies for the data exchange must be reviewed to understand how to develop the most appropriate coordinated approach.

Deliverable 6.3 [6] is dedicated to the discussion of these topics, some recommendations are given in order to facilitate the integration of flexibility resources at a level-playing field.

Finally, an analysis of the different factors ensuring the replicability of the FlexPlan methodology and of the FlexPlan GEP tool to other regions and its scalability to the whole of Europe are analysed in this report. This analysis brought to conclude that the FlexPlan methodology has very high scores related to both replicability and scalability, while the specific implementation into FlexPlan tool has slightly lower scores. Full detail on the evaluation of the scalability and replicability factors can be found in Annex III.

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6 Annex I: Questionnaire for RC Leaders

<table>
<tr><th>Question</th><th>Answer from RC Leader</th></tr>
<tr><td colspan="2">Year 2030/2040/2050</td></tr>
<tr><td colspan="2">Complete for:
- Conventional infrastructure candidates (AC/DC branches and transformers)
- Storage Assets
- Flexible Loads</td></tr>
<tr><td>How many candidates are accepted?</td><td>Transmission network:
• XX/XX (2030)
• XX/XX (2040)
• XX/XX (2050)
Distribution network:
• XX/XX (2030)
• XX/XX (2040)
• XX/XX (2050)</td></tr>
<tr><td>Does your regional case include areas subject to different regulatory frameworks? Are the accepted candidates located in the same regulatory framework area? (country/region) If no, specify the locations</td><td>...</td></tr>
<tr><td>Can all accepted candidates be built in accordance with the regulatory framework of that area? If not, what are the regulatory limitations when building the candidate?</td><td>...</td></tr>
</table>

7 Annex II: Glossary

Active customer	a final customer, or a group of jointly acting final customers, who consumes or stores electricity generated within its premises located within confined boundaries or, where permitted by a Member State, within other premises, or who sells self-generated electricity or participates in flexibility or energy efficiency schemes, provided that those activities do not constitute its primary commercial or professional activity [2]
Ancillary service	a service necessary for the operation of a transmission or distribution system, including balancing and non-frequency ancillary services, but not including congestion management [2]
Citizen Energy Community	a legal entity that: (a) is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises (b) has for its primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and (c) may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders; [2]
Closed Distribution System	a distribution system, which distributes electricity within a geographically confined industrial, commercial or shared services site and does not supply household customers, without prejudice to incidental use by a small number of households located within the area served by the system and with employment or similar associations [11]
Common grid model	a Union-wide data set agreed between various TSOs describing the main characteristic of the power system (generation, loads and grid topology) and rules for changing these characteristics during the capacity calculation process [12]
Cross-border flow	means a physical flow of electricity on a transmission network of a Member State that results from the impact of the activity of producers, customers, or both, outside that Member State on its transmission network [10]
Curtailed Electricity	Curtailment is a reduction in the output of a generator from otherwise available resources (e. g. wind or sunlight), typically on an unintentional basis. Curtailments can result when operators or utilities control wind and solar generators to reduce output to minimize congestion of transmission or otherwise manage the system or achieve the optimum mix of resources.

Demand Response Active Power Control	demand within a demand facility or closed distribution system that is available for modulation by the relevant system operator or relevant TSO, which results in an active power modification [11]
Demand Response Reactive Power Control	reactive power or reactive power compensation devices in a demand facility or closed distribution system that are available for modulation by the relevant system operator or relevant TSO [11]
Demand Response System Frequency Control	demand within a demand facility or closed distribution system that is available for reduction or increase in response to frequency fluctuations, made by an autonomous response from the demand facility or closed distribution system to diminish these fluctuations [11]
Demand Response Transmission Constraint Management	demand within a demand facility or closed distribution system that is available for modulation by the relevant system operator or relevant TSO to manage transmission constraints within the system [11]
Demand Response Very Fast Active Power Control	demand within a demand facility or closed distribution system that can be modulated very fast in response to a frequency deviation, which results in a very fast active power modification [11]
Demand Units	an indivisible set of installations containing equipment which can be actively controlled by a demand facility owner or by a CDSO, either individually or commonly as part of demand aggregation through a third party [11]
Energy storage facility	the electricity system, deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy or use as another energy carrier [2]
Flexibility	Active management of an asset that can impact system balance or grid power flows on a short-term basis (from day-ahead to real time). Flexibility can be provided by different assets. The first three can be both directly or through an aggregator: • generation (part of the dispatchable units, RES); • load facilities (involved in a demand response programme); • storage (pumped storage power station, batteries, etc.); and/or • interconnectors (intraday energy exchanges). Flexibility can be used by: • the TSO for balancing and congestion management in the short term and planning in long-term contracting

	• the DSO for congestion management in the short term and planning in long-term • contracting and/or • the BRP for portfolio management both in the short and long term (investment) [7]
Flexibility (Demand Side)	changes in energy use by end-use customers (domestic and industrial) from their current/normal consumption patterns in response to market signals such as time variable electricity prices or incentive payments or in response to acceptance of the consumer's bid, alone or through aggregation, to sell demand reduction/increase at a price in organised electricity markets [7]
Flexibility (System)	characterises the impact of the project on the ability of exchanging balancing energy in the context of high penetration levels of non-dispatchable electricity generation [13]
Individual grid model	a data set describing power system characteristics (generation, load and grid topology) and related rules to change these characteristics during capacity calculation, prepared by the responsible TSOs, to be merged with other individual grid model components in order to create the common grid model [12]
Levelised Cost of Electricity	Levelised costs of electricity. It represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle [14]
Market congestion	a situation in which the economic surplus for single day-ahead or intraday coupling has been limited by cross-zonal capacity or allocation constraints [12]
Non-frequency ancillary service	a service used by a transmission system operator or distribution system operator for steady state voltage control, fast reactive current injections, inertia for local grid stability, short-circuit current, black start capability and island operation capability [2]
Non-market-based measure	any supply- or demand-side measure that deviates from market rules or commercial agreements, the purpose of which is to mitigate an electricity crisis (in the context of [15])
Observability Area	a TSO's own transmission system and the relevant parts of distribution systems and neighbouring TSOs' transmission systems, on which the TSO implements real-time monitoring and modelling to maintain operational security in its control area including interconnectors [16]
Physical congestion	any network situation where forecasted or realised power flows violate the thermal limits of the elements of the grid and voltage stability or the angle stability limits of the power system [12]

Scenario	i. the forecasted status of the power system for a given time-frame [12] ii. a description of plausible futures, characterised by, amongst others, generation portfolio, demand forecast and exchange patterns with the system outside the study region [13]
Structural congestion	congestion in the transmission system that can be unambiguously defined, is predictable, is geographically stable over time and is frequently reoccurring under normal power system conditions [12]
Value of lost load (VOLL)	a measure of the costs associated with unserved energy (the energy that would have been supplied if there had been no outage) for consumers. It is generally measured in €/kWh. It reflects the mean value of an outage per kWh (long interruptions) or kW (voltage dips, short interruptions), appropriately weighted to yield a composite value for the overall sector or nation considered [13]

8 Annex III: Evaluation of Scalability and replicability potentials

Table 8.1 Assessment of scalability factors for the FlexPlan Methodology and the Tool

	Scalability				
	Factor	**Methodology**	**Score**	**The tool**	**Score**
Technical	**Modularity**	How easy it is to add new components or whether there are limits on adding components?	5	Does the tool have a modular architecture?	3
	Technology evolution	Can we expect significant improvement of computational power/time?	4	Can we expect significant improvement of computational power/time?	4
		Can we expect significant improvement of the applied mathematical methods and techniques?	3	Can we expect significant improvement of the applied mathematical methods and techniques?	4
		Does the methodology depend upon other technologies e.g. telecommunications?	5	How does methodology depend upon other technologies e.g. telecommunications?	5
	Interface design	Does the interface design e.g. interaction between different components (internal and external) limit upscaling of the methodology?	5	Does the interface design e.g. interaction between different components (internal and external) limit upscaling of the tool?	5
	Software integration	To what extent the performance of methodology is affected when the solution size increases?	4	To what extent the performance of software tools is affected when the solution size increases?	3

	Existing infrastructure	Is there any existing infrastructure, which may limit the maximum scale for deployment of the methodology?	5	Is there any existing infrastructure, which may limit the maximum scale for deployment of the tool?	4
		Average scores	**4,43**		**4,00**
Economic	**Scalability**				
	Factor	**Methodology**		**The tool**	
	Economy of scale	Internal factors:	5	Internal factors: What is the cost function for using the tool e.g. linear or exponential?	5
		External factors	3	External factors: What is the cost function for external costs e.g. linear or exponential? (collection of data, updating of grid models)	3
	Profitability	To what extent benefits grow when increasing the solution size? (e.g. increasing size of the system vs. optimal solutions)	4	To what extent the benefits grow when increasing the solution size?	4
		Average scores	**4,00**		**4,00**
	Scalability				
	Factor	**Methodology**		**The tool**	
Regulatory	Regulatory	To what extent regulatory factors may influence the size of the deployment? (e.g. limitations on access to data)	4	To what extent regulatory factors may influence the size of the deployment? (e.g. limitations on access to data)	4
		Is it necessary to change the existing roles and responsibilities, support schemes?	4	Is it necessary to change the existing roles and responsibilities, support schemes?	4
		Average scores:	**4,00**		**4,00**

	Scalability				
	Factor	Methodology		The tool	
Stakeholder acceptance	Acceptance	To what extent the methodology support increased number of users?	5	Which stakeholders like regulators, policy makers and end users are ready to embrace an enlarged project?	5
		Average scores:	**5,00**		**5,00**

Table 8.2 Assessment of replicability factors for the FlexPlan Methodology and the Tool

	Replicability				
	Factor	**Methodology**	Score	**The tool**	Score
Technical	**Standardization**	Are there any country-specific standards, which may create obstacles in deployment of the technology in another country?	4	Are there any country-specific standards, which may create obstacles e.g. imbalance settlement periods, grid models etc.?	4
	Interoperability	Are there any limitations on interoperability with methods used in other countries? (CBA rules)	4	To what extent are solutions and their components/functions interoperable or even plug-and-play?	5
	Network configuration	Are there any elements which are given and cannot be changed e.g. climate, temperatures, terrain conditions, generation	5	Are there any elements which are given and cannot be changed e.g. climate, temperatures, terrain conditions, generation mix)	5

		mix) which are limiting for replication of the methodology?		which are limiting for replication of the tool?	
		Average scores	**4,33**		**4,67**
	Replicability				
	Factor	**Methodology**		**The tool**	
	Macroeconomics	To what extent can national taxes, CO2 charges, interest rates, support schemes limit replication of the methodology?	3	To what extent can national taxes, CO2 charges, interest rates, support schemes influence replication of the tool?	3
	Market design	How dependent is replication of the tool upon national variations of market design (definition of products, services and bids) including roles and responsibilities?	3	How dependent is replication of the tool upon national variations of market design (definition of products, services and bids) including roles and responsibilities?	3
		Average scores	**3,00**		**3,00**
	Replicability				
	Factor	**Methodology**		**The tool**	
Regulatory	**Regulatory**	To what extent regulatory factors may influence replication in another country? (e.g. limitations on access to data, roles and responsibilities)	4	To what extent regulatory factors may influence replication in another country? (e.g. limitations on access to data, roles and responsibilities)	4
		Average scores:	**4,00**		**4,00**
	Replicability				
	Factor	**Methodology**		**The tool**	

Stakeholder acceptance	Acceptance	To what extent the user acceptance problems can be expected?	5	To what extent the user acceptance problems can be expected?	4
		To what extent the methodology has to be modified to be accepted in a different country?	5	To what extent the methodology has to be modified to be accepted in a different country?	4
		Average scores	**5,00**		**4,00**