



# CONCRETE IMPLEMENTATION OF NEW ENERGY PERFORMANCE CERTIFICATES FEATURES: TESTINGS AND RESULTS IN NINE COUNTRIES- ENHANCED RECOMMENDATIONS

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## eXTENDING the energy performance assessment and certification schemes via a mOdular approach

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## LIST OF ABBREVIATIONS

ADENE	Portuguese Energy Agency, Department of Buildings
AAECR	Romanian Association of Energy Auditors for Buildings
CDD	Cooling Degree Days
CRES	Centre for Renewable Energy Sources and Saving
DEA	Danish Energy Agency
DH	District Heating
EASt	Energy Agency of Styria
ENEA	Italian National Agency for New Technologies, Energy and Sustainable Economic Development
EST	Energy Saving Trust
HDD	Heating Degree Days
IEQ	Indoor environmental quality
MFH	Multi-family house
NAPE	National Energy Conservation Agency
SFH	Single family house
TREA	Tartu Regional Energy Agency

## 1 INTRODUCTION

The focus of the Horizon 2020 project X-tendo is the further development of energy performance certificate (EPCs) schemes in EU Member States. This should be done in two dimensions: on the one hand additional indicators are developed that add further relevance to EPCs. On the other hand, EPC handling should be improved to make it easier, more reliable and interconnected with other building related data. 5 features in each of the two dimensions are elaborated throughout the project. This includes the analysis of the theoretical background, the development of materials and methods, the testing of the features in concrete implementation projects, as well as the dissemination on developed ideas and materials.

The goal of the testing of the developed feature materials is to understand the practical viability and the challenges in the practical implementation of the developed ideas and materials in selected countries of the EU. Depending on the feature different types of tests and test projects have been performed. In-building tests apply the feature materials on concrete buildings, user tests consist of understanding the user perception related to the developed materials and ideas, system tests intend to understand the application of feature ideas and materials in related systems like EPC database systems.

The overall approach of testing and further developing feature materials is shown in Figure 1 and consists of the following steps:

- ① In the first phase of the project the feature leads (FL) developed beta versions of feature materials, hereby taking into account needs and feedback from Implementing Partners (IPs). An overview of FLs and involved IPs per feature can be seen in Table 1. These materials consist of different parts depending on the feature. In most cases these consist of guidelines, spreadsheets or program code in defined languages like sql or python.
- ② The beta versions of the feature materials have then been provided to the IPs to test their application in their national / regional settings. The IPs have performed different types of tests with or in the context of the developed materials. In some cases, especially for in-building tests of certain features, the tests also involved EPC assessors.
- ③ After finishing the test projects, the IPs reported about their testing results in two different ways: on the one hand they filled previously developed questionnaires (see the annex for exemplary questionnaires). On the other hand, they wrote test result reports providing more details about the context and results of the test projects.
- ④ The filled-out questionnaires as well as the testing results reports have been used as a basis to derive conclusions for the final reshape of the feature materials. They also serve as an input to guiding the implementation of the features in the different countries / regions.



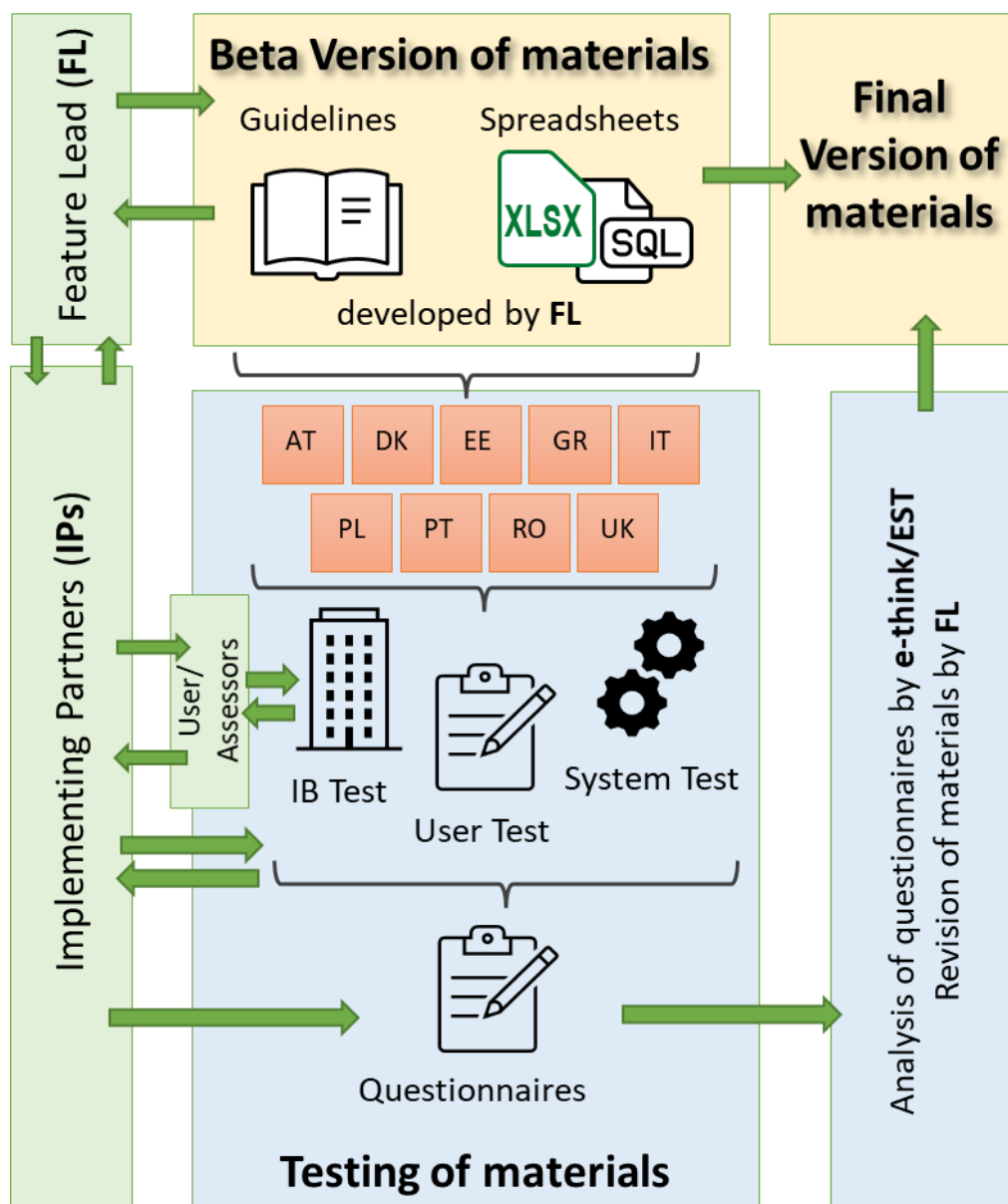


Figure 1: Approach for testing feature materials in the X-tendo project

The following Table 1 gives an overview of the types of tests that have been performed for the different features in the different implementing countries. More details of the characteristics of each test project are described in the feature chapters.

Table 1 – Overview of testing activities by feature and implementing country / partner

		1. Smart readiness	2. Comfort	3. Outdoor air pollution	4. Real energy consumption	5. District energy	6. EPC database	7. Building logbook	8. Enhanced recommendations	9. Financing options	10. One-stop shops
		Feature lead partner									
Country	Implementing Partners	VITO	BPIE	NAPE	VITO	e-think	TU Wien	BPIE	TU Wien	ADENE	ADENE
AT	EASt	IB	IB		IB				Expert		
DK	DEA					Expert	S		IB	U/S	U/S*
EE	TREA	IB Expert			IB			U/S			
GR	CRES	IB Expert	IB Expert				S	U/S			
IT	ENEA				IB	IB	S				
PL	NAPE			IB U Expert		IB			IB S	Expert	
PT	ADENE		IB					U/S Expert		U/S	U/S* Expert
RO	AAECR	IB	IB		IB Expert	IB				U/S	U/S*
UK	EST				**		Expert		IB		S
	No of partners testing	4	4	1	4	3	3	3	3	3	1 stand-alone test*

\*Feature 10 tests in DK/PT/RO are delivered alongside testing of feature 9 \*\*Note UK test under feature 10 also relevant here

This report provides the summary of the outcomes of the testing activities for each of the 10 features in one or several implementing countries. This is mainly based on the analysis of the evaluation questionnaires filled out by the implementing partners, but also on the content of the testing results reports where these have already been available at the time of writing the document. The questionnaires hereby consist of general questions along the testing steps, questions on testing time and related costs, an evaluation against defined cross-cutting criteria (Quality and Reliability, User-friendliness, Economic feasibility, and Consistency with ISO/CEN standards) and final thoughts. The questionnaires slightly differ for the different types of test projects (in-building, system, user tests) and for the different features (composition of detailed questions for the cross-cutting criteria). Exemplary evaluation questionnaires for each of the three types of test projects can be found in the Annex of this report.

With this the report should provide a summary of the outcomes of the testing activities on the different features in the different countries, provide conclusions for further development of the developed ideas and materials towards the end of the project and beyond, explain the practicability and challenges in the implementation of the features in practice, and give guidance for organising similar test projects in the future.

The report first provides an introduction to the topic of the feature, the developed methodologies and materials and the performed testing activities. This is followed by the description of the testing results structured by the types of test projects. This includes a description of overall results, estimated time and costs and the different cross-cutting criteria. Finally, conclusions out of the testing activities are presented.



## 2 FEATURE 8: ENHANCED RECOMMENDATIONS

### 2.1 Introduction

This feature demonstrates how to automatically provide enhanced recommendations in energy performance certificates (EPCs), mainly for building transactions (sell/ buy/ renovate), and how they can be linked to national long-term renovation and climate strategies for the building stock. Enhanced recommendations are especially important for owners undertaking and implementing deep renovations. Targeted recommendations require a high level of accuracy and detail, which needs to be reflected in the information collected, and the design of the tool.

EPC recommendations in many EU countries are not sufficiently informative to meet objectives. While reliable and usable indicative recommendations are sufficient for buying and selling houses, deep renovations require detailed recommendations.

The ambition of the X-tendo project is to improve on the current state of generic recommendations, which often only provide limited value to homeowners or buyers. The enhanced recommendations methodology will demonstrate a method to automatically generate useful EPC recommendations, extending the recommendations currently provided in EPC schemes. Although the proposed recommendations will improve the status quo, they cannot fully replace professional advice.

Additionally, the methodology suggests an approach to align the EPC recommendations with the national long-term renovation strategies. This approach could enhance the quality of recommendations by ensuring that they are not only in line with building requirements, but also in line with the national long-term energy and climate objectives.

More information about the feature can be found in the [introductory report](#) or on the [X-tendo website](#).

Feature 8 was tested in Denmark (DEA), Poland (NAPE) and Scotland (EST)

Denmark did an in-building-, user- and system test, Poland did an in-building- and system test and Scotland did an in-building test.

Table 2 – Description of F8 tests – Enhanced recommendations

Denmark (DEA)			Poland (NAPE)			Scotland (EST)		
In-building test name	In-building test type	Description	In-building test name	In-building test type	Description	In-building test name	In-building test type	Description
F8.IB.01.DK Test of python script	Software code test	Feature leads will develop a python script based on the XML-file in Denmark. The python script will then be tested to extract data from 5-10 SFH buildings into an excel sheet.	F8.IB.01 - F8.IB.10	Software code test	Data from energy audits will be used to test the Excel calculation code from TUW.	F8.IB.01 - F8.IB.10	Software code test	Data from energy audits will be used to test the Excel calculation code from TUW.
System test name	System test type	Description	System test name	System test type	Description			
F8.ST.01.DK Analysis of recommendations	Excel calculations software from TUW	Comparison between the recommendations from the Excel calculation code from TUW and the recommendations from the actual EPC.	F8.ST.01 ST.PL.01	Verification of the results obtained from in-building testing against the real energy audit documentation	The in-building test project F8.IB.01-10 will be compared with the real energy audit calculation of test buildings. This will allow to compare results obtained from Feature 8 tool (spreadsheet) against full energy audit calculation.			

## 2.2 Results of the testing activities

### Overall results of in-building tests

#### In-building tests summary

##### Denmark (DEA)

The testing contains three phases:

1. Data extraction from existing EPC's. The data extraction was a Python script performed on the XML-files from the Danish database.
2. Data transfer from the data extraction to the calculation software developed by TU Wien. The data transfer was performed manually between two excel sheets.
3. Comparison between calculation software and existing EPC. The data comparison was summarised in a word document.

The testing can evaluate the need for standard recommendations based on the data in the building. In Denmark the EPC consultants are already imposed to recommend renovation approaches. It is possible to estimate if the calculation tool can support the EPC consultant when performing the EPC.

##### Scotland (EST)

Testing the features, functionality and useability of the TU Wien calculation tool on ten residential buildings.

## Poland (NAPE)

Testing was performed for ten multi-family buildings. Parameters tested included energy consumption, building envelope, type of modernization of building envelope, and the heating and domestic hot water systems and their costs.

DEA and EST both stated that it was 'Somewhat easy' to implement the feature, however, NAPE thought it was 'Somewhat difficult'.

DEA thought it was 'Somewhat easy' to explain the feature to the assessor and/or other stakeholders involved in delivering the test, whereas EST thought it was 'Somewhat difficult'. NAPE responded, 'Neither easy nor difficult'.

All IPs were able to carry out all of the planned steps for implementing the feature. EST didn't carry out a final optional step (a Pre- and Post-comparison), due to the 'Appropriate inputs unavailable from XML and wasn't feasible to test post-WHS work without access to SAP software.'

## Challenges encountered

DEA stated that they encountered a challenge carrying out the Calculation phase (Calculation with use of the tool), stating, 'The model does not fit all. So there were some issues with some data inputs, that does not exist in the Danish EPC Scheme. One of the challenges was to convert the registered U-value in Denmark into a value that the calculation software could use. In Denmark each layer of the envelope is not registered, but instead the complete U-value of the part of the envelope (e.g., U-value of the exterior wall)'. This was also reported by EST.

EST also reported an issue when running data through X-tendo tool, 'Some complicated inputs are required that an assessor in the field would have difficulty providing, limiting use in the real world (e.g., thermal coefficient values).'

NAPE reported that they had issues during the Administration/ Data collection phase, stating that 'not all data can be obtained from the building administrator'. Also, during the Data collection step of the Calculation phase, they reported that. 'sometimes some information was missing in the building documentation and it was not possible to check it, e.g., the exact structure of partitions.'. During the Evaluation of assessor step, they found that. 'there are no national databases on modernization costs, all data has to be collected by yourself and it is time-consuming.'. Finally, during the Calculation with spreadsheet tool step, they reported that, 'in some places of the tool there was a lack of, for example, hints on what to insert if there is no data in the documentation, the descriptions lacked a definition whether it was the efficiency of the entire system or, for example, only a heat source.'

Both DEA and EST responded that they thought it was 'Somewhat unpractical' to include the feature as part of a standard EPC assessment. NAPE responded, 'Very practical'.' Supporting narrative was provided:

DEA: 'The feature and the product in itself is quite easy to implement, and it would be possible to integrate it fairly easy in the EPC issuing programs in Denmark. But it would be as a support tool. In Denmark the EPC consultant are already responsible for delivering renovation suggestions in the EPC, which would be categorised as highly tailored. But sometimes building parts could be forgotten or maybe the EPC consultant has not thought of a specific building part. The tool could then support the EPC consultant in making holistic suggestions for all building parts in the EPC.'

EST: 'There are many assumptions/inputs that are needed from an assessor - some of these will not be obvious or available without SAP software.'

NAPE: 'Providing recommendations and economic effectiveness of modernization projects is a very important element for EPC recipients. The recommendations are an important guideline on how and at what cost the EPC can be improved.'

## Testing time & costs

The following table shows the summary of responses from the different IPs.

**Table 3 – F8 testing time and costs**

Testing time & costs		DEA (DK) IB		EST (UK) IB		NAPE (PL) IB	
How much time (in minutes) did it take to perform each step	Implementing partner or assessor	Administration/ Data collection	300	Identify properties with pre- and post-retrofit XMLs from Warmer Homes Scotland projects (WHS)	60	Administration/ Data collection	1 - 2 hour
		Calculation phase	600	Extract relevant data from XMLs	30	Calculation phase	8 hour
		Comparison	120	Reverse engineer SAP calculation software to acquire required data for X-tendo data input tab	120	1. Data collection	1 - 2 hour
				Run data through X-tendo tool	10	2. Evaluation of assessor	1 - 3 hour
What are the approximate costs incurred in each step. Please specify the positions as well as an approximate estimate. (costs per EPC)	Implementing partner or assessor	Administration/ Data collection	not applicable	Identify properties with pre- and post-retrofit XMLs from Warmer Homes Scotland projects (WHS)	N/a	3. Calculation with spreadsheet tool	1 hour
		Calculation phase	not applicable	Extract relevant data from XMLs	N/a	Administration/ Data collection	10 Euro
		Comparison	not applicable	Reverse engineer SAP calculation software to acquire required data for X-tendo data input tab	N/a	Calculation phase	200-350 Euro
				Run data through X-tendo tool	N/a	1. Data collection	
				Pre- and Post-WHS comparison (optional)	N/a	2. Evaluation of assessor	
						3. Calculation with spreadsheet tool	

EST performed a user test on the TU WIEN calculation tool, which they reported was quick to use, at roughly 10 minutes per property.

DEA and NAPE reported similar times for the calculation phase of their system testing (6 – 8 hours).

Only NAPE provided the approximate costs incurred in each step, (DEA and EST responded 'NA', since neither carried out an in-home assessment by an EPC assessor):

Administration/ Data collection: 10 Euros

Calculation phase: 200-350 Euros

## Cross cutting criteria

### Quality and reliability

All IPs responded 'Partly' to the question 'Are the calculation methods clearly described?'.

DEA responded: 'The calculation software could have been more transparent. It is somehow difficult to follow your registrations and the following calculations around the sheet.'. EST responded: 'Some data input fields would have benefited from some explanation and flagging that they are essential to the calculations. It would also help if there were clearer explanations of how certain calculations were performed. For example, as references like "U\_value\_Roof" are used in formulae it means that a user needs to briefly double check where data is pulled from when trying to understand how calculations/IF statements are being implemented.'. NAPE responded: 'not in all points the description is sufficient'.

All IPs responded 'Partly' to the question 'Is the required input data clearly asked?'.

DEA responded: 'Some of the parameters are not applicable in every country.'. EST responded: 'It would be beneficial to label which input fields are essential for a country to use the tool to work for the results fields. Some data was not easily available in a UK XML leading to #N/A errors which may confuse a user and they spend additional time trying to 'fix' this error.'. NAPE responded: 'sometimes there is no exact information on what to enter, the terms used must be compatible with European standards.'.

DEA and NAPE responded 'Partly' to the question 'Are the results shown transparently?', but EST responded 'Yes'.

DEA responded: 'The results are shown in a nice table. But the unit in which the envelope is presented is a bit odd. It is difficult to see, that it is the extra added insulation. Maybe there should be some kind of elaboration.'. EST responded: 'The use of columns to breakdown a summary of each recommended retrofit is helpful to understand the benefits and costs of these measures. However, there are some errors and it would be useful to explain in some more detail what each co-benefit means (e.g., prevent or reduce pathologies is a little ambiguous)'. NAPE responded: 'there are errors in the worksheet in some cells, not all wording is clear.'.

DEA and EST responded positively ('Yes') to the question 'Does the user have access to formulas/application interface?', and NAPE responded 'Partly'. DEA noted 'There is an excel interface. Somewhat technical. Requires some insight to navigate perfectly.', and NAPE: 'not all formulas can be accessed.'.

All IPs responded, 'Yes' to the question 'Does the user have access to weightages for the calculation of final results?'. DEA alone provided a comment: 'It is possible to analyse the background of the calculations, yes. But it also requires some technical insight to navigate perfectly.'.

DEA and EST responded 'Partly' to the question 'Does the user have access to reliable information needed to take decision on building renovation measures?', with NAPE responding 'Yes'. DEA noted 'Since the calculation software is not 100% applicable with the Danish EPC, some of the recommendations are missing.'. EST commented 'Not all retrofit recommendations were available (due to UK EPC XMLs not holding all the required data) and so limited the applicability to consider a full building retrofit.'. NAPE responded: 'however, you can improve the sheet to make it more legible and user friendly.'.

DEA and EST responded 'Partly' to the question 'Is the user provided fundamental technical knowledge needed to understand the details of the feature?', with NAPE responding 'Yes'. DEA commented 'Difficult question to answer. The input phase of the calculation software is fairly intuitive, if the person has some experience with EPC's.'. EST noted 'Not fully by the tool, but with an experience in UK EPCs, a user should be able to understand most details of the tool.'. NAPE thought that 'however, the use of the spreadsheet was difficult by the lack of some explanations.'.

### User-friendliness

DEA and EST responded 'No' (and NAPE: 'NA') to the question 'Are graphics used to increase user's understanding of the feature?'. DEA suggested that 'This could be recommendable.'. EST commented 'There are no graphics, but this may be useful to help illustrate the breakdown of costs, number of benefits etc.'.

All IPs responded 'No' to the question 'Are the results presented in graphical way?', with DEA and EST repeating their comments to the above question.

EST and NAPE responded 'No' (and DEA 'NA') to the question 'Are the requirements for application of the feature to other building types clearly outlined?'. EST commented 'But a consideration of different building types (or archetypes) for the tool to help guide a user may be useful.'. NAPE commented 'but after improving the sheet, it will seem possible to apply it to other types of buildings as well.'.

DEA responded positively ('Yes') to the question 'Does the evaluation of the feature consider flexibility to adapt the methodology to different building types?', commenting 'The feature does not only extent to a specific type of building. The recommendations included are pretty generic.'. EST responded 'Partly', and NAPE responded 'NA'.

DEA responded positively ('Yes') to the question 'Is the stepwise description for feature assessment provided?', and commented 'It would have been better if all the documents were delivered at the same time in a combined package. It was quite the scavenger hunt to gather all the information.'. EST responded 'NA', and NAPE responded 'Partly', stating 'not all descriptions were clear.'.

EST and NAPE responded 'No' to the question 'Is the calculation/process description provided in guidelines?'. DEA responded 'NA'.

DEA responded 'NA' to the question 'Does the tool have stepwise description of the assessment?', with the comment 'It makes more sense if the feature lead answers these questions.'. EST responded 'No' and NAPE 'Partly', stating 'not all steps and their results are fully described.'.

### **Economic feasibility**

EST and NAPE responded 'Partly' to the question 'Does this feature increase EPC costs?'. EST commented 'Potentially, as there would be a need to increase the amount of data collected.' NAPE commented 'due to the need to collect additional data, the workload increases.'. DEA responded 'No', commenting 'Since the Danish EPC's already have highly tailored recommendations, it could maybe support and save time for the consultants when identifying recommendations in the building.'.

All IPs responded, 'Yes' to the question 'Does the methodology require additional data to the one already included in current EPC derivation?'. DEA commented 'The calculation software is not ready for an implementation as it is in Denmark. It needs to be more adaptive to the Danish data. There are too many data points that the Danish EPC's does not gather or gather in a different unit.'. NAPE commented 'for example modernization costs.'.

EST and NAPE responded 'Partly' to the question 'If additional data is required, does it take longer than 1 hour to gather them?'. EST commented 'Depending on the data, yes as it requires a reverse engineering of the data using other available data', and NAPE 'it depends on the building and the scope of possible modernization works.'. DEA responded 'No', stating 'It is the software that needs a revision in order to fit the Danish model.'.

NAPE responded 'Partly' to the question 'Is an additional on-site visit or measurement needed?', stating 'in some cases it may be needed due to the need to collect additional data, e.g., measuring the available space for PV panels.'. DEA and EST responded 'No'. DEA commented 'In Denmark all the information is gathered during the on-site visit. If the feature is implemented as a supporting tool to the EPC assessor it would not result in extra work. As of now, all the data was extracted by a Python script. It was possible to recalculate some of the data to fit in the testing of the feature, hence an additional on-site visit was not needed.', and EST 'No on-site measurements were used to test this tool as existing EPC XMLs were used. However, there is a small risk that a user may have to go and take additional on-site measurements (beyond their first survey) when using the tool if it remains slightly unclear as to which data is required in which format for a user.'.

### **Consistency with ISO/CEN standards**

NAPE responded 'Yes' to the question 'Have any national regulations been used in the methodology of this feature? If yes, which one?', stating 'Regulation on the methodology of calculation EPC.'. DEA and EST responded 'No'.

DEA and EST responded, 'Yes' to the question 'Is the data used for the feature already covered by the current EPC?'. NAPE responded 'Partly', stating 'not all, e.g., the costs of modernization and its scope are not included now.'

All IPs responded 'No' or 'NA' to the question 'Are there any restrictions in changing the methodology? If yes, was it documented?'

### Overall results of system tests

#### System tests summary

##### Denmark (DEA)

The testing consisted of three phases:

1. Data extraction from existing EPC's. The data extraction was a Python script performed on the XML-files from the Danish database.
2. Data was transfer from the data extraction to the calculation software developed by TU Wien. The data transfer was performed manually between two excel sheets.
3. Comparison between calculation software and existing EPC. The data comparison was summarised in a word document.

The testing was to evaluate the need for standard recommendations based on the data in the building. In Denmark, the EPC consultants are already directed to recommend renovation approaches. It is possible to estimate if the calculation tool can support the EPC consultant when performing the EPC.

##### Poland (NAPE)

The testing method was based on the results of in-building test done with the use of the Enhanced recommendations calculation tool and the documentation of a real energy audit for each of the building. For the system test the results (recommended measures) obtained from F8 tool and real energy audit were compared in order to verify if and differences occurs. In the test a data for 10 residential (multi-family) buildings in 5 different locations: Warsaw, Wołomin, Piaseczno, Zwoleń and Ożarów Mazowiecki has been used.

Both IPs stated that no key changes were planned to make to the existing 'back-end' EPC systems to enable the feature. DEA commented 'No changes was needed in the original EPC system. All the data was already available in the XML-files in the database. A python script for extraction was although needed.', and NAPE commented 'The testing did not include implementation of the F8 tool into existing EPC system.'



### Main advantages of the feature

DEA stated 'The feature can be timesaving. So instead of calculating all the measures individually, it is possible to gain access to a complete calculation of a series of standard renovation measures.'

NAPE stated, 'The calculation provided within F8 tool are simplified and maybe less accurate, however the calculation time is shorter than for full energy analysis done for the energy audit.'

IPs were also asked to describe the methodology how the recommendations are developed, which are compared with the recommendations yielded by the X-tendo F8 tool.

DEA responded: 'The recommendations are performed by the Danish EPC consultants. After inspecting a house and registering all parameters the consultant performs individually calculated renovations. There are some national legislations stating some minimum requirements, that the consultant shall comply to. But it is also based on the knowledge and experience of the consultant.'

NAPE responded: 'The methodology of an energy audit is based on the required maximal values of thermal transmittance (U-value in W/m<sup>2</sup>K) for each considered partition. This value is used to set a few variants of modernization measure (i.e., with different insulation material thickness). Next for the existing state and each of the variant an energy need is calculated. Also, the investment costs are estimated for each of the variant. The savings of energy needs with the price of the energy are used to calculate the energy cost savings. The investment costs are then divided by the yearly energy savings in order to calculate a Simple Pay Back Time (SPBT). The SPBT is then used to choose the recommended variant – the variant with the lowest SPBT is chosen. Such procedure is used for each of the building partition analysis. At the end a list of recommended measures is given.'

IPs were asked to describe the objective of the survey

DEA responded: 'The objective was to determine the differences between an automatic calculated method for recommendations and the current tailored and individually calculated method. The expectation was also to get an idea whether the automatic would save resources. This could either be as a support tool for the consultants or a stand-alone tool.'  
NAPE responded: 'The survey was not conducted.'

IPs were asked to describe the main differences in the recommendations yielded by X-tendo F8 tool and the other methodology

DEA responded: 'The X-tendo tool always provide standard recommendations and are only taking data into account such as U-value etc. The recommendations from the EPC consultant also takes other considerations into account such as aesthetics, convenience, profitability etc. This means that the X-tendo tool almost always will provide a recommendation, where the consultant may exclude some recommendations due to other factors. It is still a great

support tool for the consultant, to make sure he remembers every detail and to get a quick overview of all the recommendations in the building.'

NAPE responded: 'In the full energy audit calculation several variants of the modernization measure are taken into consideration and the variant with the lowest SPBT (Simple Pay Back Time) is chosen. In case of the F8 tool only one variant is considered. The F8 tool does not provide energy saving calculation.'

IPs were asked to describe the main findings of the comparison of both approaches for generating recommendations

DEA responded: 'The tool will suggest recommendations almost every time making it a bit unreliable. E.g. It is not feasible to raise your U-value from 0.16 to 0.12. The tool does not calculate the rentability of the recommendations. That's why the tool will function well as a supporting tool, making sure that the consultants have considered all possibilities when performing an EPC. The consultants are also able to combine the suggestions with actual prices.'

NAPE responded: 'The calculation provided within F8 tool are simplified and maybe less accurate, however the calculation time is shorter than for full energy analysis done for the energy audit. As for the calculation within energy audit real weather data are used, the energy calculation is more accurate but also more time consuming.'

### Overall results of user tests

At the time of finalising the report, the results of the user test from Denmark were not yet available.

## 2.3 Conclusions and discussion

### In-building tests

All IPs thought that the TU Wien calculation tool was useful and generally easy to use. The main barriers to testing that all IPs reported were around not having access to all the input data required for the calculation tool, either because it couldn't be obtained from the EPC data administrator (DEA), or wasn't captured presently by the country's EPCs (all IPs).

Both DEA and EST reported that they were unable to convert the registered wall U-value into a value that the calculation software could use. This was due to the fact that the tool was expecting a thermal conductivity value for each component layer of the wall, which were not available.

EST and NAPE both reported difficulties in populating the measures databases with national information on installation measures.

It was felt by all IPs that further development of the tool would be useful, including around improving the ease of use for the user. Suggested examples are listed below.

## Suggestions for improving the feature

### DEA

'If it should be applicable in e.g., Denmark, it should be based on the parameters in Denmark. The idea is good, and the tool can be used as a valuable support tool for the consultants. In Denmark the consultants collect approximately 240 parameters, it is just in different units or based on other methodologies than the calculations software allows. E.g., the U-value.'

### EST

'The X-tendo tool currently forms a solid foundation to supplement (or bridge the gap in assessment tools for areas lacking EPC software/framework) EPC assessments. However, additional features would be beneficial:

Highlighting required data input cells (i.e., let the user know which data is absolutely essential for the tool function at all like U-values and building component area measurements) - X-tendo can use a lot of different data, but some will be unavailable for an assessor and so it would be useful to focus their efforts and not lead them to try and find data they simply won't be able to locate.

A more detailed description of certain input data and the underlying assumptions (a simple how to guide with a worked example to explain the steps would be ideal).

Some work towards automating the results for comparing pre- and post-retrofit work (Results\_energy performance tab; this is very complicated and time-consuming to try and achieve for a user) - it is counter-intuitive to have a results tab that completely requires user input/calculations. Could there be further work to estimate the energy demand of a property if X-tendo recommended measures were installed? Some regression analyses between property component U-value and energy demand to give broad estimate?

Incorporate insulation thickness required (as well as area to cover walls) when estimating cost.

Additional look-up tables to aid users in selecting appropriate values (e.g., "property type" in data input which will help inform what the target standard for wall U-value is, but also what is achievable for the property - X may be the target value for the UK but Y is what is actually feasible and achievable; this could be quite broad (e.g., flats vs. house).

If possible automatic selection of the "pre-fabricated text" for additional benefits - it's not clear which ones to select or how many. The additional advice is useful and supplements the assessment but it's the last tab and may be overlooked.'

### NAPE

'Improvements need to be made in all of the mentioned elements. The sheet should be more user-friendly, contain precise wording. It is also needed to improve the connections between

the individual sheets. The manual should also be completed. The correction of the errors in the spreadsheet that were found during testing is needed.'

'This functionality is very important. you should consider supplementing the sheet with e.g., modernization of the domestic hot water system.'

'To better understand the results, one summary tab could be added in the tool. Also, the energy savings calculation should be added in the tool.'

'The system testing showed that the F8 tool is rather understandable and quite easy to use. The results obtained from the tool are in line with the results from the real energy audit documentation.'

### **Additional comments**

Additional responses were gathered by EST from one EPC assessor using the calculation tool. These are presented in the following.

#### **How practical is it to use as a standard EPC procedure?**

- ⊙ Lots of calculations needed rather than simple data input. The calculations require lots of intricate construction data that is not immediately available e.g., the full breakdown of the wall construction.
- ⊙ The calculations are quite complicated too e.g., generating accurate U-values for hot water pipes, and involves lots of assumptions.

#### **Building input data-elements**

- ⊙ Should allow direct input of U-values as well as calculating in the sheet
- ⊙ Calculating U-values is more complicated than it would appear to be in the sheet – for example, mixed layers, wall ties and surface types should be included.
- ⊙ If calculating U-values, standard lookup values for parts of elements should be provided e.g., thermal conductivity for bricks, blocks etc., otherwise there is inconsistency.
- ⊙ In the future, it would be good to allow more than one wall, floor type etc.

#### **Building input data-Services section**

- ⊙ U-value for heat pipelines - is this needed?
- ⊙ Do you need the number of heaters with thermostats? Would a whole dwelling heating control be better?
- ⊙ Allowance if the property doesn't have mechanical ventilation (most of UK)
- ⊙ Does primary energy demand allow for external temperatures?
- ⊙ Could the 'code No' be clarified and be unique?
- ⊙ Total energy consumption – what is this based on?

## 3 ANNEX

### 3.1 Questionnaires

Table 4: Exemplary questionnaire for in-building tests

General questions and testing steps	
	Provide a short summary of the test you are carrying out. Please describe in your words.
	Overall, how easy or difficult was the feature to implement? Please select an option.
	How easy or difficult was it to explain the feature to the assessor and/or other stakeholders involved in delivering the test? Please select an option.
	List all of the planned steps for implementing the feature. Please list performed tasks in each step
	Were you able to perform each step? Please select an option for each step
	[Only answer this question for options you selected "No" or "In part" in previous question] Why were you not able to perform or complete these steps? Please describe in your words.
	[Only answer this question if you were able to perform the step and you faced any challenges] Did you face any challenges in steps that you were able to complete (for those you answered "Yes")? Please describe in your words.
	Overall, how feasible is it to include the feature as part of a standard EPC assessment? Please select an option.
	Explain your answer to the above question. Please describe in your words.
Testing time & costs	
	How much time (in minutes) did it take to perform each step
	What are the approximate costs incurred in each step? Please specify the positions as well as an approximate estimate. (Costs per EPC)
Cross Cutting Criteria	
	<b>Quality and Reliability</b>
	Are the calculation methods clearly described?
	Is the required input data clearly asked?
	Is the user provided fundamental technical knowledge needed to understand the details of the feature?
	Is training of experts/assessors needed for the feature?
	Are the results shown transparently?
	Does the user have access to formulas/application interface?
	Does the user have access to weightages for the calculation of results?
	Are measures foreseen to ensure that data collected is verified (e.g. completeness, accuracy timelines etc.)?
	Is training of experts/assessors needed for the feature?
	<b>User-friendliness</b>
	Are the technical terms used provided in a glossary?
	Are the references to documents provided?
	Is the stepwise description for feature assessment provided?
	Are the results presented in graphical way?
	Did you consider the impact of graphical results on the user?

	Does the evaluation of the feature consider flexibility to adapt the methodology to different building types?
	Are the multiple-benefits (health, energy, cost saving etc.) of the feature studied?
<b>Economic feasibility</b>	
	Does this feature increase EPC costs?
	Does the methodology require additional data to the one already included in current EPC derivation?
	If additional data is required, does it take longer than 1 hour to gather them?
	Is an additional on-site visit or measurement needed?
<b>Consistency with ISO/CEN standards</b>	
	Have any national regulations been used in the methodology of this feature? If yes, which one?
	Is the data used for the feature already covered by the current EPC?
<b>Final thoughts</b>	
	Do you have any suggestions for improving this feature? For example, the description, recommendations, modules, or calculation methodology. Please describe in your words. Do you have any other comments? Please describe in your words.

Table 5: Exemplary questionnaire for system test

<b>Questions</b>	
	Provide a short summary of the test you are carrying out. Please describe in your words.
	Overall, how easy or difficult was the feature to implement? Please select an option.
	List all of the key changes you planned to make to the existing 'back-end' EPC systems to enable the feature. Include all changes, whether they were successfully implemented or not. Please put a small description (5 words or less) for each change in a cell.
	Were you able to perform each planned change? Please select an option for each change.
	[Only answer this question for options you selected "No" or "In part" in previous question] Why were you not able to perform or complete these steps? Please describe in your words.
	What are the major challenges in implementing the new feature? Please describe in your words.
	What are the main advantages of the feature? Please describe in your words.
	Explain the major areas of monetary cost in implementing the new feature. Please describe in your words.
	What can be done to minimise the monetary cost in each area? Please describe in your words.
<b>Cross Cutting Criteria</b>	
<b>Quality and Reliability</b>	
	Are the calculation methods clearly described?
	Is the required input data clearly asked?
	Are the results shown transparently?
	Does the user have access to formulas/application interface?
	Does the user have access to weightages for the calculation of final results?
	Are the specific requirements to carry out the assessment outlined for assessors?
	Is training of experts/assessors needed for the feature?
	Are the qualification requirements clearly outlined for experts/assessors?
<b>User-friendliness</b>	
	Is the stepwise description for feature assessment provided?
	Are reporting templates used?
	Is the calculation/process description provided in guidelines?
	Does the tool have stepwise description of the assessment?
<b>Economic feasibility</b>	
	Does the implementing need additional infrastructure in the form of servers, programs, ...? If so, are these costs higher than €1000 to purchase, according to a rough estimation?
	Are there high skills (for example: IT and programming knowledge) required to implement and handle the feature?
<b>Consistency with ISO/CEN standards</b>	
	Have any national regulations been used in the methodology of this feature? If yes, which one?
	Is the data used for the feature already covered by the current EPC?
<b>Final thoughts</b>	
	Do you have any suggestions for improving this feature? For example, the description, recommendations, modules, or calculation methodology. Please describe in your words.
	Do you have any other comments? Please describe in your words.

Table 6: Exemplary questionnaire for user tests

Questions	
	Provide a short summary of the test you are carrying out. Please describe in your words.
	List all of the planned steps for delivering the test. Please put a small description (5 words or less) for each step in a cell.
	Were you able to perform each planned step? Please select an option for each step.
	[Only answer this question for options you selected "No" or "In part" in previous question] Why were you not able to perform or complete these steps? Please describe in your words.
	[Only answer this question if you were able to perform the step and you faced any challenges] Did you face any challenges in steps that you were able to complete (for those you answered "Yes")? Please describe in your words.
	How well did the users understand the feature? Please select an option. (Only answer if a question regarding perception was in the questionnaire)
	What did the test tell you about how much users find the feature useful? Please select an option.
	What did the test tell you about how much users liked or disliked the feature? Please select an option.
	What did the test tell you about how users would use the information provided in the new feature? Please describe in your words.
	List the headline quantified results from your test, for example, the percentage of users who found the feature useful. Please describe in your words. (Please provide at least the top 3 findings)
	Did users make any suggestions for changing the feature? Please describe in your words.
New questions	
	Please describe the participation in the survey (number of participants, potentially split to different target groups; share of returned questionnaires)
	Please describe the objective of the survey
	Please describe the main questions asked
	Please describe the main findings of the survey
	Please provide us with quantitative results in the form of additional xls file as much as possible (e.g. anonymised filled questions or aggregated results of the survey questionnaires)
Testing time	
	How much time (in minutes) did it take to perform each step
Final thoughts	
	Do you have any suggestions for improving this feature? For example, the description, recommendations, modules, or calculation methodology. Please describe in your words.
	Do you have any other comments? Please describe in your words.





eXTENDING the energy performance assessment and  
certification schemes via a mOdular approach



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