ATTEST

Ref. Ares(2023)7380370 - 30/10/2023

WP7

Impact assessment

D7.3

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864298.

DOCUMENT CONTROL PAGE

DOCUMENT	D7.3. Impact assessment
TYPE	Deliverable
DISTRIBUTION LEVEL	Public
DUE DELIVERY DATE	31 / 05 / 2023
DATE OF DELIVERY	25 / 10 / 2023
VERSION	
DELIVERABLE RESPONSIBLE	ICENT
AUTHOR(S)	Filipe Soares, Mirna Gržanić
OFFICIAL REVIEWER(S)	

DOCUMENT HISTORY

VERSION	AUTHORS	DATE	CHANGES
1.0	Filipe Soares (INESC TEC)	1.10.2023.	Content formation and calculation
2.0	Mirna Gržanić (ICENT)	25.10.2023.	Figures formatting and description of KPIs

Table of Contents

List of Figures

Abbreviations and Acronyms

DA	Day-Ahead
DG	Distributed Generation
DER	Distributed Energy Resources
DSA	Dynamic Security Assessment
DSO	Distribution System Operator
EES	Electrical Energy Storage
FL	Flexible Loads
LV	Low Voltage
MPC	Model Predictive Control
MV	Medium Voltage
NLP	Non-Linear Programming
OP	Operating Point
OPF	Optimal Power Flow
PV	Photo-Voltaic
SCOPF	Security Constrained OPF
RES	Renewable Energy Sources
RT	Real-time
TSO	Transmission System Operator

Executive Summary

This report compares contributions from the ATTEST project proposal and Grant Agreement with achieved results, developed tools, and platform demonstration.

Fifty-one Key Performance Indicators (KPIs) were defined in the proposal and grouped into 5 categories: joint ICT platform to facilitate TSO/DSO collaboration and coordination, open-source tools to optimize network operation, open-source tools to optimize network planning, open-source tools to optimize assets maintenance, and demonstrate the joint ICT platform operating in a real-world environment.

The deliverable provides a detailed description of each KPI and how it is achieved. If the KPIs are partially achieved, not achieved, or not calculated, a valid explanation was provided which explains the background of the calculation or the demonstration.

1. Introduction

To ensure a successful low-carbon transformation of the energy sector, it is crucial to develop innovative methodologies and tools for distribution and transmission network planning and operation. The ATTEST project developed 14 tools that enable the secure and efficient operation of power systems in the upcoming years:

1. Day-ahead and real-time optimization tools to support MES aggregators
2. Market simulator
3. Optimization tool for distribution network planning
4. Optimization tool for transmission network planning
5. Optimization tool for planning TSO/DSO shared technologies
6. Tool for ancillary services procurement in day-ahead operation planning of the distribution network
7. Tool for ancillary services activation in real-time operation of the distribution network
8. Tool for state estimation of distribution networks
9. Tool for ancillary services procurement in day-ahead operation planning of the transmission network
10. Tool for ancillary services activation in real-time operation of the transmission network
11. Tool for online dynamic security assessment
12. Tool for the characterization of the condition of assets
13. Tool for the definition of condition indicators based on heterogeneous information sources
14. Tool for the definition of smart asset management strategies

These tools were tested and validated on the realistic distribution and transmission network data from Croatia, UK, Spain, and Portugal as described in deliverable D7.2. Each country provided renewable energy sources, electric vehicles as flexible load, and battery storage integration plans for each upcoming decade for transmission and distribution levels. Key Performance Indicators (KPIs) are calculated by using tools developed in the project to demonstrate the efficiency of proposed ATTEST solutions. Moreover, KPIs related to the demonstration phase and joint ICT platform to facilitate TSO/DSO collaboration and coordination are also described.

The focus of this deliverable is to show that achieved results with ATTEST tools are in line with the contributions and indicators from the project proposal and Grant Agreement. The deliverable is structured as follows: each section focuses on a specific group of indicators, the titles of subsections highlight the value of the indicator proposed in the Grant Agreement, while the content of each subsection describes if and how the specific indicator is achieved.

2. Joint ICT platform to facilitate TSO/DSO collaboration and coordination

Four contributions and ad-hoc indicators were defined in the proposal and all of them are successfully achieved as described below:

1. Three modules with open source tools for TSOs/DSOs embedded in the platform and fully interoperable with the common data access component and with the market simulator
    - 3 modules with tools for planning, asset management and operation are fully integrated and operational in the ATTEST platform.
2. 18 visualization tools (GUIs) - 1 for the platform, 3 for the modules and 14 for the open source tools,
    - 18 visualization tools available in the ATTEST platform:
        - 1 for the entire platform,
        - 3 for the networks visualization (table view and diagram view – full network or substations),
        - 3 for the modules (planning, operation and asset management);
        - 3 for the planning tools,
        - 5 for the operation tools,
        - 3 for the asset management tools.
3. Three TSO/DSO coordination mechanisms embedded in the market simulator to avoid operation planning and real-time operation conflicts - 1 for the congestion management phase, 1 for ancillary services procurement, 1 for the activation of ancillary services:
    - 1 coordination mechanism is developed in the optimization tool for planning TSO/DSO shared technologies (Task 3.3) to ensure that the flexibility available in the distribution networks is shared with the TSO (via the DSO), guaranteeing the safe operation of both transmission and distribution networks.
    - 1 coordination mechanism is developed in the tool for ancillary services procurement in day-ahead operation planning of the transmission network (Task 4.4), which considers P and Q operating envelopes at the TSO/DSO boundary provided by the DSO – calculated with the tool for ancillary services procurement in day-ahead operation planning of the distribution network (Task 4.1).
    - 1 coordination mechanism is developed in the tool for ancillary services activation in real-time operation of the distribution network (Task 4.2), which activates flexibility to ensure the distribution network safe operation and the compliance with the operating points requests from the TSO.
4. One tool for coordinated planning of distribution and transmission networks:
    - 1 tool is developed that defines an investment plan in shared ESSs to be installed per year and interface node (primary substation) between the transmission and distribution networks – optimization tool for planning TSO/DSO shared technologies (Task 3.3).

3. Open source tools to optimize networks operation

Eleven contributions were defined in the proposal and all of them were successfully achieved through the project:

1. 3 tools to optimize distribution networks operation (integrated in the “operation module” of the joint ICT platform)
2. 3 tools to optimize transmission networks operation (integrated in the “operation module” of the joint ICT platform)
3. 15% savings in the distribution networks OPEX when compared with Business-as-Usual (BaU) strategies (average generated by the operation tools in 2030 scenario for the test networks)
4. 10 % savings in the transmission networks OPEX when compared with BaU strategies
5. 50% reduction in the over/under voltages occurrence in distribution networks when compared with BaU strategies.
6. 30 % reduction in the over/under voltages occurrence in transmission networks when compared with BaU strategies
7. 50% reduction in the branches overloading occurrence in distribution networks when compared with BaU strategies.
8. 20% reduction of the branches overloading occurrences in transmission networks in case of contingencies when compared with BaU strategies.
9. 15% energy losses reduction in distribution networks when compared with BaU strategies.
10. 10% energy losses reduction in transmission networks when compared with BaU strategies.
11. Reduction of pollutants’ emissions from electricity generation :
    - 18% reduction in emissions with global warming potential (CO_2, CH_4, N_2O);
    - 13% reduction in particulate matter emissions (PM, NO_x, SO_2);
    - 12% reduction in emissions with human toxicity potential (heavy metals, hydrocarbons);
    - 13% reduction in emissions that contribute to photochemical oxidant formation (NO_x, unburned hydrocarbons);
    - 14% reduction in emissions with terrestrial acidification potential (NO_x, SO_2).

3.1. Three tools to optimize distribution networks operation

3 tools to optimize distribution networks operation are successfully integrated in the joint ICT platform:

- Tool for ancillary services procurement in day-ahead operation planning of the distribution network (Task 4.1).
- Tool for ancillary services activation in real-time operation of the distribution network (Task 4.2).
- Tool for state estimation of distribution networks (Task 4.3).

3.2. Three tools to optimize transmission networks operation (integrated in the “operation module” of the joint ICT platform)

3 tools to optimize transmission networks operation are successfully integrated in the joint ICT platform:

- Tool for ancillary services procurement in day-ahead operation planning of the transmission network (Task 4.4).
- Tool for ancillary services activation in real-time operation of the transmission network (Task 4.5).
- Tool for on-line dynamic security assessment (Task 4.3). The tool is not directly available in the platform. It was embedded in the tool of Task 4.4.

3.3. 15% savings in the distribution networks OPEX when compared with Business-as-Usual (BaU) strategies (average generated by the operation tools in 2030 scenario for the test networks)

This KPI was calculated with the outputs of the tool for ancillary services procurement in day-ahead operation planning of the distribution network (Task 4.1). The distribution networks OPEX was calculated for the years 2020, 2030, 2040, and 2050, for two scenarios – Business as Usual (BAU) and with the tools of ATTEST, for the four distribution networks available. Results are presented in the charts below:

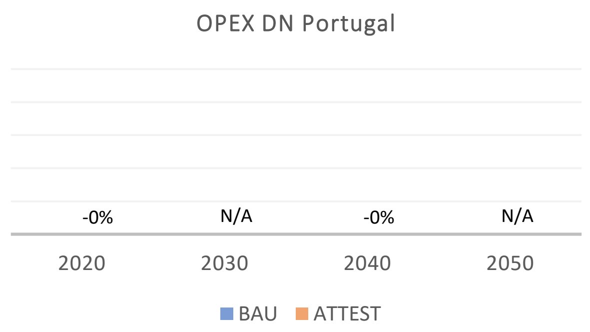

FIGURE 1 OPEX COMPARISON WITH BAU AND ATTEST APPROACH IN PORTUGAL OVER THE YEARS

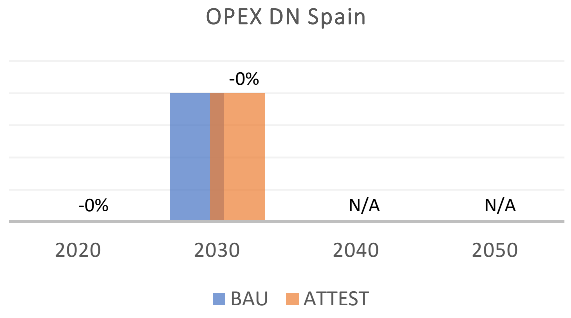

FIGURE 2 OPEX COMPARISON WITH BAU AND ATTEST APPROACH IN SPAIN OVER THE YEARS

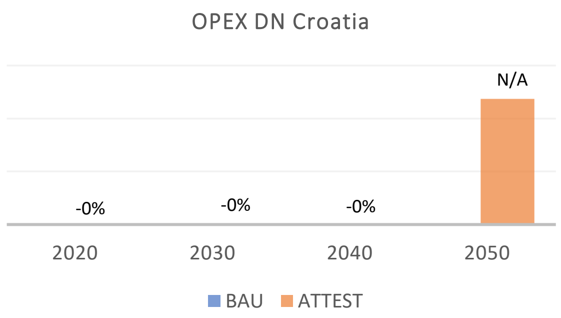

FIGURE 3 OPEX COMPARISON WITH BAU AND ATTEST APPROACH IN CROATIA OVER THE YEARS

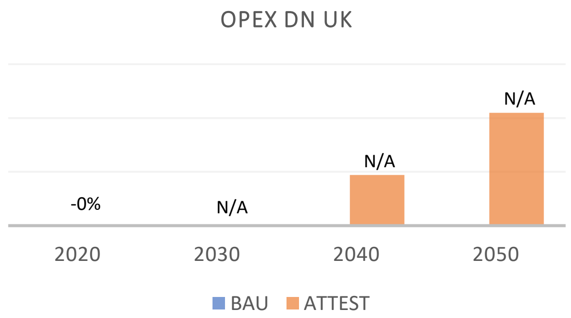

FIGURE 4 OPEX COMPARISON WITH BAU AND ATTEST APPROACH IN THE UK OVER THE YEARS

Unfortunately, the calculation of this KPI was severely affected by power flow convergence problems, which resulted from the massive integration of DER. "N/A" in the charts above means that the OPEX savings with the ATTEST tools, when compared to the BAU, could not be entirely calculated.

3.4. 10 % savings in the transmission networks OPEX when compared with BaU strategies

This KPI was calculated with the outputs of the tool for ancillary services procurement in day-ahead operation planning of the transmission network (Task 4.4). The transmission networks OPEX was calculated for the years 2020, 2030, 2040, and 2050, for two scenarios – Business as Usual (BAU) and with the tools of ATTEST, for the three transmission networks available. Results are presented in the charts below:

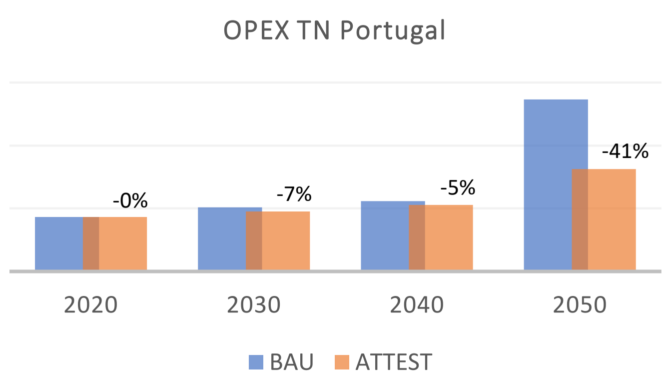

FIGURE 5 OPEX COST REDUCTION WITH ATTEST APPROACH IN PORTUGAL

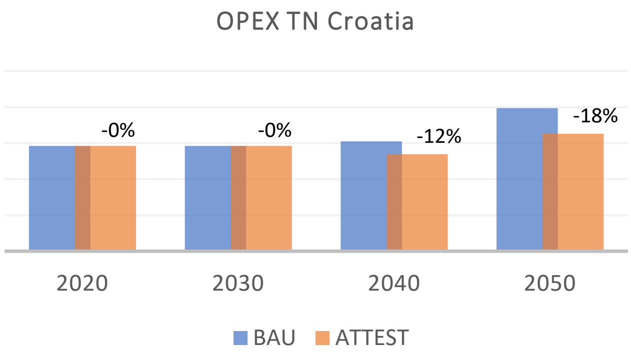

FIGURE 6 OPEX COST REDUCTION WITH ATTEST APPROACH IN CROATIA

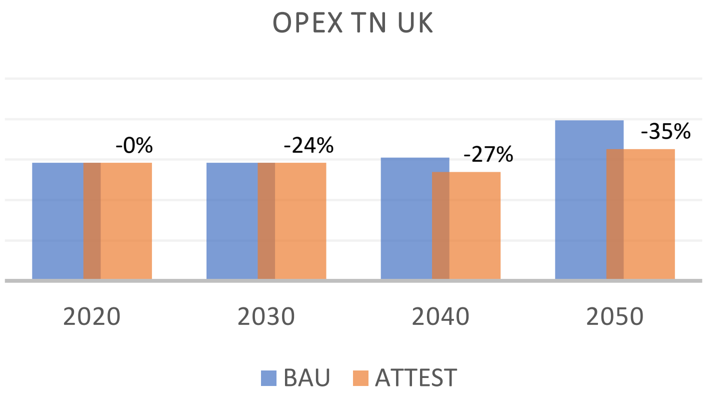

FIGURE 7 OPEX COST REDUCTION WITH ATTEST APPROACH IN THE UK

3.5. 50% reduction in the over/under voltages occurrence in distribution networks when compared with BaU strategies

This KPI was calculated with the outputs of the tool for ancillary services activation in real-time operation of the distribution network (Task 4.2). The over/under voltages were calculated for the years 2020, 2030, 2040, and 2050, for two scenarios – Business as Usual (BAU) and with the tools of ATTEST, for the four distribution networks available. Results are presented in the charts below. Cases for Portugal, Spain, and the UK show 0% voltage deviations because there were not any voltage violations in these countries for both the BaU and ATTEST approaches. In Croatia, in 2050 all voltage violations were solved with ATTEST solution.

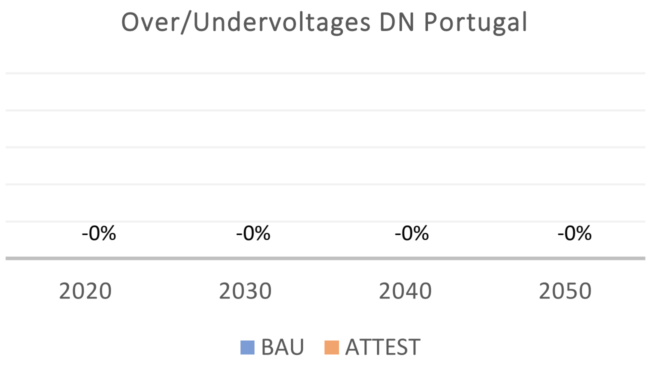

FIGURE 8 REDUCTION IN OVER/UNDERVOLTAGES IN DISTRIBUTION NETWORK IN PORTUGAL OVER THE YEARS

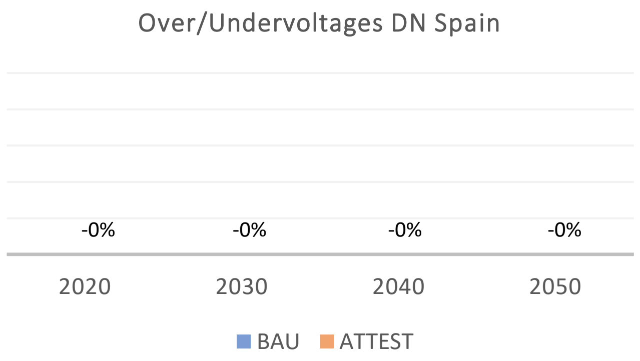

FIGURE 9 REDUCTION IN OVER/UNDERVOLTAGES IN DISTRIBUTION NETWORK IN SPAIN OVER THE YEARS

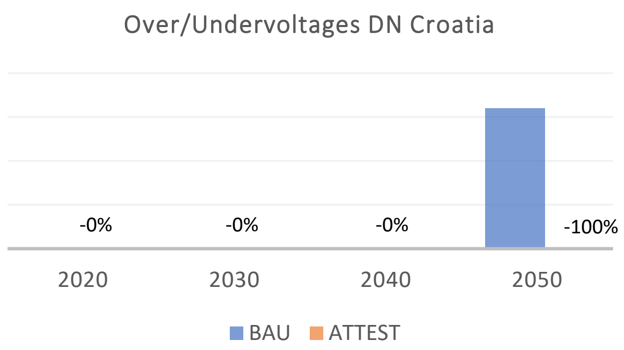

FIGURE 10 REDUCTION IN OVER/UNDERVOLTAGES IN DISTRIBUTION NETWORK IN CROATIA OVER THE YEARS

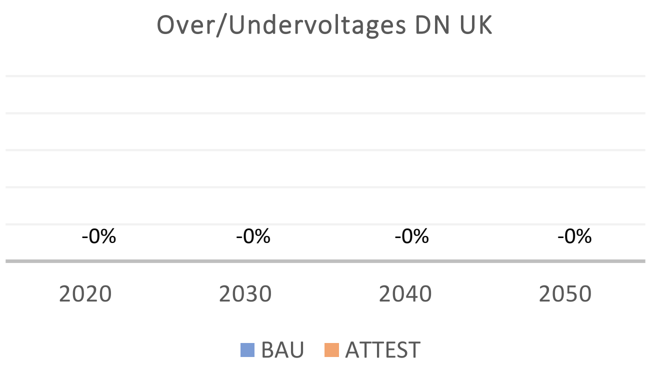

FIGURE 11 REDUCTION IN OVER/UNDERVOLTAGES IN DISTRIBUTION NETWORK IN THE UK OVER THE YEARS

3.6. 30 % reduction in the over/under voltages occurrence in transmission networks when compared with BaU strategies

This KPI was calculated with the outputs of the tool for ancillary services activation in real-time operation of the transmission network (Task 4.5). The over/under voltages were calculated for the years 2020, 2030, 2040, and 2050, for two scenarios – Business as Usual (BAU) and with the tools of ATTEST, for the three transmission networks available. Results are presented in the charts below:

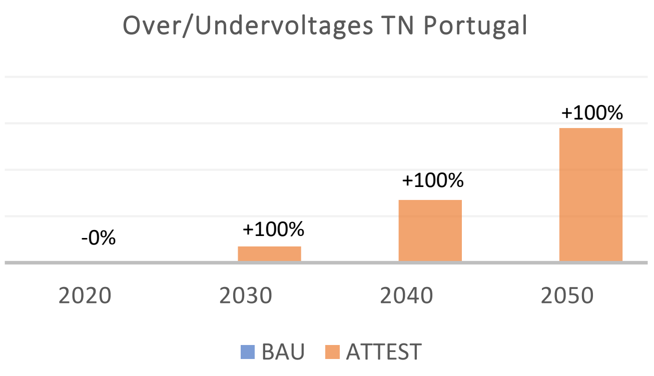

FIGURE 12 REDUCTION IN OVER/UNDERVOLTAGES IN TRANSMISSION NETWORK IN PORTUGAL OVER THE YEARS

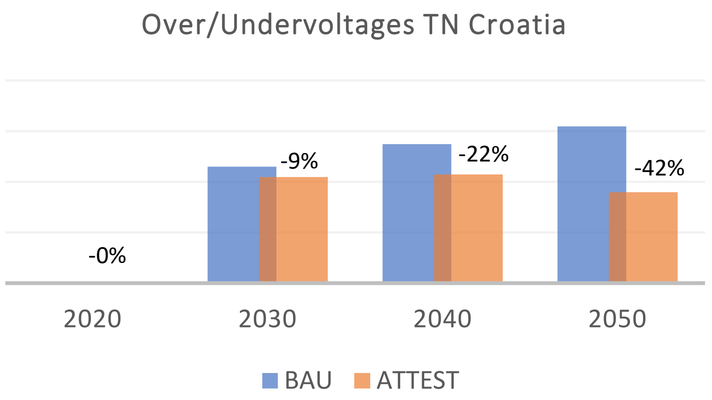

FIGURE 13 REDUCTION IN OVER/UNDERVOLTAGES IN TRANSMISSION NETWORK IN CROATIA OVER THE YEARS

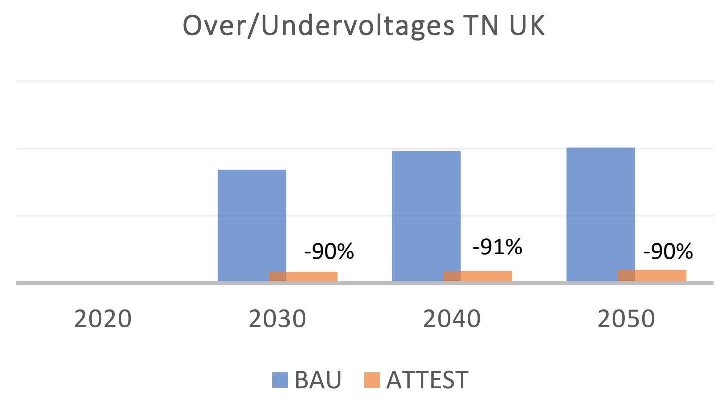

FIGURE 14 REDUCTION IN OVER/UNDERVOLTAGES IN TRANSMISSION NETWORK IN THE UK OVER THE YEARS

The results for the Portuguese networks are counterintuitive but have a reasonable explanation. The increase in the over/under voltages in the ATTEST scenario results from the methodology used in this tool, which considers a double penalty scheme in the objective function that prioritizes the resolution of overloading problems over over/under voltage problems (see D7.2 for more details).

3.7. 50% reduction in the branches overloading occurrence in distribution networks when compared with BaU strategies

This KPI was calculated with the outputs of the tool for ancillary services activation in real-time operation of the distribution network (Task 4.2). The branches' overloading was calculated for the years 2020, 2030, 2040, and 2050, for two scenarios – Business as Usual (BAU) and with the tools of ATTEST, for the four distribution networks available. Results are presented in the charts below:

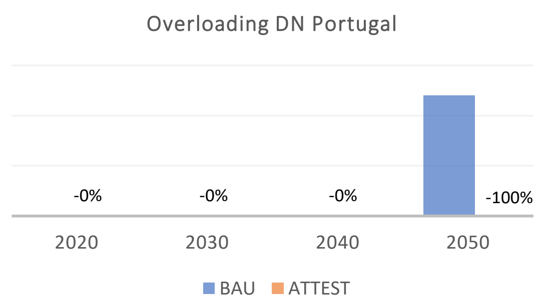

FIGURE 15 REDUCTION IN THE BRANCHES OVERLOADING IN DISTRIBUTION NETWORK IN PORTUGAL

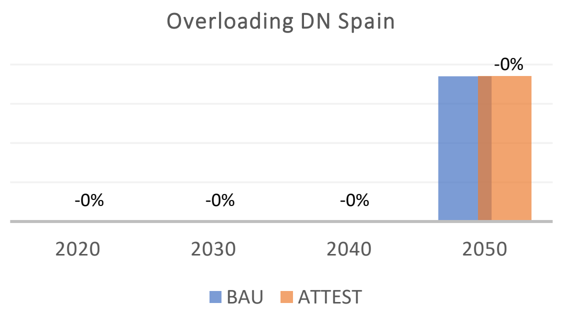

FIGURE 16 REDUCTION IN THE BRANCHES OVERLOADING IN DISTRIBUTION NETWORK IN SPAIN

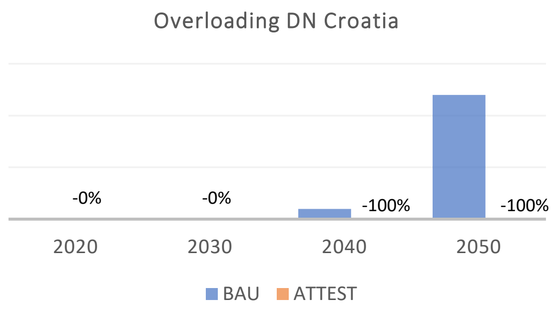

FIGURE 17 REDUCTION IN THE BRANCHES OVERLOADING IN DISTRIBUTION NETWORK IN CROATIA

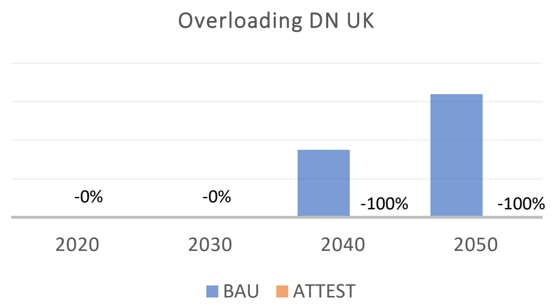

FIGURE 18 REDUCTION IN THE BRANCHES OVERLOADING IN DISTRIBUTION NETWORK IN THE UK

The results for the Spanish networks are counterintuitive but have a reasonable explanation. There was no improvement in 2050 due to the location of the flexible assets – the feeders in need of flexibility did not have flexible resources available (see D7.2 for more details). In all other countries the ATTEST tool was capable of solving all overloading problems.

3.8. 20% reduction of the branches overloading occurrences in transmission networks in case of contingencies when compared with BaU strategies

This KPI was calculated with the outputs of the tool for ancillary services activation in real-time operation of the transmission network (Task 4.5). The branches' overloading was calculated for the years 2020, 2030, 2040, and 2050, for two scenarios – Business as Usual (BAU) and with the tools of ATTEST, for the three transmission networks available. Results are presented in the charts below:

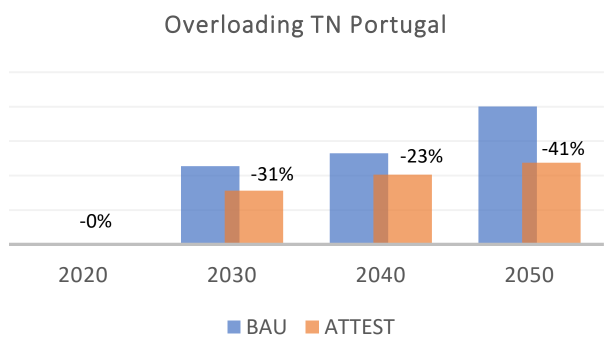

FIGURE 19 REDUCTION IN THE BRANCHES OVERLOADING IN TRANSMISSION NETWORK IN PORTUGAL

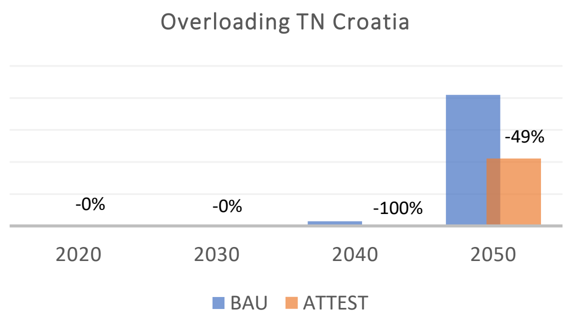

FIGURE 20 REDUCTION IN THE BRANCHES OVERLOADING IN TRANSMISSION NETWORK IN CROATIA

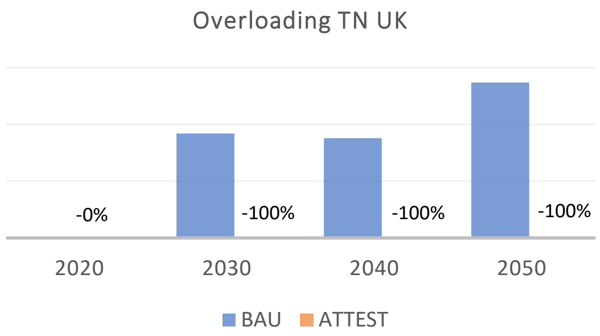

FIGURE 21 REDUCTION IN THE BRANCHES OVERLOADING IN TRANSMISSION NETWORK IN THE UK

3.9. 15% energy losses reduction in distribution networks when compared with BaU strategies

This KPI was calculated with the outputs of the tool for ancillary services activation in real-time operation of the distribution network (Task 4.2). The energy losses were calculated for the years 2020, 2030, 2040, and 2050, for two scenarios – Business as Usual (BAU) and with the tools of ATTEST, for the four distribution networks available. Results are presented in the charts below:

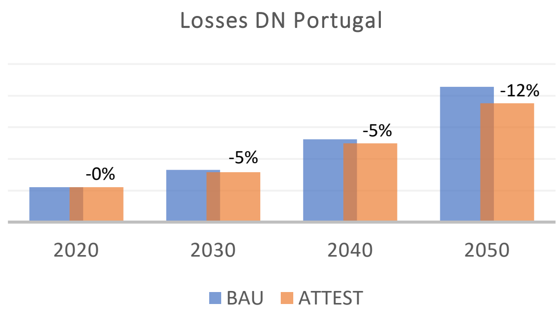

FIGURE 22 ENERGY LOSSES REDUCTION IN DISTRIBUTION NETWORKS IN PORTUGAL

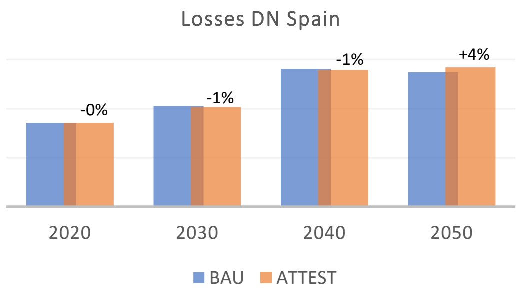

FIGURE 23 ENERGY LOSSES REDUCTION IN DISTRIBUTION NETWORKS IN SPAIN

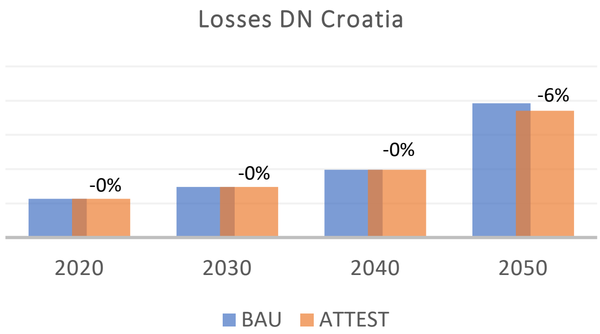

FIGURE 24 ENERGY LOSSES REDUCTION IN DISTRIBUTION NETWORKS IN CROATIA

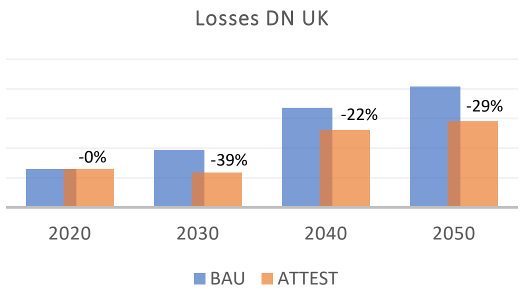

FIGURE 25 ENERGY LOSSES REDUCTION IN DISTRIBUTION NETWORKS IN THE UK

3.10. 10% energy losses reduction in transmission networks when compared with BaU strategies

This KPI was calculated with the outputs of the tool for ancillary services activation in real-time operation of the transmission network (Task 4.5). The energy losses were calculated for the years 2020, 2030, 2040, and 2050, for two scenarios – Business as Usual (BAU) and with the tools of ATTEST, for the three transmission networks available. Results are presented in the charts below:

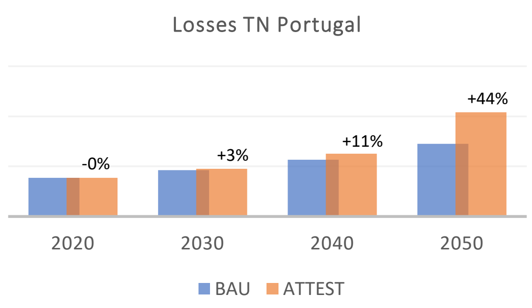

FIGURE 26 ENERGY LOSSES REDUCTION IN TRANSMISSION NETWORKS IN PORTUGAL

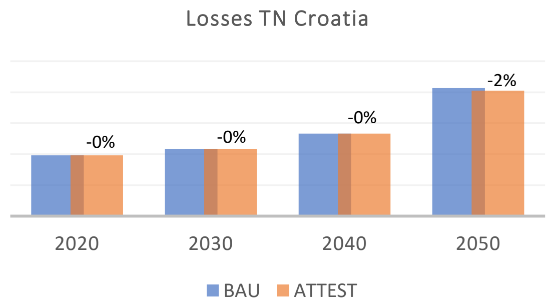

FIGURE 27 ENERGY LOSSES REDUCTION IN TRANSMISSION NETWORKS IN CROATIA

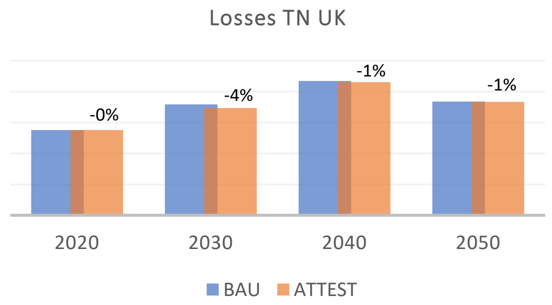

FIGURE 28 ENERGY LOSSES REDUCTION IN TRANSMISSION NETWORKS IN THE UK

In the Portuguese case, the energy losses increased due to the high number of new DER integrated at national level, which led to a very significant increase in the power flows in the transmission network.

3.11. Reduction of pollutants' emissions from electricity generation

ATTEST project proposed to achieve the following contributions with the tools developed in the project:

- 18% reduction in emissions with global warming potential (CO_2, CH_4, N_2O);
- 13% reduction in particulate matter emissions (PM, NO_x, SO_2);
- 12% reduction in emissions with human toxicity potential (heavy metals, hydrocarbons);
- 13% reduction in emissions that contribute to photochemical oxidant formation (NO_x, unburned hydrocarbons);
- 14% reduction in emissions with terrestrial acidification potential (NO_x, SO_2).

KPIs are calculated considering the ATTEST scenarios regarding the evolution of the electricity generation mix-up to 2050 and the associated integration of distributed energy resources. As the separation of environmental impacts per group of tools (operation and planning tools) was impossible to establish, it was decided to calculate these KPIs using the evolution of the power systems and the expected energy mixes. The full life cycle was considered in this analysis – this is the reason why some indicators worsen between 2020-2050, despite the higher share of renewables and the significant increase in electrification. Pollutants' emissions variations are shown in Figure 29 and Figure 30.

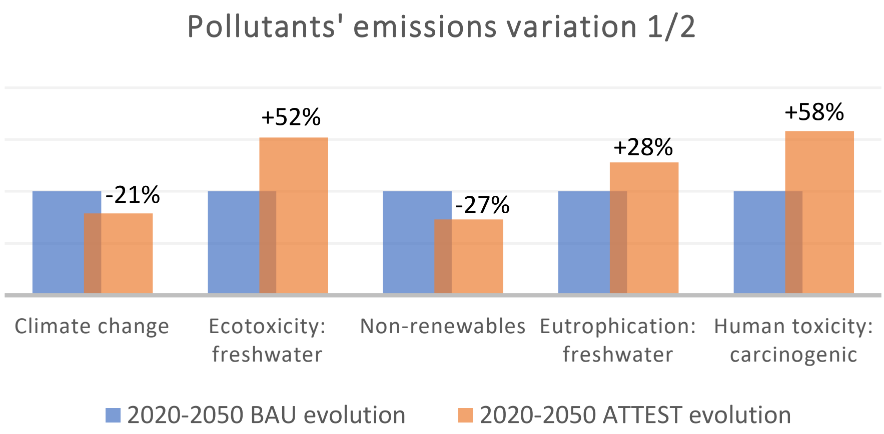

FIGURE 29 POLLUTANTS' EMISSIONS VARIATIONS 1

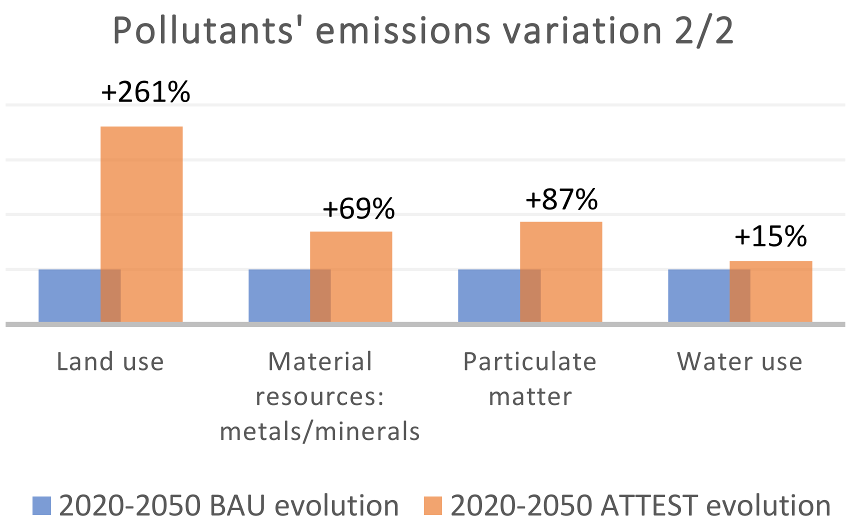

FIGURE 30 POLLUTANTS' EMISSIONS VARIATIONS 2

4. Open source tools to optimize networks planning

Six indicators were described in the proposal. All of them were successfully achieved:

1. 1 tool to optimize distribution networks planning (integrated in the "planning module" of the joint ICT platform)
2. 1 tool to optimize transmission networks planning (integrated in the "planning module" of the joint ICT platform)

3. 1 planning tool to optimize the location and size of assets shared between TSOs and DSOs (integrated in the "planning module" of the joint ICT platform)
4. 20% savings in the distribution networks planning CAPEX when compared with BaU strategies
5. 15% savings in the transmission networks planning CAPEX when compared with BaU strategies
6. Reduction of pollutants' emissions from electricity generation when compared with BaU in 2040 and 2050:
    - Reduction of 13% in 2040 and 16% in 2050 of the emissions with global warming potential (CO_2, CH_4, N_2O);
    - Reduction of 12% in 2040 and 15% in 2050 of the particulate matter emissions (PM, NO_x, SO_2, NH_3);
    - Reduction of 12% in 2040 and 14% in 2050 of the emissions with human toxicity potential (heavy metals, hydrocarbons);
    - Reduction of 12% in 2040 and 15% in 2050 of the emissions that contribute to photochemical oxidant formation (NO_x, unburned hydrocarbons);
    - Reduction of 13% in 2040 and 15% in 2050 of the emissions with terrestrial acidification potential (NO_x, SO_2).

4.1. One tool to optimize distribution networks planning

1 tool to optimize distribution networks planning was successfully integrated in the joint ICT platform:

- Optimization tool for distribution network planning (Task 3.1).

4.2. One tool to optimize transmission networks planning

1 tool to optimize distribution networks planning was successfully integrated in the joint ICT platform:

- Optimization tool for transmission network planning (Task 3.2).

4.3. One planning tool to optimize the location and size of assets shared between TSOs and DSOs

1 tool was successfully integrated into the joint ICT platform that defines an investment plan in shared energy storage systems to be installed per year and interface node (primary substation) between the transmission and distribution networks:

- Optimization tool for planning TSO/DSO shared technologies (Task 3.3).

4.4. 20% savings in the distribution networks planning CAPEX when compared with BaU strategies

This KPI was calculated with the outputs of the Optimization tool for distribution network planning (Task 3.1). The distribution networks CAPEX was calculated for the years 2030, 2040, and 2050, for two scenarios – Business as Usual (BAU) and with the tools of ATTEST, for the four distribution networks available. Results are presented in the charts below:

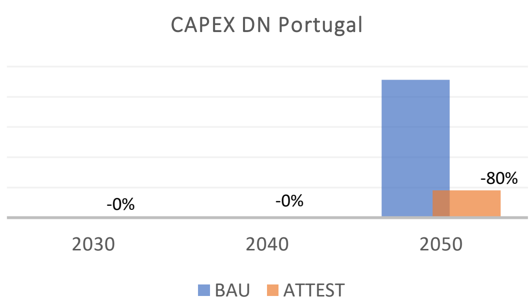

FIGURE 31 SAVINGS IN THE DISTRIBUTION NETWORKS PLANNING CAPEX IN PORTUGAL

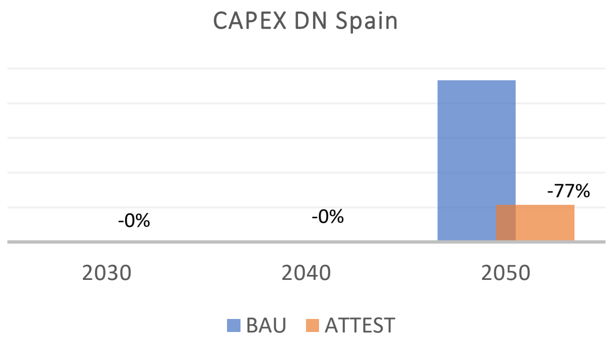

FIGURE 32 SAVINGS IN THE DISTRIBUTION NETWORKS PLANNING CAPEX IN SPAIN

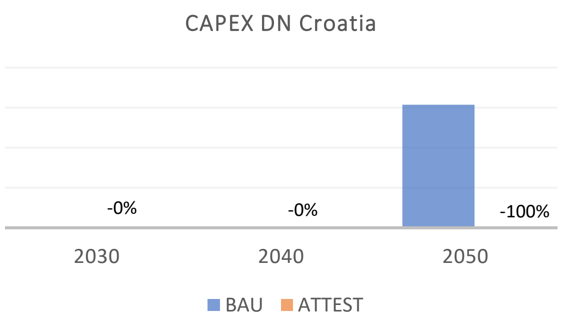

FIGURE 33 SAVINGS IN THE DISTRIBUTION NETWORKS PLANNING CAPEX IN CROATIA

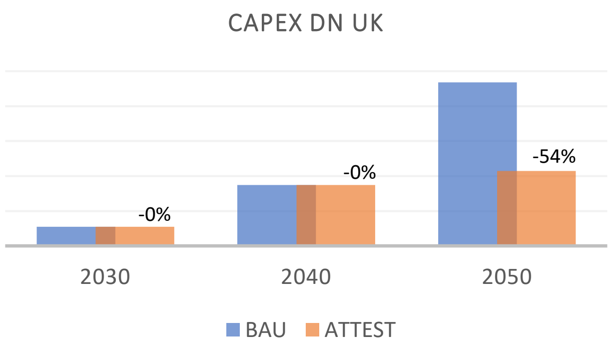

FIGURE 34 SAVINGS IN THE DISTRIBUTION NETWORKS PLANNING CAPEX IN THE UK

4.5. 15% savings in the transmission networks planning CAPEX when compared with BaU strategies

This KPI was calculated with the outputs of the Optimization tool for transmission network planning (Task 3.2). The transmission networks CAPEX was calculated for the years 2030, 2040, and 2050, for two scenarios – Business as Usual (BAU) and with the tools of ATTEST, for the three transmission networks available. Results are presented in the charts below:

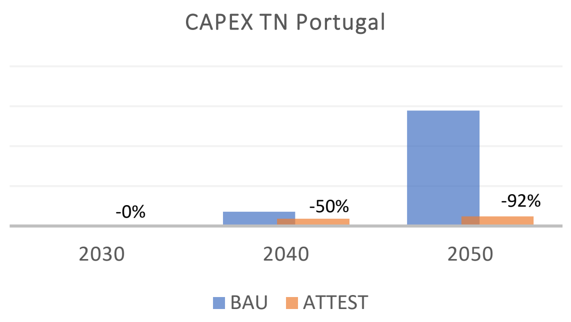

FIGURE 35 SAVINGS IN THE TRANSMISSION NETWORKS PLANNING CAPEX IN PORTUGAL

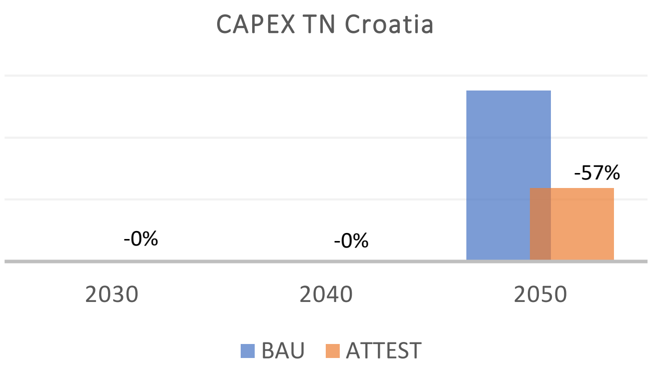

FIGURE 36 SAVINGS IN THE TRANSMISSION NETWORKS PLANNING CAPEX IN CROATIA

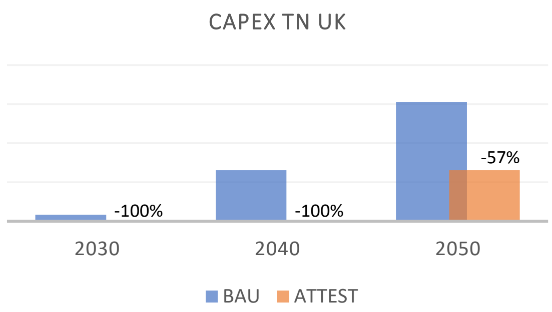

FIGURE 37 SAVINGS IN THE TRANSMISSION NETWORKS PLANNING CAPEX IN THE UK

4.6. Reduction of pollutants' emissions from electricity generation in 2040 and 2050

Pollutants' emissions variations are shown in Figure 29 and Figure 30.

5. Open source tools to optimize assets maintenance

Four contributions were highlighted in the proposal:

1. 3 tools to optimize assets management in distribution/transmission networks
2. 1 common "life indicator" defined for heterogeneous assets
3. 15% savings in assets maintenance in distribution networks when compared with BaU strategies
4. 15% savings in assets maintenance in transmission networks when compared with BaU strategies

Two of them were completely achieved, while two of them partially. A detailed description is provided below.

5.1. Three tools to optimize assets management in distribution/transmission networks

Three tools to optimize assets management are successfully integrated in the joint ICT platform:

- Tool for the characterization of the condition of assets (Task 5.1),
- Tool for the definition of condition indicators based on heterogeneous information sources (Task 5.2,
- Tool for the definition of smart asset management strategies (Task 5.3).

5.2. One common "life indicator" defined for heterogeneous assets

One "total indicator" is calculated for each power grid asset. This KPI provides a quantifiable measure of the overall condition of the assets: a value between 0 and 1, where 0 represents the best condition and 1 the worst. The Tool for the definition of condition indicators based on heterogeneous information sources (Task 5.2) also estimates the condition of the entire power grid by calculating the mean value of the condition indicators obtained from all the power grid assets for 2020, 2030, 2040, and 2050. This KPI enables a comprehensive evaluation of the power grid condition over time, as well as the identification of areas that need improvement.

5.3. 15% savings in assets maintenance in distribution networks when compared with BaU strategies

This KPI was calculated with the outputs of the tools:

- Tool for the characterization of the condition of assets (Task 5.1),
- Tool for the definition of condition indicators based on heterogeneous information sources (Task 5.2),
- Tool for the definition of smart asset management strategies (Task 5.3).

Due to the difficulty in collecting the costs of specific asset management actions, this KPI was not calculated as described in the Grant Agreement. Still, asset conditions were calculated ("total indicator" described in Subsection 5.2) with and without implementing the tool's results, but it was not possible to calculate the costs associated with asset management actions. Therefore, only the assets conditions are presented in the charts below for the years 2020, 2030, 2040 and 2050, for three scenarios:

- “Without_flex” – Business as Usual,
- “With_flex” – considering the output of the ATTEST operation tools but without considering the outputs of the WP5 tools,
- “With_flex (WP5) – considering both the output of the ATTEST operation tools and the outputs of the WP5 tools.

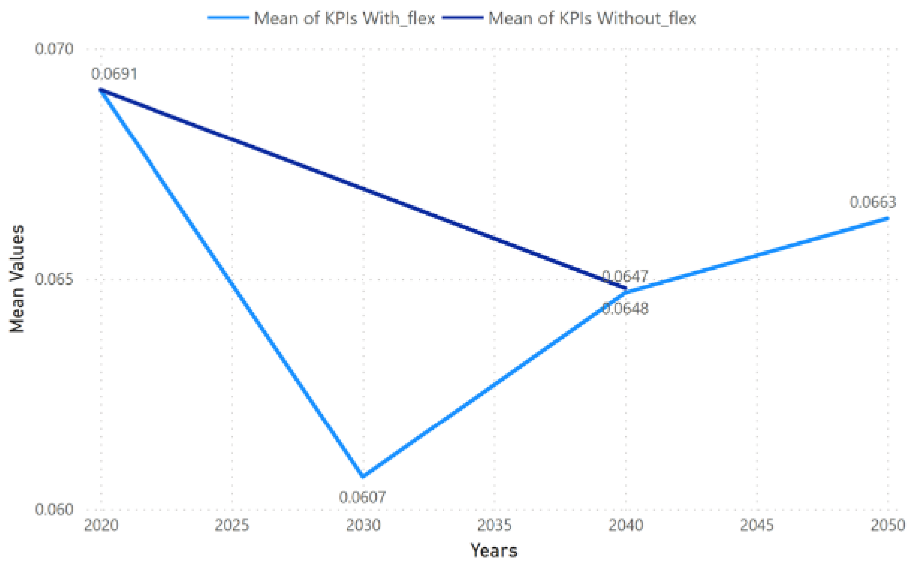

FIGURE 38 COMPARISON OF MEAN VALUES OF LIFE ASSESMENT OF ASSETS IN PORTUGAL

KPI values below 0.25 in Figure 38 indicate that the assets are in good condition, functioning effectively without special asset management efforts different from those applied in the current asset management and maintenance plans. KPIs have not been calculated with WP5 tools due to their extremely low values, signifying that all assets are in good condition and do not require any special recommendations. Scenarios 2030 and 2050 do not have values due to power flow convergence problems.

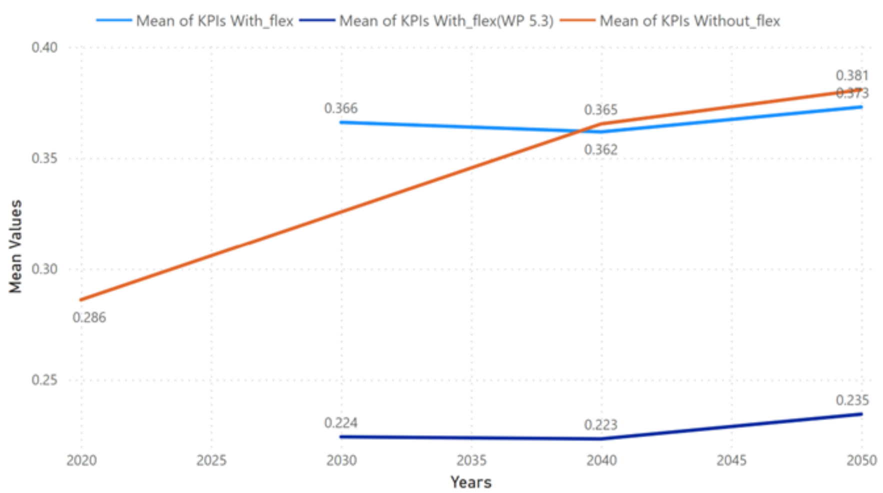

FIGURE 39 COMPARISON OF MEAN VALUES OF LIFE ASSESMENT OF ASSETS IN CROATIA

KPI values below 0.25 in Figure 39 indicate that the assets are in good condition and functioning effectively without needing special maintenance efforts different from those in the current maintenance plan. However, in this case, there are certain assets with KPI values higher than 0.75, meaning a very different condition with respect to most assets. This suggests paying special attention to these assets and to their maintenance. Some KPIs were not possible to estimate due to power flow convergence problems. In general, the condition of the assets will be stressed over time due to the growing load profiles in the assets. If the asset management actions recommended with WP5 tools are implemented, the mean value of the KPIs should improve by approximately 1/3.

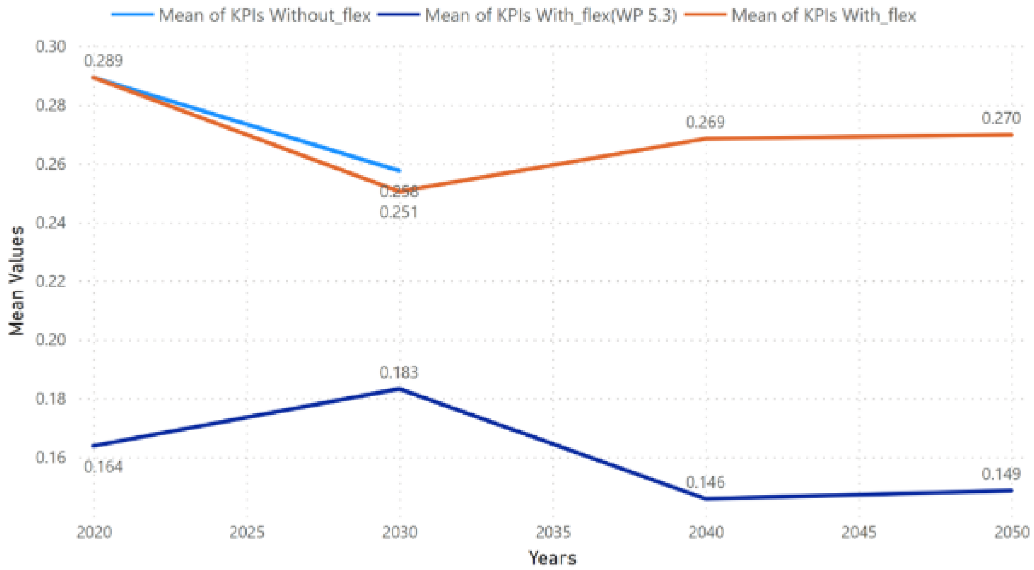

FIGURE 40 COMPARISON OF MEAN VALUES OF LIFE ASSESMENT OF ASSETS IN THE UK

The mean values of the KPIs in Figure 40 are below 0.25, meaning that the assets are generally in good condition. There are some assets whose KPI values exceed 0.75, suggesting that they are more stressed than most of the other assets and should be under special attention from an asset management point of view. As in the previous case, if the recommendations from WP5 tools are implemented, an improvement in the KPI is expected. Some KPIs were not possible to estimate due to power flow convergence problems.

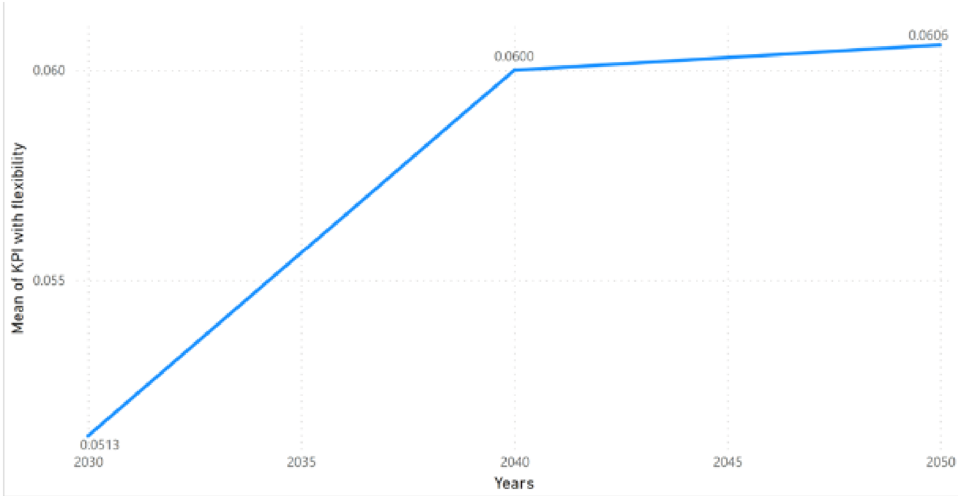

FIGURE 41 COMPARISON OF MEAN VALUES OF LIFE ASSESMENT OF ASSETS IN SPAIN

The case shown in Figure 41 had power flow convergence problems in most part of the cases studied. The recommendations of actions from WP5 tools were not estimated due to the extremely low values of the KPIs observed. According to the values obtained for the KPIs, the current asset management strategy is sufficiently effective to be continuously applied in the future.

5.4. 15% savings in assets maintenance in transmission networks when compared with BaU strategies

This KPI was calculated with the outputs of the tools:

- Tool for the characterization of the condition of assets (Task 5.1),
- Tool for the definition of condition indicators based on heterogeneous information sources (Task 5.2),
- Tool for the definition of smart asset management strategies (Task 5.3).

Similar to Subsection 5.3, due to the difficulty in collecting the costs of specific asset management actions, this KPI was not calculated as described in the Grant Agreement. Still, asset conditions were calculated ("total indicator" described in Subsection 5.2) with and without implementing the tool's results, but it was not possible to calculate the costs associated with asset management actions.

Therefore, only the assets conditions are presented in the charts below for the years 2020, 2030, 2040, and 2050, for three scenarios:

- "Without_flex" – Business as Usual,
- "With_flex" – considering the output of the ATTEST operation tools but without considering the outputs of the WP5 tools,
- "With_flex (WP5) – considering both the output of the ATTEST operation tools and the outputs of the WP5 tools.

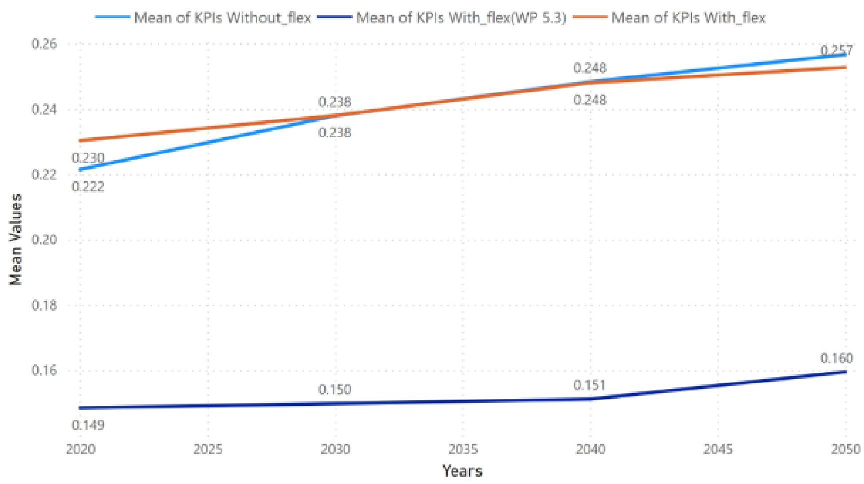

FIGURE 42 COMPARISON OF MEAN VALUES OF LIFE ASSESMENT OF ASSETS IN TRANSMISSION NETWORK IN PORTUGAL

The values observed in Figure 42 suggest continuing to apply the resources used in the current maintenance and asset management plans. However, some assets in the study have KPI values higher than 0.75, meaning a worse condition than most part of the assets. They should be monitored carefully or replaced as soon as possible. Implementing the actions suggested by WP5 tools should improve the KPIs, demonstrating the enhanced condition of the assets after accepting the recommended management actions. Over time, the increasing trend observed in all the cases is due to the growing profile of loads in the assets that will stress their lives.

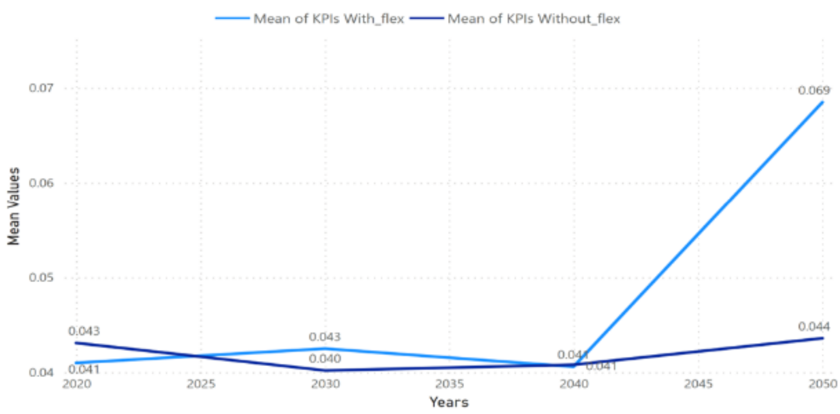

FIGURE 43 COMPARISON OF MEAN VALUES OF LIFE ASSESMENT OF ASSETS IN TRANSMISSION NETWORK IN CROATIA

The KPIs with the WP5 tools in Figure 43 were not calculated for this case due to their extremely low values, signifying that the assets do not require any different asset management strategy than the one that is currently applied. It is important to note that for the scenario 2050, an important change in the health condition of the assets is expected with respect to the previous periods. This is due to a significant increase in the load.

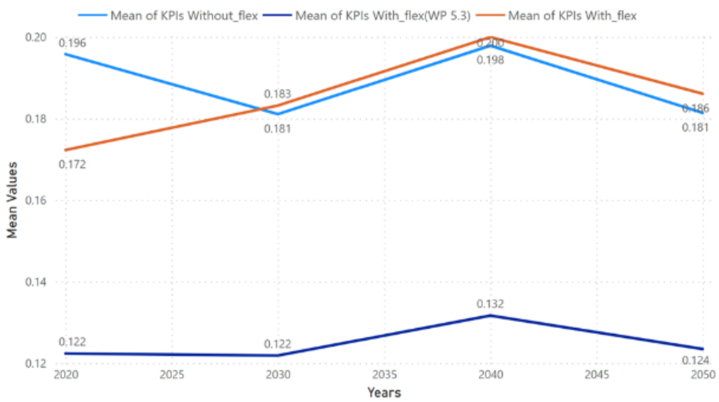

FIGURE 44 COMPARISON OF MEAN VALUES OF LIFE ASSESMENT OF ASSETS IN TRANSMISSION NETWORK IN THE UK

The KPI mean values in Figure 44 are below 0.25, meaning that most of the assets are not stressed and the current asset management strategy is effective to keep these values over time. In 2040, the KPI mean value is higher compared to values in 2030 and 2050. This could be attributed to a higher distribution of loads in some zones of the power grid that can cause more stress to the assets. If the actions suggested by WP5 tools are applied, the KPIs obtained are lower, keeping the assets in a better health condition.

6. Demonstration of the joint ICT platform operating in a real-world environment

Contributions and ad-hoc indicators showing the efficiency of the joint ICT platform operating in a real-world environment were defined in the proposal. Their detailed descriptions and achievements are provided in the subsections below.

6.1. One demonstrator with the joint ICT platform

The ATTEST ICT platform was replicated for the Croatian demonstrator with the network of Koprivnica and the neighboring region.

6.2. Five tools from the “operation module” tested in the demonstrator

This KPI was partially achieved, because three tools of the “operation module” are implemented in the Croatian demonstrator:

- Tool for ancillary services activation in real-time operation of the distribution network (Task 4.2),
- Tool for state estimation of distribution networks (Task 4.3),
- Tool for ancillary services activation in real-time operation of the transmission network (Task 4.5).

6.3. Three tools from the “planning module” tested in the demonstrator

This KPI is completely achieved. Three tools of the “planning module” are tested with the Croatian demonstrator network:

- Optimization tool for distribution network planning (Task 3.1),
- Optimization tool for transmission network planning (Task 3.2),
- Optimization tool for planning TSO/DSO shared technologies (Task 3.3).

6.4. One tool from the “asset management” tested in the demonstrator

This KPI is completely achieved. Three tools of the “asset management module” are tested with the Croatian demonstrator network:

- Tool for the characterization of the condition of assets (Task 5.1),
- Tool for the definition of condition indicators based on heterogeneous information sources (Task 5.2),
- Tool for the definition of smart asset management strategies (Task 5.3).

6.5. 15 visualization tools tested in the demonstrator (GUIs)

18 visualization tools are available in the ATTEST platform:

- 1 for the entire platform,
- 3 for the networks visualization (table view and diagram view – full network or substations),
- 3 for the modules (planning, operation, and asset management),
- 3 for the planning tools,
- 5 for the operation tools,
- 3 for the asset management tools.

However, only three operational tools operate with real-time data:

- Tool for ancillary services activation in real-time operation of the distribution network (Task 4.2),
- Tool for state estimation of distribution networks (Task 4.3),
- Tool for ancillary services activation in real-time operation of the transmission network (Task 4.5).

The remaining tools operate with network static data uploaded to the ATTEST platform.

6.6. Two real databases linked in real-time with the joint ICT platform

3 real databases linked in real-time with the ATTEST platform in the demonstrator:

- 2 data sources from the Croatian DSO and
- 1 data source from the Croatian TSO.

6.7. One transmission network fully represented in the platform with data in real-time

Part of the Croatian transmission network was successfully represented and integrated in the ATTEST platform.

6.8. Two distribution networks fully represented in the platform with data in real-time

Three MV feeders from the region of Koprivnica are fully represented in the platform with data in real-time.

6.9. Reduction of pollutants' emissions from electricity generation, during the demonstration, due to optimal networks operation, when compared with BaU

Reduction of pollutants' emission provided in the proposal for 2020 in demonstration phase are listed below:

- 6% reduction in emissions with global warming potential (CO_2, CH_4, N_2O);
- 4% reduction in particulate matter emissions (PM, NO_x, SO_2, NH_3);
- 3% reduction in emissions with human toxicity potential (heavy metals, hydrocarbons);

- 3% reduction in emissions that contribute to photochemical oxidant formation (NOx, unburned hydrocarbons);
- 4% reduction in emissions with terrestrial acidification potential (NOx, SO2).

Reduction of pollutants' emission provided in the proposal for 2030 in the demonstration are listed below:

- 18% reduction in emissions with global warming potential (CO_2, CH_4, N_2O);
- 13% reduction in particulate matter emissions (PM, NO_x, SO_2, NH_3);
- 12% reduction in emissions with human toxicity potential (heavy metals, hydrocarbons);
- 13% reduction in emissions that contribute to photochemical oxidant formation (NO_x, unburned hydrocarbons);
- 14% reduction in emissions with terrestrial acidification potential (NOx, SO2).

In the demonstration the same results are achieved as presented in Figure 29 and Figure 30.

6.10. 10% savings in the distribution networks planning CAPEX during the demonstration when compared with BaU strategies

This KPI was calculated with the outputs of the Optimization tool for distribution network planning (Task 3.1). The distribution network CAPEX was calculated for the years 2030, 2040, and 2050, for two scenarios of the Croatian system – BaU and with the tools of ATTEST, for the Koprivnica distribution network. Results are presented in the chart below:

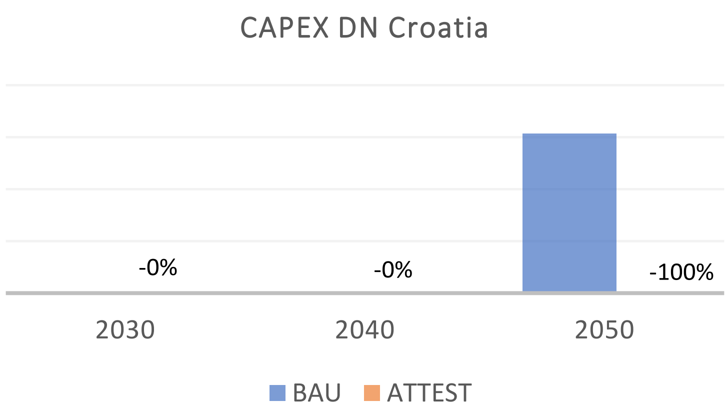

FIGURE 45 SAVINGS IN DISTRIBUTION NETWORK PLANNING CAPEX IN CROATIA

6.11. 5% savings in the transmission network planning CAPEX during the demonstration when compared with BaU strategies

This KPI was calculated with the outputs of the Optimization tool for transmission network planning (Task 3.2). The transmission networks CAPEX was calculated for the years 2030, 2040, and 2050, for two scenarios of the Croatian system – Business as Usual (BAU) and with the tools of ATTEST, for the Koprivnica transmission network. Results are presented in the chart below:

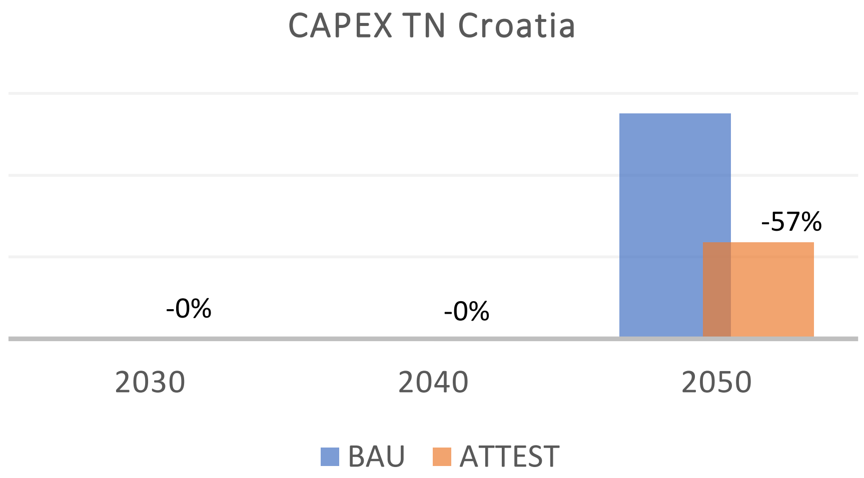

FIGURE 46 SAVINGS IN TRANSMISSION NETWORK PLANNING CAPEX IN CROATIA

6.12. 10% savings in assets maintenance in distribution networks during the demonstration when compared with BaU strategies

This KPI was calculated with the outputs of the tools:

- Tool for the characterization of the condition of assets (Task 5.1),
- Tool for the definition of condition indicators based on heterogeneous information sources (Task 5.2),
- Tool for the definition of smart asset management strategies (Task 5.3).

Due to the difficulty in collecting the costs of specific asset management actions, this KPI was not calculated as described in the Grant Agreement. Still, asset conditions were calculated ("total indicator" described in Subsection 5.2) with and without implementing the tool's results, but it was not possible to calculate the costs associated with asset management actions.

Therefore, only the assets conditions are presented in the chart below for the years 2020, 2030, 2040, and 2050, for three scenarios:

- "Without_flex" – Business as Usual,
- "With_flex" – considering the output of the ATTEST operation tools but without considering the outputs of the WP5 tools,
- "With_flex (WP5) – considering both the output of the ATTEST operation tools and the outputs of the WP5 tools.

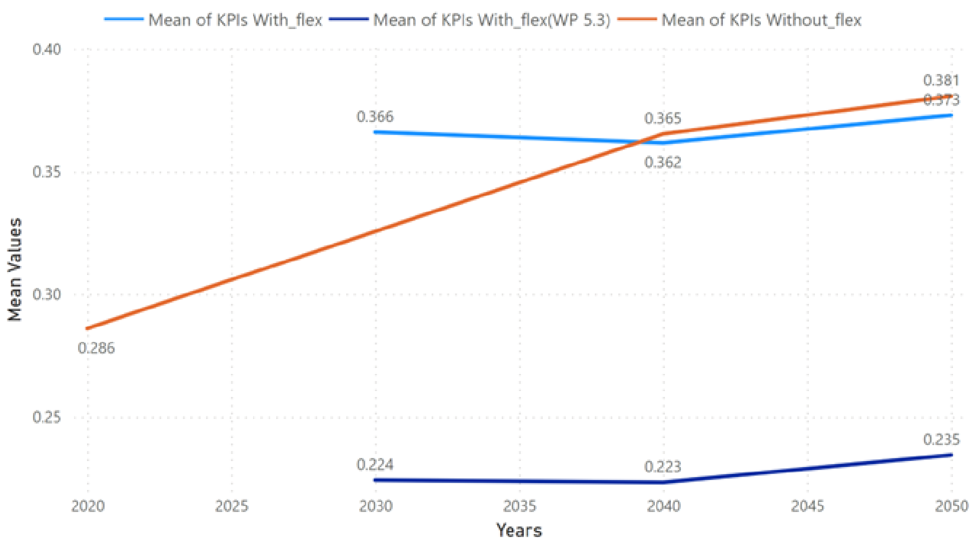

FIGURE 47 MEAN VALUES OF ASSET CONDITIONS IN KOPRIVNICA DISTRIBUTION NETWORK OVER THE YEARS

KPI values below 0.25 in Figure 47 typically indicate that the assets are in good condition and functioning effectively without needing special maintenance efforts different from those in the current maintenance plan. However, in this case, there are certain assets with KPI values higher than 0.75, meaning a very different condition with respect to most assets. This suggests paying special attention to these assets and to their maintenance. Some KPIs were not possible to estimate due to power flow convergence problems. In general, the condition of the assets will be stressed over time due to the growing load profiles in the assets. If the asset management actions recommended with WP5 tools are implemented, the mean value of the KPIs should improve by ca. 1/3.

6.13. 5% savings in assets maintenance in transmission networks during the demonstration when compared with BaU strategies

This KPI was calculated with the outputs of the tools:

- Tool for the characterization of the condition of assets (Task 5.1),
- Tool for the definition of condition indicators based on heterogeneous information sources (Task 5.2),
- Tool for the definition of smart asset management strategies (Task 5.3).

Due to the difficulty in collecting the costs of specific asset management actions, this KPI was not calculated as described in the Grant Agreement. Still, asset conditions were calculated (“total indicator” described in Subsection 5.2) with and without implementing the tool's results, but it was not possible to calculate the costs associated with asset management actions.

Therefore, only the assets conditions are presented in the chart below for the years 2020, 2030, 2040, and 2050, for three scenarios:

- “Without_flex” – Business as Usual,
- “With_flex” – considering the output of the ATTEST operation tools but without considering the outputs of the WP5 tools,

- "With_flex (WP5) – considering both the output of the ATTEST operation tools and the outputs of the WP5 tools.

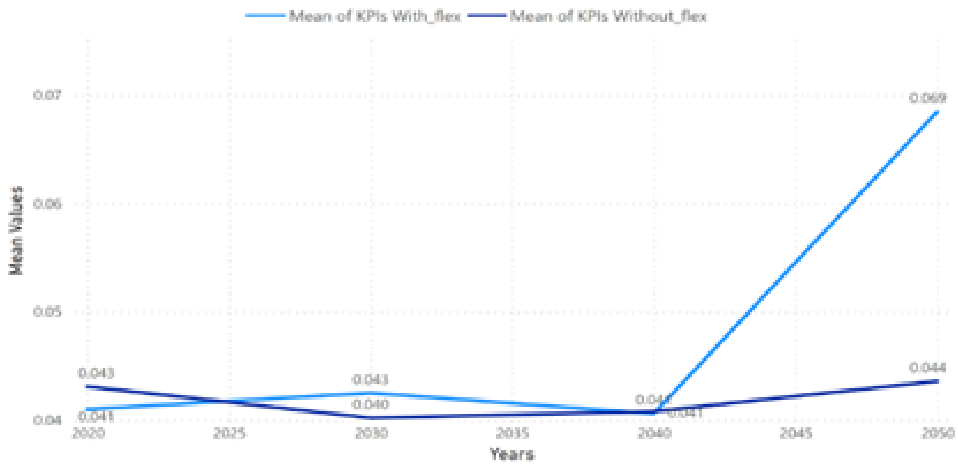

FIGURE 48 MEAN VALUES OF ASSET CONDITIONS IN KOPRIVNICA TRANSMISSION NETWORK OVER THE YEARS

The KPIs in Figure 48 with the WP5 tools were not calculated for this case due to their extremely low values, signifying that the assets do not require any different asset management strategy than the one that is currently applied. It is important to note that for the scenario 2050, an important change in the health condition of the assets is expected with respect to the previous periods. This is due to a significant increase in the load.

6.14. Not achieved KPIs

Due to technical impediments related to the safe operation of the networks involved in the demonstration, the consortium was only allowed to provide the results of the tools to the network operators in a decision-support fashion. No actual control over the network equipment was allowed through the platform. Because of this, the following proposed contributions were not achieved:

• 55 primary substation OLTC transformers and 1 PS transformer in TS Senj + voltage regulation in power plants controlled in real-time through the platform (from the primary substation in the demonstrator),

• 1 primary substation OLTC+ topology of 35 kV and parts of 10 and 20 kV network + 3 10 kV capacitor banks + 1 DG unit controlled in real-time through the platform (from the distribution network in the demonstrator),

• 1 flexible client in the transmission network controlled in real-time through the platform,

• 2 flexible clients in the distribution network controlled in real-time through the platform.

6.15. Not calculated KPIs

In the current setup of the demonstration, there are no flexible loads that can be controlled, there are no operational gains that can be calculated from the tools integrated into the demonstrator. These KPIs were not calculated:

- 10% savings in the distribution networks OPEX during the demonstration when compared with BaU strategies,
- 5 % savings in the transmission networks OPEX during the demonstration when compared BaU strategies,
- 40% reduction in the over/under voltages occurrence in distribution networks during the demonstration compared with BaU strategies,
- 20% reduction in the over/under voltages occurrence in transmission networks during the demonstration when compared with BaU strategies,
- 40% reduction in the branches overloading occurrence in distribution networks during the demonstration when compared with BaU strategies,
- 10% reduction of the branches overloading occurrences in transmission networks in case of contingencies N-1 during the demonstration when compared with BaU strategies,
- 10% energy losses reduction in distribution networks when compared with BaU strategies,
- 5% energy losses reduction in transmission networks when compared with BaU strategies.

7. Conclusion

This deliverable focuses on the impact assessment to quantitatively assess the benefits from the implementation of the overall ATTEST solution as well as to evaluate the impact of the individual tools, not only for the Croatian demonstrator but also for several networks included in the test cases from WP2.

To assess the performance of the tools developed in the project and the overall ATTEST solution, this deliverable compares contributions and ad-hoc indicators defined in the Grant Agreement with the results of the project achieved by using tools and methodologies developed in the project. Key Performance Indicators are calculated with the tools developed in the project addressing an economic, technical, and environmental perspective.

51 KPIs are defined in the Grant Agreement. 28 KPIs were successfully achieved (almost 55%), 10 of them are partially achieved (19.6%), 5 are not achieved (9.8%), and 8 are not calculated (15.7%).

The calculation of some KPIs was severely affected by power flow convergence problems, which resulted from the massive integration of DER, such as KPI related to the savings in the distribution network OPEX.

When it comes to the reduction of pollutant emissions from electricity generation, a full life cycle was considered in the analysis. Because of that, some indicators worsen between 2020-2050, despite the higher share of renewables and the significant increase in electrification.

Due to the difficulty in collecting the costs of specific asset management actions, the KPIs related to savings in asset maintenance in distribution and transmission networks were not calculated as described in the Grant Agreement. Still, asset conditions were calculated as the “total indicator” with and without implementing the tool's results.

Due to technical impediments related to the safe operation of the networks involved in the demonstration, the consortium was only allowed to provide the results of the tools to the network operators in a decision-support fashion. No actual control over the network equipment was allowed through the platform, which implies that 4 KPIs related to the demonstration of the platform could not be achieved. In the current setup of the demonstration, there are no flexible loads that can be controlled, there are no operational gains that can be calculated from the tools integrated into the demonstrator resulting in 8 not calculated KPIs.