FlexPlan

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

Final project exploitation plan

D7.5

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FlexPlan

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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.

Partners

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List of Abbreviations and Acronyms

Abbreviation/Acronym	Meaning
CBA	Cost benefit analysis
DSO	Distribution system operator
EU	European Union
ENTSO-E	European association for the cooperation of transmission system operators (TSOs) for electricity.
GUI	Graphic user interface
JSON	JSON (JavaScript Object Notation) is a format for data collection and exchange
Julia	Programming environment specifically designed for numerical calculation
JuMP	Domain-specific modelling language for mathematical optimization embedded in Julia
NRA	National regulatory authority
R&D	Research and development
TSO	Transmission System Operator
TYNDP	Ten-year network development plan of ENTSO-E
T&D grids	Transmission and distribution grids

FlexPlan

Executive Summary

The present report focusses on the effective suitability for further exploitation of the results achieved by the FlexPlan project.

Two parallel lines of investigation are proposed on this regard: a top-down analysis, which provides details on the five key macro-products of the FlexPlan project (pre-existing industrial situation, progress over status quo, new opportunities, potentially interested stakeholders, scenarios for future exploitation, possible barriers) and a bottom-up analysis consisting of a collection of declarations from the FlexPlan Consortium members on their interest for future exploitation and a comparative analysis of these declarations.

However, the most important engine for a potential adoption of the FlexPlan methodology is the changing regulatory context and the request by the European Commission to take into account flexible elements within future planning analyses by the system operators (Directive 2019/944 - Art. 32, Art. 40) and by ENTSO-E (Regulation 2022/869 - Art. 13). Storage elements and demand side management will prove to be of paramount importance to provide flexibility services to the system and a key for the success of the ambitious present EU goals on decarbonization and independence on primary energy sources acquisition. Depending on the actual regulatory context, the possibilities to apply the FlexPlan methodology and its effectiveness can vary considerably. For a comprehensive analysis of this aspect, we defer the reader to the analysis carried out in deliverable D7.6 (impact assessment). Additionally, we signal deliverable D6.2, which includes an additional interesting analysis on scalability and replicability of the results achieved by the FlexPlan project.

1 Introduction

With the term "exploitation", one usually indicates a set of activities to be carried out to promote the acquisition of the results of a certain activity or project by the external world. This definition can be declined further both in terms of **industrial development** (i.e. creation of an industrial set of products and its placing on the market) and **know-how acquisition**, potentially capable to improve industrial procedures, sector regulation, etc.

More specifically, the acquisition from the external world of the results of the FlexPlan project can be seen both in terms of know-how improvement, i.e. a new methodology allowing to take into account the role flexibility can play to support congestion management and reduce overall system costs and a set of tools that can be used to implement such methodology (see Fig.1.1).

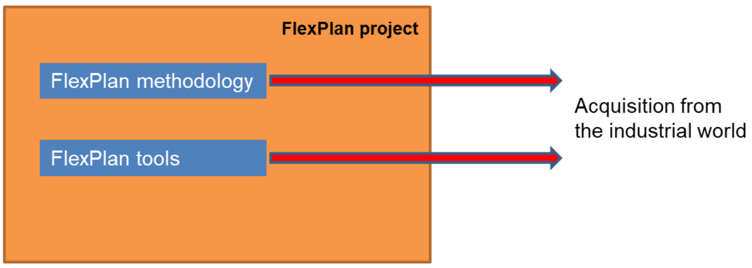

Figure 1.1 – Exploitation of the results of the FlexPlan project

Basically, the two issues concerning dissemination which should be answered by the FlexPlan Consortium, as well as the one of any other project about to conclude its activities :

- What actions can be concretely carried out by the Consortium members (in particular: the industrial members of it) to valorize the methodological achievements and insert them into the real-world chain of value creation?
- What will remain after the end of the project?

The present report aims at providing a few answers to these two questions. For that, two different approaches have been followed:

- a **bottom-up approach** consisting of the request made to all FlexPlan consortium members to formulate a statement of its willingness and intentions to valorize the results of FlexPlan both in their own future activities and in terms of know-how acquisition for the entire electric system. These statements are collected in Appendix to the present report and summarized in chapter 2.
- a **top-down approach** consisting of the **identification of the most important macro-products** of the project (the FlexPlan methodology, the FlexPlan T&D decomposition, the FlexPlan simulation platform, the FlexPlan Open Access libraries, the six regional case models) and to dedicate to each of them a chapter in which a thorough analysis is carried out:

- pre-existing industrial situation and drivers to implementation,
- progress realized by FlexPlan over the status quo,
- opportunities created by the new platform,
- potentially interested stakeholders,
- scenario for future exploitations,
- barriers for future exploitation and ways to remove them.

The two approaches convergen to the conclusions, where some final considerations arew brought.

Finally, it must be remarked that the opportunities to bring to a concrete set of dissemination initiatives is well highlighted in the FlexPlan Annex I, where the following text can be found (Part B, pag.24):

> Even if the project FlexPlan will be able to demonstrate the advantages that the new planning tool can bring to the system, the best impact can only be achieved if an **exploitation** is carried out after the end of the project and, in particular, if there is some possibility that the tool can be incorporated by the European TSOs into their current planning practice. For that, a further engineering and customization of the tool will for sure be needed. However, no further provisions to ensure up-scalability of the tool should be needed, as the six regional cases will already constitute an important benchmark to show that the tool can be applied to study real-sized networks with full nodal details. The three TSOs as well as the big DSO group members of the consortium will be explicitly requested to provide their expertise for getting a tool that fully corresponds to the needs of real SO. Besides, **in order to allow the SOs that do not belong to the FlexPlan consortium as well as other external stakeholders to get acquainted with the tool and evaluate their possible interest to test it, the package will be made available in open access[10] (but not open source) format and it will be allowed to download it upon request by e-mail to the consortium coordinator.** In this way, tool testing will be possible for external SOs and stakeholders upon data sets taken from the project regional studies and by allowing them to link a mathematic solver of their choice. Data for which confidentiality issues subsist will be masked and non-modifiable. A specific task will also be devoted to study an ergonomic graphic user interface, explicitly studied in order to work with the tool for non-specialists in optimization models and to allow a working approach similar to the standard tools used by the SOs for planning purposes. The three TSOs as well as the big DSO group members of the consortium will help in this design activity.
>
> As a further exploitation provision, after the end of the project, the consortium members will still remain available to assist SOs and other stakeholders to test the package and discuss with them about possible customization requests in case the new tool meets their interest. However, the contact with European SOs and European stakeholders should not stay limited to the period after the end of the project, but their engagement will be requested also during the project in terms of participation to the **Advisory Board**. As auspicated by the call text, the FlexPlan project will promote a "more active involvement of all stakeholders" by dedicating a specific care to the set-up of the project Advisory Board by the project coordinator: maximizing stakeholders' involvement during the project can help to improve the results quality and to create more interest for them. So, beyond gathering the Advisory Board once a year, some consultations will also be carried out via project web on a periodical basis by collecting advisors' feedback on specific short documents and questionnaires.
>
> [10] Open access will not concern the pre-processing tool as well as other support tools not included into the planning package.

What FlexPlan realized goes beyond these promises. In fact, on top realizing a **Planning Toolbox** implementing the new FlexPlan methodology and putting available a **free evaluation version** (see deliverable D3.3), a new set of **Open Access libraries** is put available on the GitHub platform:

- the **OptimalTransmissionRouting.jl package**, which is a Julia/JuMP package to determine the **optimal transmission system route** considering spatial information. The open access license toolbox and can be found on: https://github.com/Electa-Git/OptimalTransmissionRouting.jl

- the **FlexPlan.jl package**, which consists of a Julia/JuMP library capable to carry out transmission and distribution network planning while considering AC and DC technology, storage and demand flexibility as possible expansion candidates. A mixed-integer linear problem is constructed to be solved with any commercial or open-source MILP solver. The open access license toolbox can be found under: https://github.com/Electa-Git/FlexPlan.jl Installation instructions, information regarding problem types and network formulations are provided in the package documentation (https://electa-git.github.io/FlexPlan.jl/dev/).

The FlexPlan Toolbox is a complete and professional software able to realize the complete chain of the planning process: specification of the most promising interventions for network upgrade including flexibility options (pre-processor tool), resolution of the planning expansion problem bringing to single out those interventions that minimize total system costs – i.e. dispatching + investment costs (grid expansion planning tool). The grid expansion planning tool is also endowed with a Graphic User Interface that was expressly built up with the help of the system operators members of the FlexPlan Consortium with the goal of proposing synoptics similar to the ones the system operators are used to analyze in order to judge the results of a grid planning study.

By contrast, the Open Access libraries include neither the pre-processor nor the Graphic User Interface but are nonetheless a complete set designed to make it easy to perform grid planning studies with the methodology proposed by FlexPlan. They are the ideal tool for R&D companies (also because available for free in open access).

2 Analysis of consortium members declarations

During the last months of the FlexPlan project activities, the project coordinator requested all partners member of the FlexPlan consortium to formulate a declaration:

- on their willingness to exploit the results of the project and
- on the kind of actions such dissemination would contemplate.

The results, reported in Appendix 1 of this deliverable, give rise to several interesting considerations.

First of all, not surprisingly, the declarations can be split into two categories depending on whether the formulating company was an industrial partner (ENEL, ELES, N-SIDE, REN, TERNA) or an R&D company (RSE, EKC, KUL, R&D NESTER, SINTEF, TECNALIA, TUDO, VITO).

Industry partners put the accent more on the possibility to re-use (directly or, most frequently, after an adaptation/customization) the project toolbox (i.e. pre-processor and Grid Expansion Planning Tool developed in the framework of WP3) for future studies, whereas R&D companies show more interest for the open access set of tools developed by the WP1 to be used for further studies as well as external consultancies.

Among the most significant declarations by industry partners:

- **ENEL**: "*a possible exploitation of the experience gained in the project participation is to have a deeper understanding of the project methodology for evaluate an extension of internal tools for the best flexibility services (provided by DERs) integration in grid planning stage. Once the rules will be defined at National level, an interface layer for integrating T&D grids planning tool could be investigated, even if the reference period for DSOs and TSOs covers different time scales.*"
- **ELES**: "*ELES is very interested in further development of the existing software suite, especially as it represents one of a kind in the planning field. A particular advantage is the ability to simulate the network and automatically integrate new projects, including storages, whereas other tools simulate only the conditions where the network and its power injections are strictly defined. By doing so, the planning process can be more dynamic, less time consuming and thus resulting in reduced financial investments in the future. It can also highlight solutions that were not even considered in the first place. Thus, ELES is considering continuing to cooperate with project partners regarding further development of the tool. The talks are already ongoing…*"
- **REN**: "*REN will exploit the knowledge accomplished in the FlexPlan project for internal use in operational and long-term planning activities… New features of the Flex Plan Grid Expansion Planning Tool methodology will be analyzed to complement the current methods used by our grid planning department. Regulatory considerations on market design carried out by the FlexPlan project (e.g. on capacity markets) will be shared with the national regulatory authority (NRA) to improve the Iberian market…*".
- **TERNA**: "*The FlexPlan project has brought a significant value for Terna and especially for the System Operator division through many of the deliverables that have been achieved… For what concerns the two applications released …, given the low TRL …, they are not going to be directly integrated into the*

operational process. However, they both have a demonstrative value and help to have a first methodology to assess the role that each resource may play. The open-source model is particularly helpful to acquire a full comprehension of some innovative algorithms… Terna has already started a discussion with the developers in order to share the potential of the FlexPlan tool with the management and the relevant colleagues that have not been directly involved in the project."

A particular position among the industry partners is covered by **N-SIDE**, as the developer of the FlexPlan toolbox and particularly interested to a future development and customization to cover the needs of the European TSOs and DSOs: "*… N-SIDE would like to assess the market traction of the developed software. This assessment will be done towards TSOs, DSOs and regulators, who are the identified potential users of the new tool. The primary goal will be to identify the remaining gaps between the FlexPlan planning tool and an ideal software which would perfectly fit the needs of these stakeholders… Based on the feedback provided by the stakeholders, the observed needs of the market and shortcomings of the tool observed during its use in the FlexPlan project, N-SIDE will continue to develop and improve the planning software…. In terms of feeding the tool with data, a custom JSON structure is currently being used to gather input data and export results. However, this custom model could be limiting for future exploitation…. In the future, N-SIDE plans to include CGMES in the list of accepted formats. This will reduce the startup time to use the tool. All those enhancements will have the purpose to create a complete software which will be used by N-SIDE consultants in order to provide consulting services to external stakeholders such as TSOs, DSOs and regulators… Depending on the market traction, the tool can also be turned into a product and not only used for consulting services. Finally, N-SIDE will also reuse and extend the developed Graphical User Interface (GUI). On one hand, the existing GUI can be improved by adding new visualizations and giving the possibility to end-users to modify the data directly in the GUI. On the other hand, the GUI can also be reused for other applications requiring grid visualizations."*

Among the **R&D partners**, all of them agree that the methodologies, the tools (in particular the open access libraries) and the applications set up to simulate the 6 regional cases will be reused and further expanded in the future to lead new studies (also in the framework of consultancies for supporting TSOs, DSOs and Regulators) as well as new future EU project.

In particular, **EKC** signals that their organization is *"deeply involved in the system development processes in the South-East Europe directly supporting the TSOs in the region. This region is, similar to others, tackled by high-speed deployment of RES that makes development planning in transmission or distribution systems more and more complex. At the same time, investments are higher and followed by stronger obstacles in the process of their implementation… FlexPlan methodology can be used as the basis for improvements in the system development planning processes especially the ones carried out by TSOs in the region … Joint effort with TSOs and DSOs in the region in further customization of the tool."*

KUL, major contributor together with RSE for the development of the open access libraries, stresses that: *"From the perspective of KU Leuven, there is a strong interest in further exploiting the FlexPlan project results, especially with respect to the open-source tools … that have been (co)developed by KU Leuven in the course of the FlexPlan project. Considering that KU Leuven's activities center around optimization models for* *power system planning and operation, we further want to develop the afore-mentioned tools in follow-up national and international research projects".*

SINTEF stresses the activities done in collaboration with CINELDI towards the Norwegian industry sector: "*SINTEF Energy Research is using the results from the FlexPlan project to help updating the grid planning processes for Norwegian distribution grids. The FlexPlan methodologies have been assessed by viewing them in the context of a framework for planning of active distribution grids that is developed in the research centre CINELDI (hosted by SINTEF). Parts of the methodologies have then been adapted to Norwegian conditions and incorporated in methods and prototype tools developed in CINELDI and collaborating research projects co-funded by the Norwegian electricity distribution industry. More specifically, the generic flexibility model and the net present value calculations specified in FlexPlan D1.2 have already been implemented.".* SINTEF also remembers the current synergic actions being carried out within the DiPoFlex EU project: "*SINTEF has received funding from the Research Council of Norway for the supplementary project DiPOFlex (Distribution network Planning and Operation with flexibility resources) to support the organization of two physical workshops with Norwegian stakeholders, … These workshops have been used to discuss and disseminate methods developed and implemented in the FlexPlan project. The supplementary project has also supported the development of lecture material for a new course on flexibility and grid planning that is being prepared for master students at the Norwegian University of Science and Technology (NTNU).*"

3 Macro product 1: the FlexPlan methodology

3.1 Pre-existing industrial situation and drivers to implementation

Currently, network expansion planning is performed by transmission and distribution grid operators on a case-by-case basis and using a limited set of possible expansion options. Although the general guidelines for system planning and how to conduct cost benefit analysis (CBA) are outlined[1], there is no harmonization in terms of the used tools, data sets and calculation procedures applied by the system operators.

There are a number of different commercial and open-source software tools which are at the system operators' disposal today, all serving a specific purpose. In the procedure of system planning, two main classes of software tools are used in general. The first set of tools refers to long term energy system modelling and market analysis tools. These tools use large-scale linear optimization models to determine the future expansion of power generation assets on the European scale, using macro scenarios with respect to renewable energy sources growth. In the process of the optimization usually technical constraints of generators are considered as unit commitment constraints. In interzonal settings, transfer capacities between different market zones are considered as binding constraints to limit exchanges. These models provide as outcome the expected generation and market prices over a long-time horizon and possibly the need in transfer capacity increase. However, usually no detailed network constraints are considered in such tools. Some examples of such tools are Plexos, or Artelys Super Grid.

Using the information obtained with the first set of tools, e.g., the analysis of generation expansion and the electricity market, as input, in the second stage of system planning, typically detailed power system analysis software tools are used in order to determine possible congestion in the grid and analyze possible grid expansion options in terms of their potential to relieve congestion. The core of the congestion and mitigation analysis is the application of power flow calculations. There are several commercially available software products which are used by system operators worldwide, such as PSSE, Digsilent Power Factory or Neplan. However, typical power system analysis tools have limited capability in terms optimization, and as such are not suitable to analyze the effects of demand side management and storage utilization.

The FlexPlan address three main objectives in this context:

- To provide a holistic and transparent methodology that can be utilized by all system operators alike.
- To provide an optimization methodology that minimizes the need for manual intervention by system planners and minimizes the number of tools to be used.
- To provide an optimization-based planning methodology that can utilize a large number of planning candidates while still representing the grid in sufficient detail.

[1] For example such as the CBA methodology imposed by ENTSO-E for TYNDP projects

3.2 Progress realized by FlexPlan over status quo

FlexPlan provides the first realization of a holistic network planning tool, allowing a complete analysis of flexibility offered by demand side management and storage, environmental impact while considering a large set of grid expansion candidates. Furthermore, by performing transmission and distribution grid planning at the same time, potential substitutions of investments between both networks can be identified resulting in a more efficient system design. Although the academic literature provides a large variety of different models and their implementations, to date there are no large-scale implementations of such models able to cover European-scale system sizes. In this respect, FlexPlan has pushed the boundaries of the available literature by successfully applying the developed planning methodology to most parts of the European continent. We believe that this demonstration will increase the confidence for system operators to invest into optimization-based power system planning tools for efficient grid design in the coming years.

3.3 Opportunities created by the new platform

We think that the FlexPlan methodology can build the basis of the new type of system planning tools that are needed to design the power grid for the immediate challenges ahead. In this respect, FlexPlan provides as a first of a kind, a holistic system planning approach for both transmission and distribution grids and fully internalizes the environmental impact in the optimization process. In the future system, where construction of overhead grid expansion will be ever more difficult to obtain permits for, the developed approach will prove very beneficial as it is able to determine the trade-offs with respect to different technologies, networks, environmental impact and eventually infrastructure costs. As such, we think that the FlexPlan methodology can evolve to a reference methodology in the coming years for a holistic cost benefit analysis for the comparison of different grid expansion options.

3.4 Potentially interested stakeholders

In the first instance, the developed models and tools are expected to be most useful for transmission and distribution grid operators. Further, providers of power system planning software would be important stakeholders with exploitation potential, further developing the provided solutions. Also, coordination bodies such as ENTSO-E could benefit from the set of the developed tools for improving their capabilities to perform cost benefit analysis in a standardized way. Also, national regulators could benefit from the developed tools for the assessment / validation of the expansion plans provided by the network operators.

3.5 Scenario for future exploitations

For industrial exploitation of the FlexPlan methodology, in the first instance, interfaces to existing software tools are necessary. Software tools used at TSOs premises are often deeply embedded within their IT structure, used indifferent departments from long-term planning to day-ahead operation. A change in the used software can be a multi-year process and can come at a major cost and the need for retraining for the workforce. Therefore, in the first instance, interfacing with the most used software tools by system operators should be achieved, and if possible certain functionalities of the existing tools be embedded within the FlexPlan approach, such as performing power flow analysis, security analysis etc. This will lower the barrier for system operators for using the FlexPlan approach. Further, interfacing to the main sources of grid data as well as time series data are crucial for lowering the barrier for system operators to quickly adopt the FlexPlan methodology and the tools developed.

Secondly, depending on the internal expertise and internal tool availability, different system operators might only be interested in certain functionalities, or tools developed within the FlexPlan framework. As such, in further development and exploitation of the FlexPlan approach, modularity will be crucial for achieving the maximum possible utilization.

3.6 Barriers for future exploitation and ways to remove them

The main barrier for immediate exploitation of the FlexPlan methodology is the computational efficiency, which needs to be improved for large-scale industrial application. To that end, a number of paths can be followed, ideally in parallel. Firstly, model decomposition techniques such as applied within FlexPlan can be leveraged and further improved. These can be algorithmic approaches such as Benders and Danzig–Wolfe decomposition, but also the application of surrogate models to represent different parts of networks. Furthermore, machine learning approaches can be leveraged in order to determine the most critical system states, the most impactful investment candidates, or the parts of the network that have the most binding constraints, in order to reduce the problems size. Secondly, cloud computing and parallel computing approaches can be further leveraged for making more computational resources available for faster solution of the problem.

Another barrier identified is the determination of the most important parameters for the environmental impact analysis. Especially cost data to assess air quality and landscape impact are based on empiric values, and as such for a meaningful and transparent comparison, more effort is needed to derive a common set of parameters. This can most efficiently be achieved by means of stakeholder interactions with various environmental and governmental organizations as well as the general public.

Last but not least, for the long-term exploitation of the FlexPlan approach the modelling of integrated energy systems will be inevitable to consider the interactions between different energy vectors and to assess substitution effects between them. This will require the development of new types of models which can simulate the energy flows in different types of networks, while being able to consider their inherently different time constants. This is only possible by means of further research projects.

4 Macro product 2: the FlexPlan T&D Decomposition

4.1 Pre-existing industrial situation and drivers to implementation

In the last years, the importance of storage and demand flexibility has grown significantly due to the increasing integration of renewable energy sources into the power system. As a result, their contribution cannot be ignored during the planning phase. Since most demand flexibility resources are connected to distribution grids, it is imperative to consider the flexibility provided by distribution networks when planning the transmission network. However, combining both network levels creates models of significant size, making the resulting optimization problem unmanageable even with modern hardware.

To address this issue, a decoupled approach, which optimizes transmission and distribution networks separately, is the most feasible option. However, it is still imperative to coordinate the transmission and distribution optimization problems to ensure an effective data transfer. In particular, both transmission and distribution models must consider flexibility constraints, including the intertemporal ones. Notably, this must be achieved while accounting for multiple stochastic scenarios for renewables and demand. The resulting approach is one of the most significant novelties introduced by the FlexPlan project: to our best knowledge, no other previous R&D activity has tackled these issues.

4.2 Progress realized by FlexPlan over status quo

As part of the implementation of the FlexPlan planning tool, a novel heuristic procedure has been proposed and effectively employed to solve the planning problem by decoupling the transmission and distribution network models. The addressed challenges are twofold. Firstly, the procedure is capable of optimizing investments made in distribution networks and computing the flexibility that can be provided by distribution with a fast calculation. Secondly, the flexibility provided by the distribution networks is considered during the transmission planning, without significantly delaying the solution process. Notably, the proposed heuristic successfully incorporates the intertemporal constraints of flexibility and stochastic scenarios.

Existing techniques for estimating the capability of distribution networks typically consider both active and reactive power, which is necessary for operation-oriented applications. However, the proposed heuristic is tailored to planning applications and introduces modeling simplifications which highly increase its efficiency. It is worth noting that, although the proposed heuristic only considers active power flexibility, the reactive power constraints of the distribution networks are still taken into account. As a result, the solutions generated by the heuristic are feasible from an operational standpoint. The proposed procedure is notably efficient when compared to the combined solution of the entire planning problem, and produces good-quality, near-optimal results.

4.3 Opportunities created by the new platform

The decoupling heuristic is a crucial component that facilitates the solution of planning problems on large-scale networks, including both transmission and distribution levels. Specifically, it enables an improved representation of the grid's flexibility in system operators' expansion plans. Additionally, it facilitates the analysis of how various integration trajectories of distributed resources can impact power exchanges in the whole system, thereby enabling better comparisons of the required investments in each scenario.

Furthermore, thanks to the decoupling procedure, TSOs and DSOs do not need to share detailed modelling information about their networks, which are considered strategic assets. Instead, they only need to communicate summary information about the expected time- and scenario-dependent capability of the distribution networks and the expected power exchange at the interface.

4.4 Potentially interested stakeholders

As TSO-DSO coordination is an active research topic, apart TSOs and DSOs themselves, the first and foremost category of potentially interested stakeholders for the decoupling procedure is the scientific community: whereas many schemes have been proposed for coordinated operation, little research has been conducted on coordinated planning.

The decoupling procedure can also be of interest to policymakers and regulators, as part of a tool enabling analyses on the effects on the power system of the integration of increasing shares of renewable energy sources.

4.5 Scenario for future exploitations

The decoupling procedure represents a further step in facilitating coordination between TSOs and DSOs in planning, opening up the possibility of jointly optimizing transmission and distribution network investments, and considering the distributed resources in a coordinated way. This can result in more efficient and cost-effective planning solutions, which ultimately benefit end-users by providing a more reliable and affordable electricity supply.

By facilitating estimates on the effects on power system of the installation of different shares of renewable energy sources, the decoupling procedure is part of the toolset needed to evaluate the integration of renewable energy sources into the power system, which is crucial for ensuring the reliability and stability of the grid. As such, the decoupling procedure can help system operators and planners make informed decisions about the integration of renewable energy sources into the power system.

4.6 Barriers for future exploitation and ways to remove them

The current decoupling procedure involves two distinct stages for deciding investments. First, the optimal planning for each distribution network is carried out by considering a constant cost for energy exchanged with the transmission network. This leads to investments being made to address congestion or voltage issues in the distribution network. In the second stage, the optimal planning for the transmission network is carried out, allowing the exploitation of the residual flexibility of distribution grids. Therefore, in the present implementation of the decoupling procedure, congestion in the transmission network cannot prompt additional investments at the distribution level. Although this approach is reasonable for the planning problem on the whole power system, it could potentially dissuade DSOs from utilizing the decoupling procedure to evaluate the extent and type of provided flexibility that the TSO would be willing to compensate them for. To address this, a more advances version of the procedure could be considered too, allowing distribution networks to propose several alternative configurations characterized by different flexibility capabilities as investment candidates for the transmission network. This would entail, however, more calculations and, possibly, a better performing hardware.

Although the FlexPlan decoupling procedure eliminates the need for TSO and DSOs to share detailed network models, it remains essential to establish common assumptions for stochastic scenarios involving renewable sources and demand. While this may not constitute an issue for TSOs and DSOs, the lack of access to real-world data may prevent the scientific community to apply the proposed heuristic decoupling approaches. In fact, the assessment of any heuristics' performance in terms of solution quality can only be conducted with real-case data. Hopefully, an increased interest, as well as opportune regulatory provisions, could lead to increase TSOs and DSOs availability to provide such data in the future.

5 Macro product 3: the FlexPlan software suite (pre-processor and planning tool)

5.1 Pre-existing industrial situation and drivers to implementation

The functionalities of existing network planning software tools used by Transmission System Operators (TSOs) and Distribution System Operators (DSOs) are nowadays rather limited as:

- they allow to do **one simulation at a time** and not to compare simultaneously many grid reinforcement alternatives,
- they plan the **transmission** network and the **distribution** network separately,
- they very often **do not consider the deployment of new energy storage facilities** and the provision of flexibility services as an option for reducing the need for new grid infrastructures but limit their analysis to modifying the shape of the load curves by taking into account the contribution of existing storage in an approximate way, and
- they sometimes do **not model individual storage facilities** (apart from big hydro and pumping power plants).

5.2 Progress realized by FlexPlan over status quo

The FlexPlan software suite analyzes transmission and distribution (T&D) grid expansion options considering the deployment of new storage facilities and grid technologies as well as the activation of flexibility resources (distributed generation and demand side management) located in key places as an alternative to building new lines or reinforcing existing ones.

The FlexPlan software suite brings many advanced innovative features compared to state-of-the-art grid planning software tools. The most important ones to be mentioned are:

- the opportunity to automatically and quickly **arbitrate between numerous investment** options for infrastructure reinforcement,
- the modeling of **demand flexibility and storage** along with the possibility to consider them as alternatives to classical reinforcement of the grid (and not only as solutions for the day-to-day operations),
- the **coupling of time periods**, allowing a correct modeling of the behavior of flexibility sources and storage units,
- the implementation of a **stochastic objective function**, allowing to account for the variability of load and renewable generation by means of different scenarios,
- the automatic generation of different reinforcement alternatives with the **preprocessor tool**, allowing to highlight solutions that would potentially not have been considered in the first place,
- the embedded **environmental modelling** in the Cost Benefit Analysis,

- the innovative **Transmission and Distribution decomposition**, allowing stakeholders to strive towards a common optimal grid reinforcement plan for Transmission and Distribution together while minimizing needed data exchanges.

5.3 Opportunities created by the new platform

The developed software suite can mainly be used for studies around three axes:

- **grid planning** (primary goal): to perform cost benefits analysis in order to optimize and prioritize the investments for grid reinforcement,
- **market simulations**: to assess the impact of different market designs,
- **flexibility**: to assess the potential of new flexibility resources and prioritize the investments and roadmaps of some flexibility resources compared to others.

5.4 Potentially interested stakeholders

The main entities identified as interested stakeholders of the new software suite are:

- **Transmission System Operators** (TSOs) and **Distribution System Operators** (DSOs) as end-users for their planning studies,
- **National Regulatory Authorities** (NRAs) to promote the software suite to TSOs and DSOs in order to reinforce their CBAs,
- and associations for cooperation such as **ENTSO-E** and **E.DSO**, to harmonize planning practices across Europe.

5.5 Scenario for future exploitations

As a first step, identified potential end-users and software developers should continue to collaborate and work hand in hand in order to further develop the FlexPlan software suite. It is essential that this is done jointly between end-users and software developers in order to identify the remaining gaps between the existing software and a product which could be used on a day-to-day basis by the interested stakeholders. Furthermore, it is important also to make sure that further developments are aligned with the needs of the end-users. Those additional developments could be financed either directly by interested stakeholders or by other R&D fundings.

Then, based on further assessment of the market traction, the existing suite could be used in order to provide consulting services to interested stakeholders along the three axes specified in subsection 5.3. Later, when the solution will become more mature, the software suite could also be turned into a complete commercial-off-the-shelf (COTS) product.

Finally, one potential scenario for future exploitation would be to analyze the possibility to also consider sector coupling. This means including gas networks and co-simulating both systems. However, this opens a large new field in which additional partners from the gas sector should participate. By doing so, both system operators could benefit in various ways – not only by better assessing the future conditions to evaluate the benefits of potential projects, but also by maintaining common models and thus further reducing the incompatibilities when exchanging network data.

5.6 Barriers for future exploitation and ways to remove them

The FlexPlan software suite is today already an advanced solution which proved to be sufficiently mature to execute simulations for six different regional cases in the context of an R&D project. However, for future exploitation, several possible improvements have been identified.

First of all, the models used to represent demand flexibility could be enhanced. Indeed, due to the ambition and size of the regional cases of the FlexPlan project, aggregated demand flexibility models were developed and used. In the future, depending on the use-case and its scope, detailed demand flexibility models might be needed. Thanks to the modularity of the implementation, these new demand flexibility models could be easily integrated in the optimization program.

Then, in terms of feeding the software with data, a custom JSON structure is currently being used to gather input data and export results. However, this custom model could be limiting for future exploitation. Indeed, the end-user needs to convert its own data into the custom JSON model before being able to start using the software. In the future, including CGMES in the list of accepted formats is expected to reduce the startup time to use the software.

Regarding the preprocessor, it has been developed to respond to the study cases of the FlexPlan project and the tables of characteristics for the calculation of the candidates for the study regions and for the years 2030, 2040 and 2050 have been "hardcoded" into the program. This limitation is easy to be fixed by moving these tables to external configuration files that would give the possibility to use the preprocessor for other regions and other years.

Another important improvement to enhance the usage of the software is the reduction of the computation time. For the software to be completely useful, the maximal computation time for the largest problems should be less than one working day. Finding the right balance of computing power and complexity of the mathematical problem should therefore be analyzed. In order, to speed-up the resolution of the optimization problems, two approaches are already envisioned:

- parallelization of the resolution of the operational problems in the Benders decomposition,
- hierarchical models / geographical decompositions.

Regarding the Graphical User Interface, it is to be mentioned that additional efforts should be done to make the interface as friendly and intuitive as possible for end-users. This should be done by further understanding how the planning engineers think when assessing new projects. The Graphical User Interface could be enhanced by adding new visualizations and adding new features. For example, the configuration of the software and modification of input data is currently done by the end-user by modifying the input files manually and the modification of these files can be seen as complicated. It would be necessary to add new screens in the Graphical User Interface to:

- show and configure the characteristics of existing assets and candidates taken from the input files and preprocessor results,
- based on the available statistics, graphs and maps with congestion, give the possibility to the end-users to modify the list of candidates if they want to test different candidates.

Last but not least, a final potential limitation which was identified is the use of a bus/branch model and not of a node/breaker model. Indeed, in some cases, the current approach can lead to wrong conclusions as some congestion could be easily solved by opening or closing a circuit breaker between two busbars in a substation and therefore no investment is required while the optimization software would identify a need for grid reinforcement. Considering bus splitting in the optimization would solve this limitation but also complexify the problem. This new approach could be further investigated.

6 Macro product 4: the FlexPlan Open Access libraries

6.1 Pre-existing industrial situation and drivers to implementation

The implementation of tools for power system planning is driven by the need to improve the performance, efficiency, and reliability of power systems, which are becoming more and more complex due to the increasing share of renewable and inverter-based energy sources.

The development of open-source software for power system operation and planning has gained significant momentum in recent years because open-source software is often more flexible, transparent, and cost-effective than proprietary software. It allows users to collaborate and share knowledge, ultimately promoting innovation and progress.

However, it is notable that the majority of open-source tools in this field[2] have focused on developing energy system models with relatively poor representation of the grid. While these models can provide insights into the overall performance of the system, they cannot account for the detailed physical constraints of the transmission and distribution networks.

Finally, the "planning" category seems to be underrepresented among open-source tools, which often focus on operation or on solving the needs of very specific research topics. This may also be a consequence of the fact that many power system operators have existing proprietary software tools for planning, which discourages building open-source alternatives from scratch.

6.2 Progress realized by FlexPlan over status quo

Open-source software has the potential to revolutionize the approach to power system optimization, and *FlexPlan.jl*, the open-source tool developed in FlexPlan, is a further step in this regard. It improves power system planning by focusing on the network infrastructure in a more comprehensive and integrated way. Rather than solely relying on energy system models, e.g. models which focus on determining the optimal future energy mix, which have limitations in accounting for the physical constraints of the transmission and distribution networks, it incorporates more detailed network models and data in the planning process. This helps to identify and analyze potential bottlenecks in the grid in a much more comprehensive way.

Furthermore, *FlexPlan.jl* represents a comprehensive network planning tool that enables a thorough analysis of the flexibility provided by demand-side management and storage, as well as the environmental impact, while considering a broad range of grid expansion possibilities. By conducting transmission and distribution grid planning simultaneously, potential sharing of flexibility resources between the two grid levels can be identified, resulting in a more efficient system design. In this respect, *FlexPlan.jl* is the first open-source model which is able to do combined transmission and distribution grid in a stochastic manner for large networks.

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[2] A review of open-source tools for power systems is available at https://g-pst.github.io/tools/.

6.3 Opportunities created by the new platform

The FlexPlan methodology is a highly adaptable and extensible framework for power system planning. To align with this approach, *FlexPlan.jl* has a modular design, making it user-friendly and easy to extend. Users can either use the tool in its entirety or integrate specific features into their existing power system planning workflows. The planning model is entirely parametric, which allows users to freely choose the power flow model that suits their preferences for accuracy and computation time. For example, if demand flexibility, or distribution planning are not in the user's focus, these building blocks can be omitted from the problem in an easy way. Additionally, the code that builds the optimization model from input data is entirely decoupled from the solver, allowing users to choose from open-source or commercial solvers. All of these features make the tool highly versatile and adaptable to a wide range of use cases.

Another key advantage of *FlexPlan.jl* is its use of the Julia language, a high-level and high-performance language specifically designed for scientific computing and optimization. Julia's algebraic modelling library, JuMP, makes it easy to formulate optimization models with the same level of ease as domain-specific languages such as GAMS and AMPL. Furthermore, Julia is a full-featured, general purpose programming language, which eliminates the need to switch to a second language for any operation not related to optimization, such as pre-processing of data or post-processing of the model outcomes, resulting in more efficient development and faster time-to-delivery. Julia also offers several benefits over other programming languages like Python or MATLAB, including faster execution times, better memory management, and native support for distributed computing. These capabilities make Julia an ideal choice for implementing complex optimization algorithms required for power system planning, and the developed tool takes full advantage of these benefits.

6.4 Potentially interested stakeholders

Thanks to the modularity and quick-prototyping approach, the open-source tools developed within FlexPlan can be readily adopted by research institutions and universities, which could use the tools as a basis for the development of further planning models. The FlexPlan tool can be further developed and used as a rapid prototyping platform by providers of power system planning software to offer more robust solutions. Experts within transmission and distribution system operators could consider an in-house customization of these open-source tools for incorporation in the company planning procedures.

6.5 Scenario for future exploitations

Firstly, developing open-source tools improves the quality management of research grade software. Secondly, by creating a user-community, advancements beyond the state-of-the art planning models can be implemented in a faster way, with constant improvement of the tools. *FlexPlan.jl* uses the same architecture as the PowerModel(ACDC).jl tools which already have more than 2000 users worldwide (*FlexPlan.jl* has 44 users to date), which allows to achieve high visibility.

Moreover, from the perspective of research institutes, developing and using open-source tools might become a requirement for publicly funded research projects. As such, having developed such tools which are successfully used, puts research institutes in a advantageous position for acquiring research projects. In the case of *FlexPlan.jl*, it has already found use in several research projects on the subject of conducting cost-benefit-analysis for hybrid AC/DC grids, planning of offshore grids, and grid planning considering stability of low inertia systems.

6.6 Barriers for future exploitation and ways to remove them

The open-source tools built within FlexPlan were entirely developed using Julia, which is a relatively new language, as its development started in 2012. Julia has features that facilitate its adoption in new projects, such its expressiveness and its availability as an open-source language. However, its adoption by stakeholders could be undermined by the effort they would have to spend updating their existing codebase to create compatible data flows. Nonetheless, the adoption of Julia is progressing at a fast pace, especially in the field of optimization, where the advantages of an open-source, fast language are more clearly evident.

Another potentially critical aspect is that within *FlexPlan.jl*, the optimization is performed by an external solver. Traditionally, proprietary solvers have always been more performant than open-source ones, as their developers could copy the best approaches from the open-source world without providing access to further improvements made internally. Therefore, at the moment, a performance gap between commercial and open-source solvers exists and can make a difference in the real use of an optimization-based software. Typically, commercial solvers can be used in universities thanks to free or highly discounted academic licenses, but the same does not hold for research centers and industry. However, some open-source solvers, such as SCIP and lately HiGHS, are emerging as performant, viable alternatives to commercial solvers, even in the field of mixed-integer programming, which decades ago was the apanage of commercial solvers.

7 Macro product 5: the six Regional Cases scenarios

7.1 Pre-existing industrial situation and drivers to implementation

Currently, the existing network development plans are still elaborated separately for distribution and transmission grids, also due to the fact that information related to distribution network development plan is scarce and usually only information about expected development of distributed generation is available. Moreover, development plans do not often integrate the potential evaluation of storage/demand flexibility, do not consider the deployment of new energy storage facilities and the provision of flexibility services as a way to reduce the need for new grid infrastructures. Nonetheless, flexibility sources (storage, demand side management) are considered at the level of market simulations by some TSOs. In addition, the stochasticity of energy resources and the reliability of network components are not directly considered in the current planning procedures and there is no implementation of heuristics aimed at pre-identifying possible solutions to network potential issues.

For scenarios time series, the results from ENTSO-E "Identification of System Needs" report and "Ten-Year Network Development Plan" are usually used in the regional perspective and a traditional techno-economic analysis is carried out, which does not include optimization techniques.

Additionally, environmental data is not usually considered in the planning procedures, only carbon footprint of the infrastructure reinforcements is evaluated if necessary.

7.2 Progress realized by FlexPlan over status quo

Since the current development plans are mainly based on transmission planning, the role of distribution systems in terms of grid operations can be underestimated and not well quantified nowadays. The FlexPlan project analyses transmission and distribution network expansion options jointly. This is also facilitated by the innovative procedure applied by FlexPlan to elaborate synthetic distribution networks based on statistics drawn from the real systems: this allows to reduce the size of the distribution grid to be simulated (thus helping to retain numerical treatability of the models) while retaining the main characteristics of the single grid branches, the information about possible bottlenecks, etc.

With regards to scenarios time series, one of the innovations of the FlexPlan project is the systematic "top-down" approach to generate time series from load and generation scenarios. However, during the study, this disaggregation of pan-European scenarios had to be complemented with local knowledge from TSOs, DSOs and regulators to have the necessary accuracy for capturing investment needs. The optimization-based approach is another novelty of the FlexPlan project methodology, as well as the extended geographical scope of the analysis, which includes calculations of power flow and investment candidates in several countries within one regional case. Moreover, the FlexPlan project promotes the integration of multi-scenario analysis and component reliability which are fundamental aspects to be considered within the planning phase.

Additionally, environmental data is used in the calculations, such as:

- carbon footprint impact for all possible candidates

- landscape impact, which considers the cost of installation and visual impact for overhead and cable transmission systems for a variety of geographical areas
- air quality impact, which determines the health impact of emissions from conventional generation based on historical data sets for different geographical regions and climatic conditions and added directly to the objective function of the optimisation process.

7.3 Opportunities created by the new platform

The approach of creation of load and generation scenarios can be used as inspiration for the development of an improved methodology for long-term load and generation prognosis, combining a "top-down" approach as illustrated by the FlexPlan methodology based on pan-European scenarios and a "bottom-up" approach using local knowledge of the TSOs and DSOs. The experience from some regional cases also shows that future studies might have a hierarchical approach where the grid planning problem is represented with higher accuracy in a local (focus) area and more coarse-grained representations are used as the distance from the focus area increases. Such a hierarchical approach can combine the "global" (regional) view and the local view in the same study while maintaining computational tractability. In addition, an important aspect is the methodology for incorporating environmental impact assessment into planning procedures, which opens up opportunities for further development of existing tools and can be refined using more detailed data.

7.4 Potentially interested stakeholders

The main entities identified as interested stakeholders of the new methodology to simulate the data for the six regional cases are:

- Transmission System Operators (TSOs) and Distribution System Operators (DSOs) as end-users for their planning studies in order to technically deepen the possibility of deploying new energy storage facilities and providing flexibility services as an option to reduce the need for new grid infrastructures
- National Regulatory Authorities (NRAs), which can be interested in the proposed methodology to demonstrate applicability and impact of the promoted flexibility-exploitation policies
- the scientific community, which can be interested in the numerical and software development challenges that the FlexPlan Consortium has encountered during the full use of the FlexPlan tool, which required to set up improved mathematical models and to optimize the use of the resources: all that is still a very active research field
- software and solution providers that can use the methodology in their studies to achieve a more in-depth analysis of the scenarios and networks to be simulated.

7.5 Scenario for future exploitations

The lessons learned from the results of six regional case study can be used as a starting point for considering both a joint planning by TSOs and DSOs and the use of storage systems not only as alternatives, but also as a support to traditional grid reinforcement, especially considering the future growth of renewable energy sources and the increase in electricity demand as a result of the energy transition and the electrification of new sectors. The exploitation of the methodology can potentially lead to a more truthful representation of the whole power grid while keeping the computational complexity of the optimization problem treatable. Moreover, thanks to the increasing interaction between network operators, software developers and researchers, FlexPlan-like tools will be more and more developed, upgraded with new features and will increase computational performance, which will lead to the positive effect in the near future, when the scenarios will require the consideration of flexibility potential within the planning methodologies of both transmission and distribution networks.

Additionally, as grid planning entities become more confident in new methodologies and as optimization models mature, it is foreseen that also optimization-based tools for selecting the best planning measures will be adopted in practice to a greater extent.

7.6 Barriers for future exploitation and ways to remove them

Possible barriers to utilizing the new grid planning approaches proposed by FlexPlan are:

- all the regional case studies have required some simplifications in terms of the transmission and distribution networks. Concerning the transmission networks, due to the limitations of the computational power that are described in Section 5.6, it was needed to implement some simplifications in the networks, such as reduction amount of AC lines (neglecting short lines) and aggregation of the generation. However, if such limitations on the available computational power are removed, it will be possible to increase the accuracy of the transmission systems modelling and overcome this barrier. Additionally, insufficient information on distribution grids data can hinder the ability of the tool to capture accurate solutions (this was the case for the FlexPlan studies); therefore, a more active participation of the network operators is needed.
- considering the large number of grid companies operating in Europe; this requires a constant interaction and mutual collaboration in order to guarantee the adaptation of the methodology to the steadily increasing complexity of the power system. In the framework of these interactions, the completeness of data to be exchanged (e.g. availability of detailed network models) will be one of the major keys for the successfulness of any future exploitations.
- the current regulatory framework does not include sufficient incentives for better TSOs and DSOs cooperation in the planning process and do not include sufficient incentives for more efficient use of flexibility sources instead of constructing new network infrastructure. As the share of renewable energy sources increases, the development planning process may face escalating constraints, which may require updating the regulatory framework in the foreseeable future, which will lead to more accurate modelling of the systems in both transmission and distribution networks.

8 Conclusions

As a conclusion of the detailed analysis caried out in this report, we can say that the many innovative aspects of the FlexPlan methodology and the convincing results obtained from the six regional cases, yet run resorting to a very limited hardware configuration due to budget limitations, are good ingredients to create an interest for the FlexPlan toolbox and the open access libraries, so as to prompt for a further engineering and customization of the products after the end of the project.

The declarations of the industrial members of the Consortium as well as the deep interest obtained from the European stakeholders during the dissemination events organized in the last months of the project activities (Final Workshop in Brussels on 14th February 2023 and the six workshops organized by the leaders of the regional cases) promise interesting future developments.

However, the most important engine for a potential adoption of the FlexPlan methodology is the changing regulatory context and the request by the European Commission to take into account flexible elements within future planning analyses by the system operators (Directive 2019/944 - Art. 32, Art. 40) and by ENTSO-E (Regulation 2022/869 - Art. 13). Storage elements and demand side management will prove to be of paramount importance to provide flexibility services to the system and a key for the success of the ambitious present EU goals on decarbonization and independence on primary energy sources acquisition. Depending on the actual regulatory context, the possibilities to apply the FlexPlan methodology and its effectiveness can vary considerably. For a comprehensive analysis of this aspect, we defer the reader to the analysis carried out in deliverable D7.6 (impact assessment). Additionally, we signal deliverable D6.2, which includes an additional interesting analysis on scalability and replicability of the results achieved by the FlexPlan project.

9 Appendix – Consortium members declarations

RSE	*RSE, coordinator of the FlexPlan project, strongly believes in the timeliness of the project activities. In the next years, the planning activities of the System Operators will have to change under the action of several drivers and mainly due to the incremental role RES and distributed generation will play in the electricity system. The FlexPlan methodology and tool, to which RSE has actively contributed, both in the elaboration of the technical specifications and in the realization of the Open Access toolbox, have the potential to help the System Operators to fill this gap. So, RSE is going to actively promote the evaluation of the FlexPlan tools by the national European System Operators and will use such tools internally for R&D studies. Beyond that, the experience acquired with the Italian regional case is for RSE an important asset because it allowed to gather significant amounts of scenario and networks data. Additionally, the results of the study have allowed RSE to build up an in-depth view on development priorities for the national system between 2030 and 2050. Finally, the regulatory analysis, which has been led by RSE as T6.2 and T6.3 leader has allowed to develop a know-how on barriers and enabling factors for an optimal valorization of the role flexibility can play in the electric system in the mid-long term. All this know-how will be for sure re-used and further developed by RSE for future R&D analyses and studies, maybe on behalf of the Italian regulator or other Italian stakeholders, for the benefit of the Italian national system.*
ENEL	*ENEL has a long track in experimenting solutions for implementing flexibility in its grids, participating and coordinating projects to investigate the issues and proposing different solutions. Besides that, Enel Grids and its linked third-party E-Distribuzione has a consolidated experience in distribution grid planning; their systems have been continuously extended according to the evolving scenario, that included in the recent past the big request for DERs connection and integration. The actual challenge is to shift this approach for considering flexibility not only as a solution for the day-by-day operation, but also as a support to optimize and better prioritize the investments for infrastructural reinforcements.* *In this sense, a possible exploitation of the experience gained in the project participation is to have a deeper understanding of the project methodology for evaluate an extension of internal tools for the best flexibility services (provided by DERs) integration in grid planning stage. Once the rules will be defined at National level, an interface layer for integrating T&D grids planning tool could be investigated, even if the reference period for DSOs and TSOs covers different time scales.*

EKC	*EKC is deeply involved in the system development processes in the South East Europe directly supporting the TSOs in the region. This region is, similar to others, tackled by high-speed deployment of RES that makes development planning in transmission or distribution systems more and more complex. At the same time, investments are higher and followed by stronger obstacles in the process of their implementation.* *Having this in mind, the main directions in which results from FlexPlan will be exploited in the SEE region are the following:* • *Experience in implementation of the combined T&D planning will help in determination of the improvements in regulatory procedures related to system development planning* • *Also, results of FlexPlan will help assure the regulators and other stakeholders in the importance of combining the energy storage and aggregated demand response as distributed sources in the process of the system development planning* • *FlexPlan methodology can be used as the basis for improvements in the system development planning processes especially the ones carried out by TSOs in the region* • *Also, implementation of all open-access data and libraries (FlexPlan.jl and OptimalTransmissionRouting.jl) can improve planning process in the region* • *Joint effort with TSOs and DSOs in the region in further customization of the tool* • *EKC is planning a webinar during February 2023 with main stakeholders to present the results of the FlexPlan and discuss opportunities for further development and implementation of the methodology, algorithm or tool.*
ELES	*ELES is very interested in further development of the existing software suite, especially as it represents one of a kind in the planning field. A particular advantage is the ability to simulate the network and automatically integrate new projects, including storages, whereas other tools simulate only the conditions where the network and its power injections are strictly defined. By doing so, the planning process can be more dynamic, less time consuming and thus resulting in reduced financial investments in the future. It can also highlight solutions that were not even considered in the first place.* *Thus, ELES is considering continuing to cooperate with project partners regarding further development of the tool. The talks are already ongoing, where ELES's position is not only to be an end user of the tool, but also active participant in the further development, especially focusing on functionalities and user interface, connectivity with existing company's ecosystem (existing servers, multithreading) and testing of the tool with regards of existing problems.* *ELES has an extensive knowledge and user experience in simulations and has collaborated in the past with various software providers on how to make their tools user friendly. As an end user we can help to make the graphical user interface user friendly intuitive. Collaboration with programmers who*

	make the software can help them understand how the planning engineers think when assessing new projects, what are the barriers they are focusing, what could be additional benefit the emerging technologies could offer that are not yet modelled in the tool, what are the common data formats used by the TSOs and trends in this field etc. *Regarding future extensions of the methodology, the focus is also to include gas network and co-simulate both systems. However, this opens a large new field where additional partners from gas sector could participate. By doing so, both system operators can benefit in various ways – not only by better assessing the future conditions to evaluate the benefits of potential projects, but also by maintaining common models and thus further reducing the incompatibilities when exchanging network data.* *One of the barriers that ELES also sees for the usability of the future tool is reducing the computation time, which can be very challenging. If we want that the tool would be useful, the maximal computation time for the largest problems, should be less than one working day. Finding the right balance of computing power and complexity of the mathematical problem, should be analyzed.*
KUL	*From the perspective of KU Leuven, there is a strong interest in further exploiting the FlexPlan project results, especially with respect to the open-source tools, FlexPlan.jl and OptimalTransmissionRouting.jl, that have been (co)developed by KU Leuven in the course of the FlexPlan project. Considering that KU Leuven's activities center around optimization models for power system planning and operation, we further want to develop the afore-mentioned tools in follow-up national and international research projects to mainly to incorporate aspects of:* - *Offshore HVDC grid planning* - *TSO & DSO coordination in system planning* - *Planning of multi-energy systems* - *System planning under uncertainty, e.g., risk-based, robust and least regret planning models* *Having established a solid background in the open-source work, we believe that the FlexPlan results will enable attraction of further project funding to achieve above mentioned goals. Although there is to date no granted follow-up funding, several research project proposals have been submitted, and will be submitted in the near future.*
N-SIDE	*Regarding the produced FlexPlan planning tool, N-SIDE would like to assess the market traction of the developed software. This assessment will be done towards TSOs, DSOs and regulators, who are the identified potential users of the new tool. The primary goal will be to identify the remaining gaps*

	between the FlexPlan planning tool and an ideal software which would perfectly fit the needs of these stakeholders. *During this assessment, it will be highlighted that the FlexPlan tool brings some innovative features compared to state-of-the-art grid planning softwares. The most important elements to mention are:* • *the modeling of demand flexibility and storage along with the possibility to put those in competition with classical reinforcement of the grid,* • *the coupling of time periods, allowing a correct modeling of the behavior of flexibility and storage,* • *the implementation of a stochastic objective function, allowing to account for the variability of load and renewable generation by means of different scenarios,* • *the innovative Transmission and Distribution decomposition, allowing stakeholders to strive towards a common optimal grid reinforcement plan for Transmission and Distribution together while minimizing needed data exchanges.* *Based on the feedback provided by the stakeholders, the observed needs of the market and shortcomings of the tool observed during its use in the FlexPlan project, N-SIDE will continue to develop and improve the planning software.* *First of all, the models used to represent demand flexibility can be enhanced. Indeed, due to the ambition and size of the regional cases of the FlexPlan project, aggregated demand flexibility models were developed and used. In the future, depending on the use-case and its scope, detailed demand flexibility models might be needed. Thanks to the modularity of the implementation, these new demand flexibility models could be easily integrated in the optimization program.* *Then, in terms of feeding the tool with data, a custom JSON structure is currently being used to gather input data and export results. However, this custom model could be limiting for future exploitation. Indeed, the end-user needs to convert its data into this custom JSON model before being able to start using the tool. In the future, N-SIDE plans to include CGMES in the list of accepted formats. This will reduce the startup time to use the tool.* *In addition to these developments, customization of the planning tool might be required for some use-cases. On one side, the objective function could be customized and, on the other-side, performances could be fine-tuned in order to speed-up the execution of the simulations. Moreover, it could be beneficial to give the possibility for end-users to easily run some what-if scenario analysis on critical parameters used by the tool.*

	All those enhancements will have the purpose to create a complete software which will be used by N-SIDE consultants in order to provide consulting services to external stakeholders such as TSOs, DSOs and regulators. These consulting services can be organized in three axes: • *Grid planning (primary goal): to perform a CBA in order to define the optimal investment plan* • *Market simulations: to assess the impact of different market designs* • *Flexibility: to prioritize the investments and roadmaps of some flexible resources compared to others* *Depending on the market traction, the tool can also be turned into a product and not only used for consulting services.* *Finally, N-SIDE will also reuse and extend the developed Graphical User Interface (GUI). On one hand, the existing GUI can be improved by adding new visualizations and giving the possibility to end-users to modify the data directly in the GUI. On the other hand, the GUI can also be reused for other applications requiring grid visualizations.*
R&D NESTER	*R&D NESTER will exploit the knowledge acquired in the FlexPlan project for further related research activities and projects. The methodology to obtain Pan-European scenario data for three target years with increasing renewable generation capacity, affecting system planning and operation, and regionalization methodology to generate simplified input data will be used in the future projects. When setting up future innovative collaborative projects funded by the European Commission on similar topics, R&D NESTER will make sure to take into consideration the lessons learnt from the grid development results of the regional studies, including how these results have influenced on the national and regional regulation and practices. With regard to the FlexPlan Grid Expansion Planning Tool, R&D NESTER will keep the know-how of the algorithms developed. R&D NESTER will continue to use the developed FlexPlan algorithms with the RSE/KUL open access library.*
REN	*REN will exploit the knowledge accomplished in the FlexPlan project for internal use in operational and long-term planning activities. The expansion of new renewable generation is adding more challenges to managing the grid, and the decision to use flexibility or new investments in the network is one of FlexPlan's key contributions for us.* *New features of the Flex Plan Grid Expansion Planning Tool methodology will be analyzed to complement the current methods used by our grid planning department.* *Regulatory considerations on market design carried out by the FlexPlan project (e.g. on capacity markets) will be shared with the national regulatory*

	authority (NRA) to improve the Iberian market and combined network investments by the TSO & DSO.
SINTEF	*SINTEF Energy Research is using the results from the FlexPlan project to help updating the grid planning processes for Norwegian distribution grids. The FlexPlan methodologies have been assessed by viewing them in the context of a framework for planning of active distribution grids that is developed in the research centre CINELDI (hosted by SINTEF). Parts of the methodologies have then been adapted to Norwegian conditions and incorporated in methods and prototype tools developed in CINELDI and collaborating research projects co-funded by the Norwegian electricity distribution industry. More specifically, the generic flexibility model and the net present value calculations specified in FlexPlan D1.2 have already been implemented.* *SINTEF has received funding from the Research Council of Norway for the supplementary project DiPOFlex (Distribution network Planning and Operation with flexibility resources) to support the organization of two physical workshops with Norwegian stakeholders, in addition to the regional workshop organized by FlexPlan WP5. These workshops have been used to discuss and disseminate methods developed and implemented in the FlexPlan project. The supplementary project has also supported the development of lecture material for a new course on flexibility and grid planning that is being prepared for master students at the Norwegian University of Science and Technology (NTNU).* *Contract research is a core business activity for SINTEF Energy Research, and the main outcomes from FlexPlan project will be used in national and international R&I activities. SINTEF is also seeking to include methodologies, principles and ideas from the FlexPlan project as background knowledge in proposals for new research, development and innovation projects. This includes the open-source code package FlexPlan.jl, which is being considered as a starting point for further development.*
TECNALIA	*TECNALIA is ready to exploit the pre-processor together with rest of the GEP package, and, thus, in coordination with a possible exploitation by N-SIDE. On the other side, as regional case leader, TECNALIA will bring home know-how, models and experience that will be re-used in future studies.*
TERNA	*The FlexPlan project has brought a significant value for Terna and especially for the System Operator division through many of the deliverables that have been achieved. Among the conceptual/methodological outcomes, Terna has benefited and may further benefit particularly from the deliverables 2.2 and 2.3 which provide a characterization of all the main potential flexibility resources and a coherent modelling of their participation to congestion management. Terna has a deep knowledge on some of the*

	actual and potential future flexibility resources, namely the most mature ones, but the FlexPlan consortium has gathered a complementary and objective view useful to better understand the potential of some resources. For what concerns the two applications released (i.e. the reduced FlexPlan tool D3.3 and the open-access library), given the low TRL (estimated around 5, as targeted during the project financing), they are not going to be directly integrated into the operational process. However, they both have a demonstrative value and help to have a first methodology to assess the role that each resource may play. The open-source model is particularly helpful to acquire a full comprehension of some innovative algorithms (e.g. clustering of temperature series). Terna has already started a discussion with the developers in order to share the potential of the FlexPlan tool with the management and the relevant colleagues that have not been directly involved in the project. To conclude, Terna is actively considering the possibility to exploit what has been achieved during FlexPlan in order to develop a tool capable of assessing the potential of the new flexibility resources within the context of the grid planning and energy scenarios. Further developments might include instruments for taking into account the benefits from sector coupling.
TUDO	*We will incorporate the methods developed and results obtained into teaching and future research projects. In addition, the results achieved can still be referred to in publications after the end of the project.*
VITO	*The knowledge developed within FlexPlan is relevant for VITO's consultancy projects with transmission and distribution system operators These concern questions regarding the assessment of investing in new network assets versus using flexibility to cope with increased demand as well as increased renewable production. For this, the insights gained through the development of the FlexPlan methodology will be applied.*