D.T.2.3.6 IMPROVED VERSION OF OPERATIVE TOOLS AND PROCEDURES: VALIDATION OF 5 TESTED MODELS BY SC

Project Title: REEF2W Increased renewable energy and energy efficiency by integrating, combining and empowering urban wastewater and organic waste management systems

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Submission Date: 01/2020

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Abbreviations

WWTP	Wastewater treatment plants
LCA	Life Cycle Assessment

1. Introduction

1.1. REEF 2W project

In the wake of the energy transition an increased focus is concentrating on the yet unexploited energy-saving potential of the solid waste and wastewater sector. Wastewater treatment plants (WWTPs) are large consumers of energy and make key contributions to the carbon footprint of municipalities and urban governments. Their energy consumption usually accounts for the bulk of operational costs of wastewater utilities, sometimes up to 60 per cent. However, despite being a large source of electricity and heat, sewage is generally overlooked. In fact, the amount of energy it contains can be 10 times bigger than what is required to treat it. Lately an increasing number of utilities have deployed energy-efficiency measures and novel technologies to better harness the energy of sewage. Evaluations of pioneering projects show that utilities are not only capable of becoming energy self-sufficient, but also suppliers of energy thereby diversifying the local mix.

The project Reef 2W recognizes that waste plays a key role in transforming energy systems. The project is funded by the European Development Bank's Interreg Central Europe Programme and is carried out through 11 research institutes and wastewater utilities from Italy, Czech Republic, Germany, Croatia, and Austria. The project's main objective is to drive up energy efficiency and renewable energy production in solid waste and wastewater facilities. It focuses on solutions that integrate organic waste and waste streams and infrastructures. Where beneficial, bio-waste will be used to enrich sewage sludge, helping to elevate outputs of heat and electricity in a process called co-digestion. To prove that the new technologies can be technically feasible and make economic viable, project partners have developed a comprehensive assessment tool in close collaboration with utility operators in a series of workshops, which will be the focus of this study. Another key task of Reef 2W is to investigate the legal and policy framework conditions and to advocate for policy alternatives that spur the large-scale use of wastewater-to-energy solutions.

1.2. Scope of deliverable

The purpose of this deliverable is to document the final version of the REEF 2W tool, which is based on the methodology of the Integrated Sustainability Assessment (ISA). Specifically, it will be shown how the tool has advanced from the first prototyp to the final version, thereby exhibiting both the progress made and yet remaining issues. The REEF 2W tool is one of the major outputs of the project and is interlinked with a variety of other deliverables. For example it will be used to conduct the feasibility studies (DT.2.3.1-5).

The tool was developed as part of DT.1.4.3. During the trainings in each of the pilot countries, feedback was gathered on how well it functions, how easy it is to use, and whether it is likely to be used in practice in its current form. This feedback was systematically evaluated as part of DT.2.2.2. Those project partners responsible for developing the tool subsequently selected a range of actions that would be implemented over the common weeks to improve the prototyp version.

The structure of the deliverable is as follows. First a brief overview on the tool is provided, introducing the four different components of the tool. Subject to analysis are as well the starting and results interface of the tool. Second for each of these six components a summary of feedback gathered at the trainings is provided. Third, it is described which of the agreed upon points of feedback has been implemented. Lastly its is evaluated which major possible improvements and changes remain yet undone before the analysis closes with a brief conclusion.

2. Backround: The Integrated Sustainability (ISA) methodology

The reporting on the progress made on each of these four components builds the major part of this deliverable.

The Integrated Sustainability Assessment (ISA) methodology can be used to systematically assess technical innovations for energy optimisation of wastewater treatment plants (WWTPs) on different sustainability criteria. The method is being developed as part of the REEF 2W project, which aims to make WWTPs more energy-efficient and help them to produce renewable energy. Here the focus is set on increasing biogas yields through co-fermentation with organic waste. The instrument allows for making predictions about potentials to improve energy performance, the technical feasibility or the environmental sustainability of the REEF 2W solutions.

2.1. THE 5 COMPONENTS OF THE REEF 2W Tool

The REEF 2W tool, which was developed as an Excel spreadsheet and online tool, comprises five core steps:

I: Energy efficiency is determined through a comparative analysis that measures current energy consumption against recognized efficiency standards. This benchmarking shows the optimization potential for heat and electricity savings.

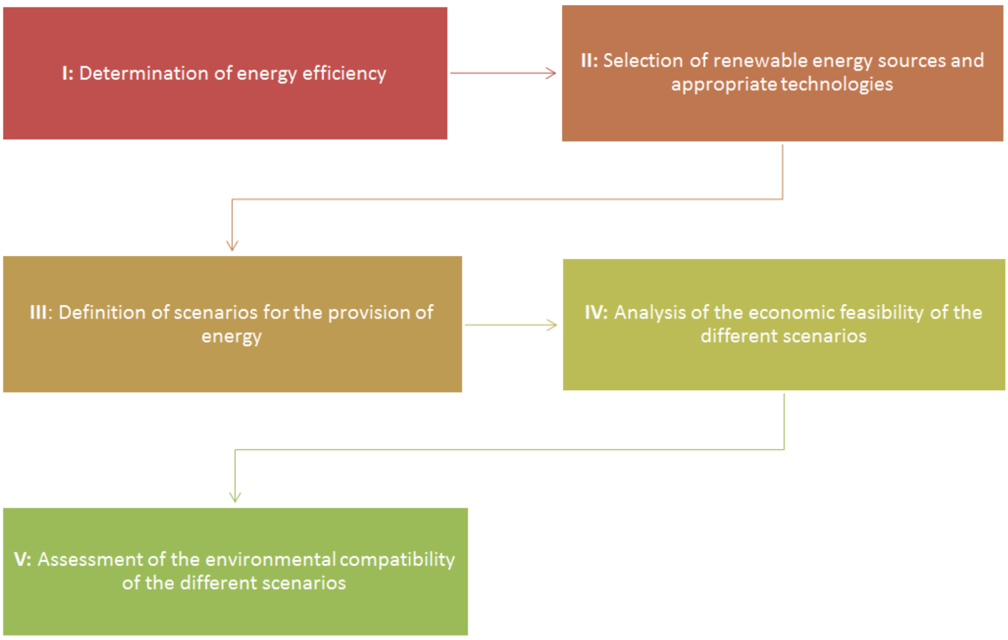

Figure 1: The five steps of the ISA method

II: Suitable technologies are selected through a potential analysis that compares different renewable energy sources. Emphasis in the project is set on improving heat and biogas yields while increasing the efficiency of subsequent uses such as biogas upgrading.

III: Different scenarios demonstrate how excess energy can be used for self-supply of the WWTP and feed-in into the gas, electricity and heat grid. These take into account the amount of available surplus energy, energy consumption and energy demand of neighbouring settlements as well as existing grid infrastructures.

IV: The economic feasibility assessment of planned measures will be carried out through a life-cycle cost analysis incorporating generated revenues from energy savings and sales, and investment and maintenance costs.

V: To assess the environmental impacts, a Life Cycle Assessment (LCA) focusing on CO_2-reduction potentials is carried out for each scenario.

In the REEF 2W tool, step I and II were later merged and are carried out jointly in this deliverable.

3. The tool'sfive core components

3.1. Starting Section (ENEA)

3.1.1. Summary of the Feedback

The first version of the Reef 2W tool was developed mainly based on the experience of the project team. This includes the calculation of the energy efficiency of a WWTP and the potential energy that can be recovered from available biomasses and other available or potential Renewable Energy Sources (RES). On the basis of this first version, potential end users have been requested in feedback rounds to evaluate the usability of the tool and its possible further implementations.

The first part of the tool includes not only those general information describing the tested treatment site and providing a first part of the evaluations, but it was include also the path that each user can follow accordingly to its available information or answer provided.

The tool was designed to provide a first assessment of the overall energy efficiency of the analysed plant in its current form (status quo). In a second section, it can instead, using further information provided by the user, describe one or more scenarios (future situation) to be compared with the status quo and technically evaluate the impacts.

During these feedback rounds, many helpful comments have been received, related to graphical aspects and the way the results of the tool are made available to users.

Sometimes, feedbacks received were contradictory, such as at the end of the trainings, where several participants asked for more detailed information on the one hand, but on the other hand also requested short explanation boxes to keep the reading effort low.

Not every valuable feedback was realizable. Reasons for this were for example, an excessively long implementation time, which would have exceeded the project time or it would have been necessary to link the REEF 2W tool with other existing tools. At the beginning of the project the project partners agreed on developing a self-sustaining tool without links to other external websites or software. This is due to the fact that external software or services are not under the control of the project team and thus may be modified causing problems for the tool or some of its parts. On the other hand, such an uncontrolled connection would further pose a problem for data security.

3.1.2. Implemented changes

One of the most significant changes was made to the graphical interface. Due to the poor design of the first version, it was feared that potential users would be deterred from using the tool at all. For this reason, the graphical interface of the first version was changed from a button-based interface to a more appealing, modern design. Figure 2 shows the graphical interface of the first version of the tool.

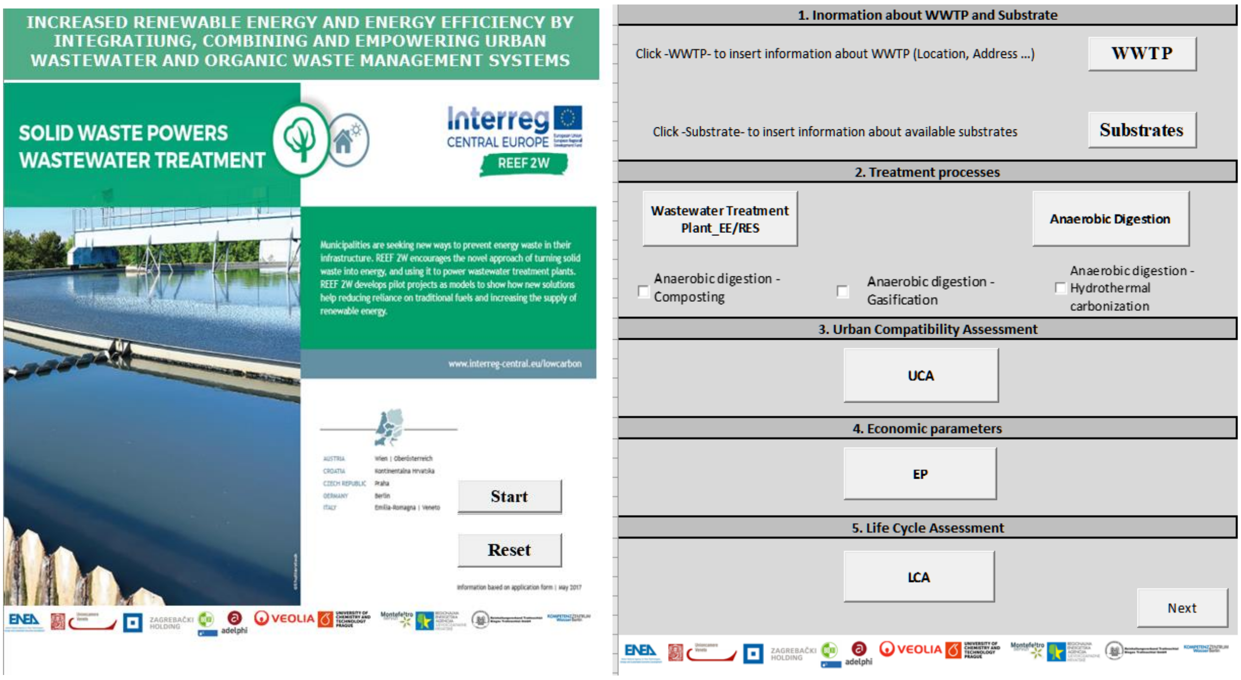

Figure 2: Graphical interface of the first version of the tool

According to the feedback received, the graphical interface of the tool was changed as shown in Figure 3 and Figure 4. One of the main changes are seen in Figure 4, where only one button is active—the coloured one. All the others will only become coloured when all information requested in the previous steps has been filled in. This was done to prevent the user from unintentionally forgetting single steps to complete.

All internal pages not reported in this deliverable have been modified consequently.

In order to inform the user about the scope of input data before the tool is started, a dialog box has been integrated between the home page and the first page of the tool, where the user is offered to print a blank report. This blank report will help the user to better collect the necessary information before starting to use the tool.

Another important aspect of the feedback received was that in the first version of the tool the language used was limited to English. In the new version it is now possible to choose between several languages. At the moment only languages spoken by the project partners are offered. In the future, it will be possible to implement any other language in the tool without any “structural” change, but just providing the translation of the labels or text-box. This will be possible due to an important change in the structure of the tool. In the first version, the tool was developed like a large and simple Excel file, whereas in the new version all technologies and decision trees are separated in specifics sheets. This new structure not only facilitates the integration of additional languages, but also the integration of new technologies and evaluations by simply adding a new sheet.

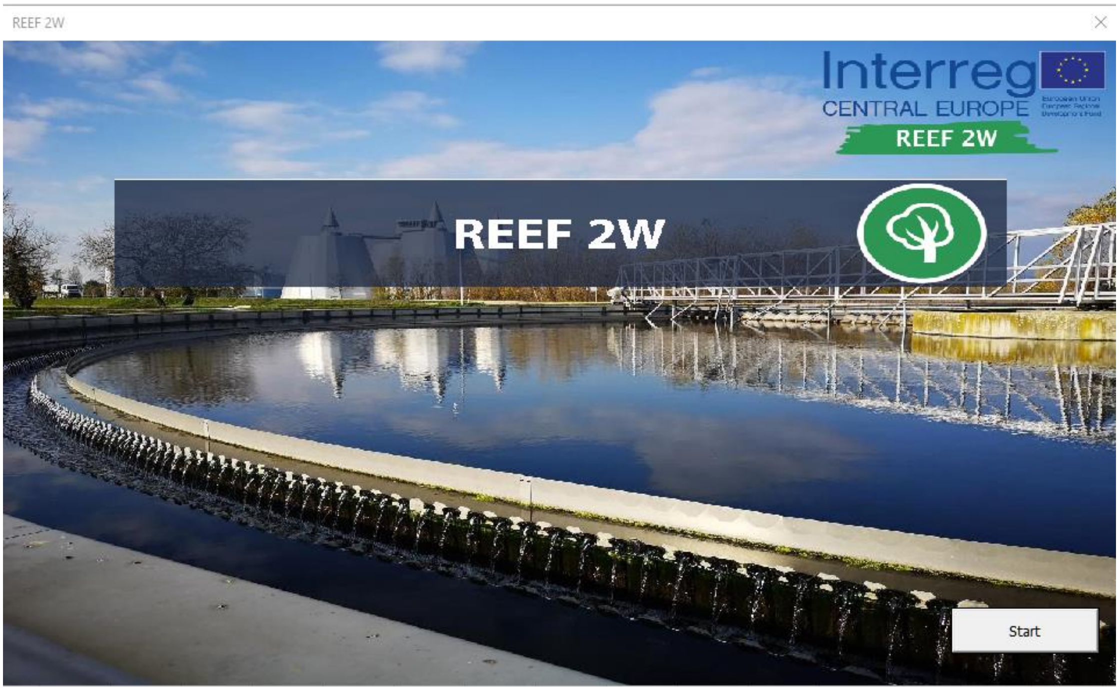

Figure 3: New home page of the Tool

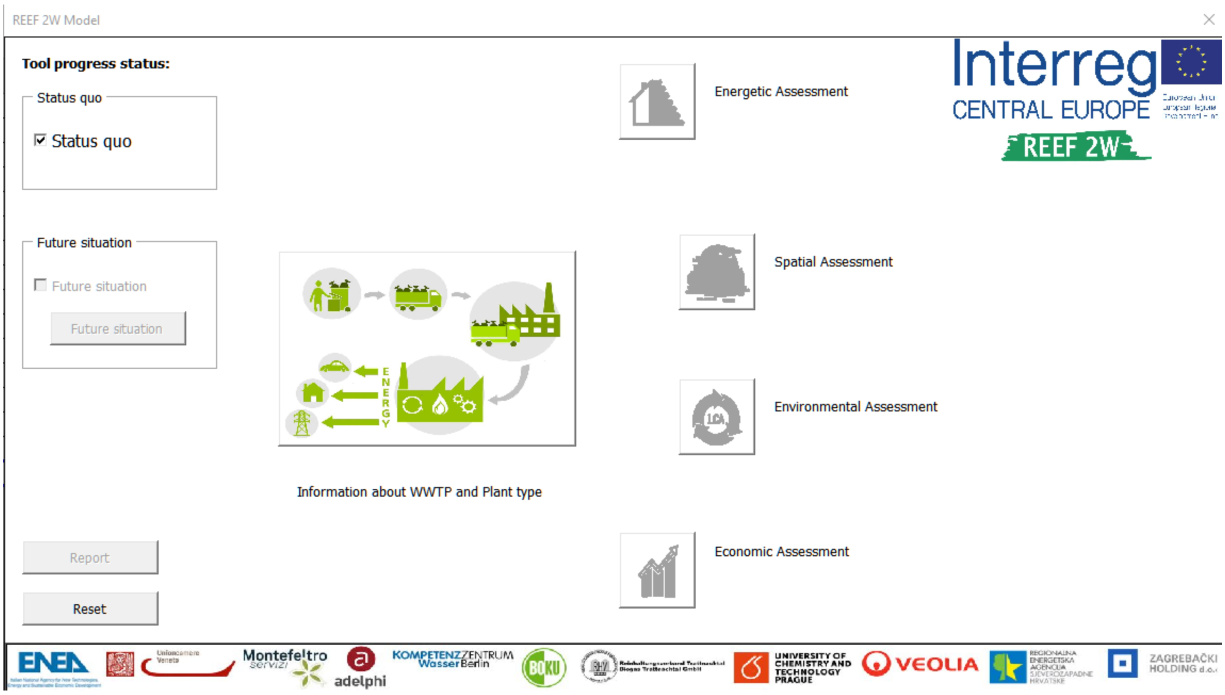

Figure 4: New starting page to provide information

Another relevant change that was made was to homogenize the units and remove any numerical information from the formulas used. This will make it easier to understand how a formula works and the meaning of the individual components of the formula. All numerical factors have been grouped on one sheet, together with additional explanations.

As the tool can be used by a wide range of users, from specialised technicians to policy makers, who might only have some rough information about WWTPs available, the possibility to tell the tool to calculate the performance parameters was integrated for the assessment of the status quo.

Furthermore, the amount of information requested from the user has been reduced. This was done in particular for the environmental assessment evaluation. In the first version of the tool, very detailed information was requested, some of which was not easy for the user to collect. As the environmental assessment is primarily aimed at a better understanding of possible carbon dioxide emissions generated by the technologies used and management applied, in the new version, most of these requests have been removed because they were too specific or because the information requested related to emergency technologies that were not always applied and were therefore difficult to evaluate even for the utilities.

Relevant changes were also implemented to the economic assessment, as also in this part of the tool the requested information was too detailed and the time required for the user too great. In the final version all values are given in €/kWh, so it is easier to understand the economic value of the item.

3.1.3. Remaining issues or deficits

At this moment, almost all comments have been considered and the tool is operating in all its parts. In cases where the opinions of the participants of the trainings on the implementation of the feedback differed, the project team voted and decided on the opinion of the majority.

Further improvements of the current version of the tool are planned. For example, the calculation of the potential electricity producible by photovoltaic panels are to be improved. This will further enhance the determination of the exact amount of energy that a WWTP is capable of producing.

3.2. Energy Efficicency Performance and Renewable Energy (BOKU)

3.2.1. Summary of the Feedback

1. There were several comments regarding the substrates list that was evaluated as unclear and too extensive. Some of the selected substrates were seen as not representative and several abbreviations were unclear. Some parameters' calculations were questioned. In detail, the following comments were obtained:
    a. The current list of substrates provided is not common (e.g. animal blood and wastes are rather exotic), others are missing (e.g. olive oil residues).
    b. Which sums of percentages have to be 100 %?

c. Unclear parameters: “fixed carbon”, “volatile matter” and “a.r.”

d. “Total solid” is not useful; instead “m^3 of sludge” and “organic percentage of sludge” should be inserted.

e. Some waste types need pre-treatment; this should be visible.

f. m^3/t gas output is not requested, how is it calculated?

g. The volume of total solids for secondary sludge must be smaller than for primary sludge (default).

h. The possibility of changing the organic loading rate is missing.

i. Default values are pseudo-precise.

2. Two technologies were missing:

   a. sludge drying (conventional, solar…)

   b. sludge incineration

3. Regarding the energy efficiency assessment of wastewater treatment plants, some minor clarifications were asked. The complexity of the sheet was considered too high and a technology was missing:

   a. There are too many parameters requested.

   b. DECAMAX (sludge heating with excess heat for dewatering) should be considered as additional technology.

   c. Is the temperature from wastewater or digestion expected?

   d. It is unclear what “total heated surface area” means.

4. Wind power is missing.

5. As for solar energy it was commented that the current tool does not allow to define the geographic location of the WWTP, although the solar irradiance is different for each site.

6. For heat pumps the following points were raised:

   a. Heat pumps should only be an optional upgrade.

   b. There should be different options for the user input: dimension (kW), temperatures: e.g. < 70°C (short distance heating) or > 70°C (district heating).

   c. (Bio)gas powered heat pumps should be an option (e.g. company ROBUR).

7. As for biogas, there was a request to add a further technology. Furthermore, some clarifications were needed. In detail, the received comments were as follows:

   a. Grid feed-in: If a number is missing in the status quo and a future case has a number, a warning should be displayed.

b. Where is electricity from biogas displayed/used in the tool?

c. How is the biogas production calculated for the actual and future situation?

d. Add amine scrubbing technology for upgrading (relatively common in Germany).

e. Upgrading: the status quo and future situation are given in "%", however, it should be possible to use (Nm^3/h). Therefore, the current total biogas production of the WWTP should be incorporated and shown in the respective table.

8. Power to Gas should be selectable like other technologies; the tool does not yet offer a future scenario for this technology.

3.2.1. Implemented changes

1a. The substrates list has been redesigned; only primary and secondary sludge as well as external sewage sludge are shown by default. All other substrates can be now chosen by a dropdown menu.

1e. A message window was implemented that informs about necessary pre-treatment of certain waste fractions.

1i. There are no default values given anymore in the substrates list.

3d. "Total heated surface area" is now called "floor area".

6c. (Bio)gas heat pumps are now implemented as additional option.

3.2.2. Remaining issues or deficits

1d. "Total solid" still exists, the calculation via m^3 of sludge and organic percentage of sludge was/could not implemented so far.

4. It is not possible to assess the wind energy potential by combining easily accessible parameters, as the distance requirements vary from region to region and the topology around the wastewater treatment plant is a complex but decisive issue.

5. It is possible to obtain local specific solar irradiation data, but until now there is no implementation of this issue in the tool.

8. Future scenarios are about to be implemented in general into the REEF 2W tool.

Those remarks considered neither in 3.2.2 nor 3.2.3 are still being reviewed by the tool programmers. Related feedback on the progress of the tool implementation is outstanding.

3.3. Spatial Assessment (former Urban Compatibility Assessment) (BOKU)

3.3.1. Summary of the Feedback

The gathered feedback, especially from DT.2.2.2, was helpful to improve the systematic and the usability of the tool (former “Urban compatibility assessment”, now labelled “Spatial Assessment”). In order to deduce a comprehensible overview, the provided feedback is broken down and summarised in the following bullet points:

- One part of the feedback suggests to consider the energy demand in the vicinity of the WWTP on a higher temporal resolution. Since the heating demand during winter is higher compared to the summer period (seasonal variations) it was recommended to provide an evaluation on the basis of monthly values.
- It was also suggested to consider the catchment area of the co-substrate supply for renewable energy generation at the WWTP.
- Another vital feedback was to provide a comparison between the (renewable) excess energy available from the WWTP and the energy demand in the vicinity of the WWTP. In other words, the tool should show how much of the excess energy from the WWTP could be used by potential energy consumers in the vicinity of the WWTP.
- In order to facilitate the decision on which type of energy consumer (or corresponding settlement type) to select for the spatial assessment, the following suggestions were given:
    - The illustrations/figures of the different types of energy consumers (e.g. village centre, multi-storey buildings etc.) lack of proper titles/descriptions. It was suggested, to implement the title within or next to the illustrations.
    - Additionally, a comparison between two illustrations/pictures should be given. This would facilitate the decision which type of energy consumer or settlement type to choose.
    - Finally, an overview on how many people are currently living within the settlement of concern, should be provided.
- Some general remarks concerned the descriptions and explanations of the parameters used in the tool. For example, the terms “grid lengths” or “occupancy density” should be explained. Also, it is not clear whether only the heating demand of buildings or also hot water supply is considered for the analysis of the heat demand in the vicinity of the WWTP.
- Another feedback asked for the implementation of a query for the distance between the WWTP and the natural gas grid (for potential biogas injection).

- It was also suggested to implement a sort of “red-flags” or warnings when there are inconsistencies between the parameters (e.g. if the wastewater heat recovery using a heat pump cannot meet the required temperature level of the district heating network).
- Last but not least, one feedback dealt with a potential scenario analysis. Currently only the status-quo of the heat consumers around the WWTP can be analysed.

3.3.2. Implemented changes

A visualisation of renewable excess energy provided by the WWTP was implemented in the spatial assessment tool. Additionally, the energy demand in the vicinity of the WWTP is summarised and displayed next to the excess energy from the WWTP. Finally, a comparison between the two values was implemented. In this way, the user can immediately see, if there is still energy available from the WWTP or if there is sufficient heat demand in the vicinity. This way, the user does not have to go through the whole tool and generate the tool report, where the results are summarised.

The layout was significantly improved. In order to facilitate the decision which type of energy consumer (or corresponding settlement type) to select for the spatial assessment the following improvements were implemented:

- Titles were added directly next to the illustrations: e.g. “Village Centre” or “Multi-storey buildings”
- A so-called “mouseover-effect” or “hover box” was implemented, which let an illustration pop up, when the user crosses the type of energy consumer. In this way, multiple types of energy consumers can be compared at once.
- Additionally, the explanatory parameters “plot ratio” (describing the footprint of the buildings in relation to the total area of the plots), “floor area ratio” (describing the relation between the usable gross floor area of the buildings in relation to the total area of the plots) and the “dwelling density” (referring to the number of dwelling units per hectare) were implemented.

Additionally, descriptions and clarifications were added within the spatial assessment screen. For instance, the parameter “share of connected heat consumers” was further clarified. In addition, some labels have been made easier for the user to understand. Finally, it has to be mentioned that a scenario analysis is currently under development for the whole tool (Software tool N.1 and N.2). However, a scenario calculation can be easily conducted by saving the tool report multiple times, whenever different input parameters were inserted.

3.3.3. Remaining issues or deficits

From a technical point of view, a higher temporal resolution of the heat demand is currently not considered. This is due to the fact that also other parts of the tool (e.g. parts of the energy provision) do not evaluate for instance monthly values. An implementation of a higher temporal resolution is only reasonable if it is implemented throughout the entire tool. The catchment area for the co-substrate supply was not considered, since it is outside the system boundaries of the developed tool. Until now, a query considering the distance from the WWTP to the feed-in-station of the gas grid is not implemented. However, this is a remaining issue that should be implemented in order to guarantee the evaluation of excess biogas provision. “Red-flags” were not yet implemented, since there needs to be a more sophisticated calibration between the different tools. This can arguably be seen as a deficit to be solved between all the tool developers.

3.4. Cost-Benefit Analysis (UCT)

The training in the Czech Republic was divided into two separate courses held in Prague on 19 and 20 November 2018. The first course organised on 19 November focused on interested parties and the second one on November 20 was aimed mainly at the technical staff of partner utilities. A Presentation of the tool was hold in form of PowerPoint presentation, showing important parts of the tool taken by screenshots, followed by a demonstration on a model example using real data from WWTP Zlín. Each partner took a similar approach in all five countries, and unified feedback on the cost-benefit analysis is presented below.

- The tool looked only at subsidizing biomethane and left out other possible subsidies. Nevertheless, in several cases, the economy of renewable energies depends on the type of energy generated and on the size of the plant. Therefore, the other subsidies should also be implemented.
- There were some cases of cost-benefit analyses of the tool units that were not listed or not clearly indicated. In some training feedback it was proposed to change units for easier completion of the survey from user side and unifying units in the same way.
- Some of the prices surveyed were not clearly defined or intransparent. For example, the user was asked about the price of electricity, but it was not stated whether it was electricity supplied to the grid or consumed.
- According to several participants, the transportation cost for disposing of sludge should be incorporated.

- In one case it was suggested to omit the cost-benefit analysis tool. The trainers explain that the cost-benefit analysis is serving as a first control for the user and shows whether the time spent on the complex financial analysis is worthwhile.

Compared to other parts of the tool, the cost-benefit analysis has only a few comments from each country, and most of them have the same observations. All comments were discussed among the developers and most of them were implemented into the tool.

3.4.1. Implemented changes

From the feedback listed above, the developers used the following points for further tool improvement:

- Besides subsidies for biomethane, other forms of subsidies have been added to the tool
- The units were added to each of the surveyed values
- The prices surveyed were better distinguished and described
- In light of the transportation cost of sludge disposal, the user will be informed to take into account the transportation costs for the disposal price when choosing the sludge disposal method.

3.4.2. Remaining issues or deficits

In terms of direct feedback on the cost-benefit analysis, all possible changes were incorporated into the tool. Current problems and deficits arise from the need to combine cost-benefit analysis with other parts of the tool that have undergone adjustments according to the feedback. For example: increasing the number of substrates, adding new ways of sludge disposal, incorporating new renewable technologies and more. In line with the ISA methodology, additional indicators need to be added that could provide more information to the user and help with the decision-making process.

3.5. Life Cycle Analysis (KWB)

3.5.1. Summary of the Feedback

In Berlin, the first training course took place in October 2018. The REEF tool was presented in form of a Power Point presentation, which included snapshots of the key components. This allowed the participants to understand the functionality of the tool step by step. During the event, the participants raised many questions and gave valuable feedback. The following points comprise a summary of the feedback for the last part of the tool, the Life Cycle Assessment (LCA):

- The tool asks for the real amount of active ingredient or chemicals in kg per year. One question, for example, asks for the amount of acetic acid that is used in a WWTP per year. However, an operator may only know the volume of a diluted chemical (solvent). Maybe, it is easier to ask this volume. Moreover, most users will not have information about chemicals, especially not the amounts of active ingredients needed to treat wastewater.
- Units should be changed into tons. Inconsistent units were a critique that applied to all parts of the tool. The amount of CO2 equivalent in kg will be a large number that is not easy to read. The conversion of the unit into tons of CO2 equivalent helps the user to better recognize the changes.
- The LCA should allow to add other external organic substrates besides methanol. The LCA does not include chemicals such as ferric chloride or other precipitation agents.
- Currently, the tool considers only two ways of sludge disposal: Mono-incineration and agricultural use. However, it is important to implement further sludge disposal such as landfilling and co-incineration in the tool. The landfilling is prohibited in Germany, but it is still done in some countries such as Croatia. Therefore, this option should be included in the LCA tool.

Overall, the points raised and questions asked about the LCA were comparatively fewer than about the other parts of the tool.

The LCA feedback was discussed and analysed to improve the quality of the LCA tool. However, some of the aspects discussed were rather writing and communication issues. For example, some of the instructions were not clearly stated and content was missing. The interview participants believed that this problem could be solved in part by providing a starting interface with detailed information.

3.5.2. Implemented changes

The following aspects were accepted and implemented in the tool:

- The above mentioned other sludge disposal methods (landfilling and co-incineration) were implemented.
- The units have been changed into tons.
- The real amount of active substance (chemicals) were considered in the tool

The implementation of disposal methods like landfilling for Germany was a challenge due to less data set in LCA because of legal prohibition since 2005. After an internal discussion and literature research, KWB was able to prepare data for this option. Additionally, some formula in the LCA sheets have to be adapted to implement these disposal options in the tool. Therefore, KWB updated these changes and sent ENEA modified LCA tool.

Two further points in the list above (changing the units and amount of active substance) were simply implemented in the LCA tool.

3.5.3. Remaining issues or deficits

The tool generally lacks visual appeal while LCA results should be simplified and complemented by graphical elements. ENEA has already started with these changes and the new version of the tool will be graphically and visually more user-friendly.

In addition, one of the points of the feedback was to add other external organic substrates except methanol in the tool. These issues should be discussed during the further development of the tool, since the tool should remain simple and understandable for everyone, even for non-experts.

The LCA model for the REEF 2W project must be realised with spreadsheet software Excel. However, it is almost impossible to implement such a complex system with a huge database behind in a simplified Excel tool. In addition, the system boundaries of the implemented life cycle assessment were adapted to other parts of the tool. As a result, some processes such as the transport of sludge for disposal were neglected in this tool. These simplicities of Excel have impacts on the results of the LCA tool and cause inaccuracies.

3.6. Results Section (ENEA)

3.6.1. Summary of the Feedback

As for the results and report section, the first version of the tool provides only numerical information on the performance of the plant analysed. The feedback was that a graphical representation in a first evaluation could facilitate the understanding of the results obtained.

3.6.2. Implemented changes

As a result of the comments, a report with the graphical representation of the results was included. In the meantime, the numerical and graphical results for the status quo and the future situation have been coupled. In this way it is easier to see the differences between both and the possible benefits.

3.6.3. Remaining issues or deficits

During the feedback phase no other specific requests were made. Nevertheless, the report is very long - almost 30 pages - as all aspects were taken into account. In the future, the focus will be to report only modified aspects or technologies used. In doing so, the scope of the report will be reduced and thus the report will be easier to read.

4. Conclusion (ENEA)

Although it is possible to implement further functions that could be commented with a more detailed description of the scenarios or with the possibility to include some other less common technology, the tool at the moment has to be considered completed. From the initial idea that the team had of a simple tool for public administrators it is strongly changed in a tool that can be used from non-sectorial expert and from professionals. In the category of sectorial experts we include not only all the policy maker and public administrators that have to take strategic decisions for the future of a community, but they cannot cover all the competences requested for the city planning, but also those stakeholders as local associations and think tanks that are interested to better understand how it could be possible innovate in a more friendly way the management of wastes and wastewater and how it is possible to take advantage from them.

The chose done to develop the tool at the beginning was the possibility to have a standalone instrument free from the web connection and without the necessity to exchange data with any other data base. This oblige us to take some decision that limited the use of the tool to only some OS or programs. For the future development of the tool it will be important to continue in the way of a confidentiality data management, but it will be important to develop a the tool as an executable program that can include all the information necessary to run.

The final version of the tool will be uploaded on the web site when the partner assembly will approve the last version delivered.