EXPLORING INNOVATIVE INDICATORS FOR THE NEXT-GENERATION ENERGY PERFORMANCE CERTIFICATES FEATURES - DISTRICT ENERGY

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Exploring innovative indicators for the next-generation EPC features

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EXECUTIVE SUMMARY

Energy performance certificate (EPC) schemes have not evolved much since their first introduction in the Member States to meet the mandatory requirements of the Energy Performance of Buildings Directive (EPBD). Stakeholders have questioned their reliability but at the same time, they have been useful for the real estate industry. All the Member States have legislation in place and existing infrastructure or systems to run EPC schemes. These schemes require evolution with the changing needs of the built environment and requirements to look beyond the energy consumption of buildings to take in elements such as better indoor comfort, reducing air pollution and others. Public authorities view them as potential instruments to improve the performance of the existing and new building stock. Extending the functionalities of existing systems will create several pathways to update and manage next-generation EPCs.

This report presents the preliminary scoping and analysis of the five technical features related to developing innovative EPC indicators proposed within X-tendo[1]: (i) smart readiness, (ii) comfort, (iii) outdoor air pollution, (iv) real energy consumption, and (v) district energy. The outcome of this report is an initial mapping and selection of the suitable options of methods for developing indicators for these five features. The follow-up activities in the project will take forward this work to elaborate and provide technical specifications of the methodologies and concepts for the five features.

This report presents an overview of existing assessment approaches and methodologies for each feature that could be adopted in the indicator development for the EPCs. Details are provided of the most suitable existing methods that can be applied in the assessment of five technical indicators when integrated with EPCs. Their suitability and applicability to EPCs is analysed in a broader context, including building typologies and ranking/scoring techniques.

The report also evaluates existing links between these methods and the energy performance of a building/EPCs to determine how these can be integrated in the feature development. Since most of the assessment methods require some type of data related to end-users, therefore, their legal boundaries are also studied. Within the scoping and analysis, a ranking and SWOT analysis of several methods is presented to assess their suitability and feasibility of application in the development of the new features. Finally, a conceptual approach is proposed for the development of each of the five features. Findings are presented, highlighting the barriers, challenges and limitations of the assessment methods for the five features.

Across all features, the following conclusions are made:

Indicators

[1] In addition to these five features, X-tendo will also provide a set of five features dealing with innovative handling of EPC data.

- 'Smart readiness' approach presents a potential method for assessing the smartness of buildings with nine domains (e.g. lighting, ventilation, envelope, monitoring and control etc.)
- 'Comfort' approach incorporates four key indicators – thermal, visual and acoustic comfort and indoor air quality – to be assessed through checklists, on-site measurements and surveys
- 'Outdoor air pollution' approach addresses a building's impact on air by two methods: an outdoor air pollution contribution index and indoor air purity index
- 'Real energy consumption' approach outlines an assessment method based on operational ratings, with options for normalisation to allow for better inter-building comparison
- 'District energy' approach focuses on predicting the potential for future development for buildings via two methods: expected future performance of district heating and heat distribution and transfer system

Cross-cutting issues

- Technical challenges that constrain the application of existing methods such as assessment time, accuracy, normalisation process, variable definitions and emission factors could be overcome by certain modifications in approach
- Features should be aligned financially to increase market acceptance and cost-effective assessments during the development
- Legal and governance issues should be addressed by dealing with challenges such as development of universal methodologies, presence of multiple standards at Member State level, control of citizen data and privacy, and acceptance of future estimations by public authorities
- From a social perspective, user acceptance and public understating of the features are key issues and should be considered in feature development
- If these indicators are well integrated within EPCs, significant environmental benefits are anticipated
- Future implementation of indicators can be strengthened by addressing lack of industry readiness, understanding of anticipated benefits and enforcement issues

Certain limitations need to be overcome to implement these innovative indicators, such as variable levels of implementation in the Member States due to different local requirements and regulations. Some indicators require extensive monitoring and measurements, and a lack or absence of data is a barrier in the development and acceptance of these features within EPC schemes.

A concise overview of all the features is given in Figure 1. Overall, a promising picture is visible with the proposed conceptual approaches for features combining new ideas with existing methods to work towards developing innovative indicators that could be tested and integrated into the EPC schemes of the implementing countries within the X-tendo project.

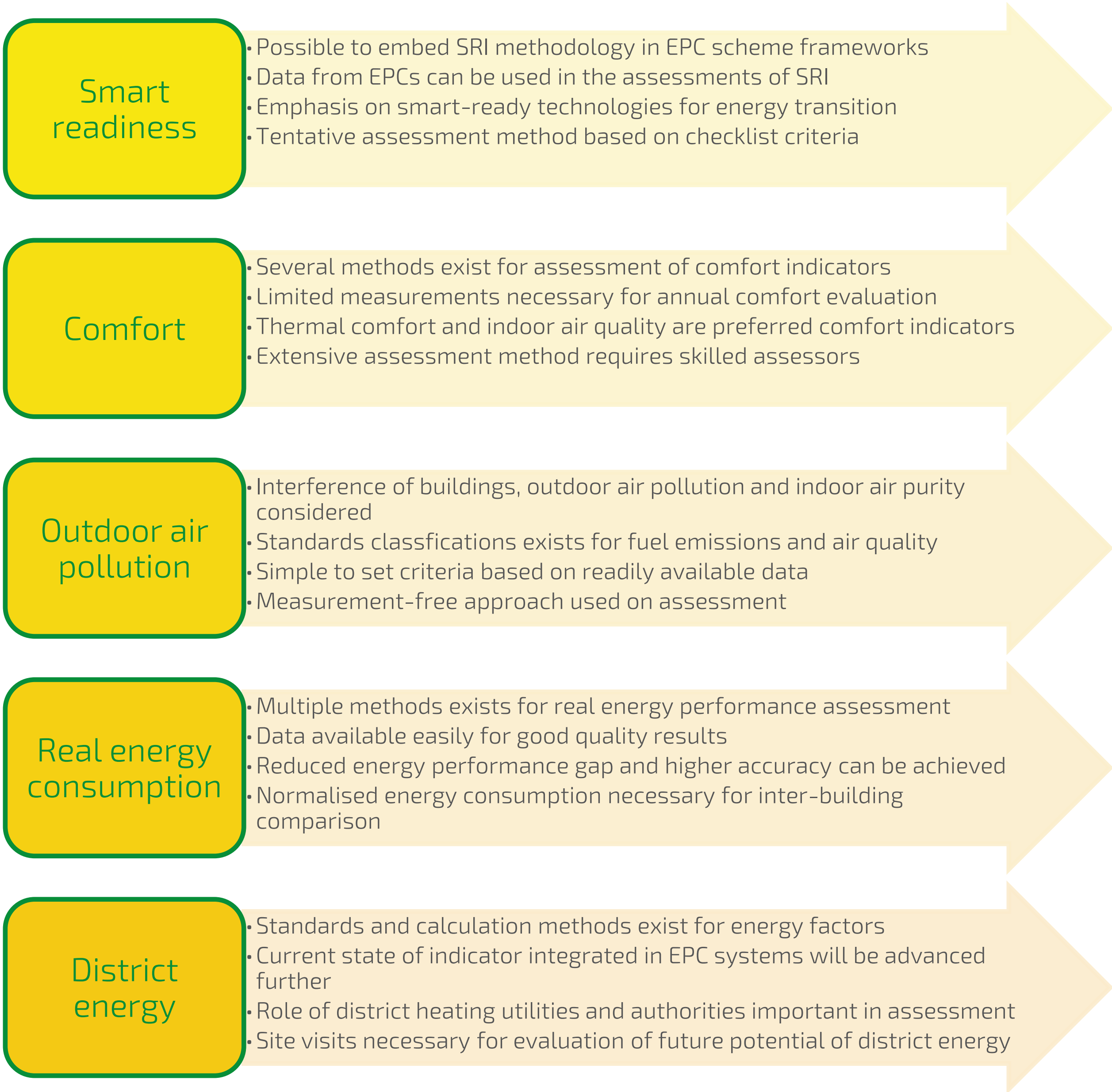

Figure 1: Overview of the five features

1 EXTENDING THE FUNCTIONALITIES OF EPCs WITH INNOVATIVE INDICATORS: SCOPING AND ANALYSIS

Energy performance certificates (EPCs) are the key source of information on the energy performance of the building stock [1]. Their role for the end-user and the real estate sector has mainly been limited to indicating and comparing the energy class of the building, helping to regulate property transaction prices and rents. They have also been attractive for end-users and builders in gaining access to funds and incentives to conduct energy efficiency improvements. EPCs have also been seen as an unreliable source of information by stakeholders in some Member States [2]. Weak enforcement, low public acceptance and awareness, quality of audits, qualifications of the auditors and widely varying certificate costs all influence the role of EPCs and how they can affect the real estate market.

Many Member States stepped up efforts in the last decade to improve their EPC frameworks after the introduction of the requirement of energy performance and assessment systems under the EPBD (2002/91/EC) and EPBD recast (2010/31/EU). The recent amendments in the EPBD (2018/844) further strengthened the existing provisions by setting out that Member States should provide information to owners and tenants on the purpose and objectives of EPCs, energy efficiency measures, and supporting financial instruments through accessible and transparent advisory tools such as direct advice and one-stop-shops.

In the current scenario, EPCs are viewed as instruments that can bring additional benefits to the end-user (e.g. property seller, buyer, or tenant) by being a vehicle for additional information other than energy efficiency.

1.1 Aim of the X-tendo project

The X-tendo project is developing a framework of 10 “next-generation EPC features”, aiming to improve compliance, usability, and reliability of the EPC. The X-tendo partners cover 10 countries or regions – Austria, Belgium (Flanders) Denmark, Estonia, Greece, Italy, Poland, Portugal, Romania, and the UK (Scotland) as displayed in Figure 2.

Figure 2: X-tendo consortium and target countries

The X-tendo project approaches next-generation EPCs by exploring 10 new features in addition to their existing functionalities (see Figure 3). The features that will be explored in the project fall into two broad categories:

- New technical features used within EPC assessment processes and enabling the inclusion of new indicators in EPCs
  1) Smart readiness
  2) Comfort
  3) Outdoor air pollution
  4) Real energy consumption
  5) District energy
- Innovative approaches to handle EPC data and maximise its value for building owners and other end-users.
  6) EPC databases
  7) Building logbook
  8) Tailored recommendations
  9) Financing options
  10) One-stop-shops

Figure 3: The X-tendo toolbox representing both innovative EPC indicators and novel ways of handling EPC data

Existing EPC schemes lack focussed vision. In order to become a catalyst for energy renovations, the next-generation EPC must provide an improved and more reliable service to the end-users. The key output of the project will be the X-tendo toolbox, a freely available online knowledge hub that will be continued beyond the project duration. For each feature, the toolbox would include (i) solution concepts and good practice examples, (ii) descriptions of methodological approaches, (iii) calculation tools, and (iv) implementation guidelines and recommendations.

1.2 Scope and objective of this report

The purpose of this report is to identify suitable methods and approaches to assess the five features (i) smart readiness, (ii) comfort, (iii) outdoor air pollution, (iv) real energy consumption, (v) district energy. Before developing individual methods for their assessment, a detailed review of the existing assessment and calculation methods is presented for developing the indicators for all the five features in this report. Although the goal of the next-generation EPC will be more holistic, the relation with energy performance remains a key boundary condition for the selected approaches presented in this report.

The identification of the suitable methods will consider the objective of the modular toolbox being developed specifically for EPC assessments. The results of the report will be an initial selection of options for methods and indicators for features 1-5. Findings of the scoping and analysis are gathered in this report for these indicators.

Table 1 lists the five innovative EPC indicators that could make EPCs more than just an informative tool. It also indicates the feature leads (VITO, BPIE, NAPE and e-think) who will develop the innovative indicators and organisations (EASt, DEA, TREA, CRES, ENEA, NAPE, ADENE, AAECR and EST) from implementing/expert partner countries that would support them in the development and testing of the indicators on several test projects.

Table 1: Innovative EPC indicators

	 Smart readiness	 Comfort	 Outdoor air pollution	 Real energy consumption	 District energy
Feature lead	*VITO*	*BPIE*	*NAPE*	*VITO*	*e-think*
EASt (Austria/Styria)	Implementer	Implementer		Implementer	
DEA (Denmark)	Implementer	Implementer			Expert
TREA (Estonia)	Implementer/ Expert			Implementer	
CRES (Greece)	Implementer	Implementer			
ENEA (Italy)				Implementer	Implementer
NAPE (Poland)			Implementer/ Expert		Implementer
ADENE (Portugal)		Implementer			
AAECR (Romania)	Implementer	Implementer		Implementer/ Expert	Implementer
EST (UK)				Implementer	

The EPCs can become much more useful for the end-users, public authorities and policymakers by providing more detailed information on the existing building stock and its performance. Next-generation EPCs can support the transition to a low-carbon building sector, provided they are revised considering new indicators, with effective mechanisms to ensure compliance and high quality, reliable certifications.

2 FEATURE 5: DISTRICT ENERGY

2.1 Strategic value of the neighbourhood for district energy

To achieve a decarbonised built environment, district heating (and cooling) has a key role. Numerous studies have shown that especially in densely populated areas district heating and cooling using renewable and excess heat from various sources are cheaper than renovating the buildings to a very low level of heat demand (e.g. Heat Roadmap Europe, progRESsHEAT, Hotmaps). In order to reach a 100% renewable energy system by mid-century numerous existing buildings have to be connected to an existing or a newly built district heating and cooling system.

In order to estimate the suitability of a neighbourhood for district energy various approaches exist. In Denmark, since the 1970s the entire country has been classified into three types of regions regarding the feasibility of different heat supply types: district heating areas, gas network areas and individual areas. These have been calculated according to national standards [128]. In district heating areas all buildings must be connected to district heating, and in gas network areas all buildings must be connected to the gas network. Thus, in Denmark this is used as a regulatory instrument.

Since the adoption of the EU Energy Efficiency Directive in 2012, all Member States must perform a comprehensive assessment of efficient heating and cooling in their countries. This includes a mapping of current demand for heating and cooling, potential future development of this demand, mapping of resource potentials, and an assessment of the technical and economic feasibility of different saving and supply options, both via district heating and via individual heating. These analyses could serve as a basis for the identification of district heating priority areas. If a building is located in a district energy priority area, this information could potentially be integrated into its EPC in order to increase the awareness of the building owners, renters, tenants, facility managers etc. on potential connections to district heating/cooling in the future. They would then be informed that potentially in the near to mid-term the public authority might implement an obligation for connecting the building to district energy.

Within the Horizon 2020 project Hotmaps a heat demand density map for the whole of Europe at a 100 x 100 m resolution has been developed [129]. This data is freely available and usable. Furthermore, a simple calculation module for identifying potential district heating areas based on thresholds for heat demand density and overall heat demand in connected areas has been derived [130]. The map together with the calculation module could be used to identify suitable regions for district heating. This information could then be made accessible for integration into EPCs around Europe. However, a number of open questions have to be clarified before the integration of such information into EPCs would be possible: e.g. Which threshold values for the identification of areas suitable for district heating should be used in the developed module? What data should be used for this estimation: EU wide estimations, as described before, if no local data is available? How valuable is this information in an EPC, if it is not based on local data? How should such information then be presented in EPCs in order to be clear that this might be a rough estimation?

Such strategic information related to the importance of a neighbourhood for district heating in a future energy system could become relevant for EPCs in the coming years. Currently, no database on buildings and buildings' energy demand for heating and cooling is available for all locations in Europe that could be used for deriving reliable estimations of the importance of single buildings for district heating systems in order to be integrated into EPC schemes. However, several regions across Europe are working to set up reliable databases to identify district heating priority areas. Such information could also be presented in EPCs. In X-tendo, an indicator will not be derived estimating the importance of a neighbourhood for district heating in a future low-carbon energy system, as such indicators depend largely on regional initiatives and their use for building owners, tenants or planners will be limited. Instead, two other indicators will be developed related to district energy: an indicator reflecting the future development of district heating systems and an indicator on the suitability of the building for low temperature district heating and thus to allow for the development of more efficient and less carbon-intensive district heating systems. These will be explained in detail in the following chapters.

2.2 Overview of the assessment methods for district energy indicator

The aim of the district energy indicator is to develop the capacity of EPCs to assess and report on the potential for the building to benefit from or contribute to future development of district heating (and if relevant also district cooling) networks. This concern:

- The future decarbonisation of heat generation in district heating systems
- The required transformation of district heating towards fourth generation (smart, lower temperature) systems.

In this context two different indicators/methods will be developed:

- Indicators to consider present and medium-term planned development of local district heating in the primary energy factors (PEFs) and carbon emission factors (CEFs) used in EPCs
- Indicators for the expectable supply line and return temperatures in the building's heat distribution and transfer system.

This feature is, therefore, directed towards two different target groups:

- Building owners/builders/designers should be provided with indicators to assist in making the building fit for fourth generation district heating.
- Public authorities should be provided with indicators on the future development plans of district heating utilities.

Medium-term development of primary energy, renewable energy and carbon emission factors of district heating systems

The EPBD recast 2010/31/EU states that Member States shall increase the number of NZEBs in their countries. In this context, a numerical indicator of primary energy consumption should be included for characterising the buildings' energy efficiency (Article

9). Furthermore, the EPC should provide information about the actual impact of heating and cooling on the energy needs of the building, on its primary energy consumption and on its carbon emissions [24].

In order to calculate the primary energy consumption of a building a relation between the energy need of the building and the primary energy consumption is needed. This ratio is called the primary energy factor (PEF). To comply with the EPBD recast many Member States have implemented methods for calculating PEFs for different heating and cooling supply systems. This is also the case for PEFs from heat supply via district heating.

Latõšov et al. [131] have analysed the applied national standards and regulations for setting or calculating the PEFs for district heating in different Member States. They found that many of the methods applied can be classified into the following three categories:

- Use of single fixed values:
  - A national authority sets one single value for district heating PEF to be used for all district heating systems in the country
  - This is applied in the following countries: Bulgaria, Denmark, Estonia, Finland and France
  - Denmark is a special case: three different values of PEF are applied depending whether the building complies with different renovation standards.
- Use of differentiated fixed values:
  - For different types of supply in district heating different PEFs are defined by a national authority
  - Differences between countries regarding supply technologies for which PEFs are defined and how they are applied to the different district heating systems
  - This is applied in Austria, Czechia, Hungary, Slovakia, Slovenia, Latvia, Lithuania and the UK.
  - In Austria a detailed calculation according to EN 15316-4-5 is also allowed [132]

- Use of values calculated for each district heating network:
  - For each district heating network in the country a PEF is calculated
  - This is applied in Poland, Italy and Germany.

Thus, methods for deriving the PEF for the use of calculating primary energy demand in buildings vary remarkably between different countries in the EU.

Supply line and expectable return temperatures in the heat distribution system of the building

The temperature level (supply/return line temperature) of the heat distribution system within buildings influences the efficiency of heat supply systems. This becomes especially important when low-exergy heat supply systems are used. This means that heat supply technologies such as solar thermal, heat pumps or fourth generation district heating networks (low temperature district heating) can only be efficiently implemented where the heat distribution system inside buildings is designed to work at low temperature levels. In order to evaluate the potential for changing a building's energy supply system towards more efficient systems, it would be beneficial to include the temperatures in the heat distribution system in the EPC of a building. Further details are discussed in Section 2.3.

2.3 Description of approaches used for the assessment of district energy

2.3.1 Integrating primary energy, renewable energy, and carbon emission factors in EPCs

In the following section, we describe the standard calculation in EN 15316-4-5:2017 [132], which is applied or can be used alternatively in several Member States. Also, we describe the methods used in Poland, Italy and Germany. We also focus on aspects of the implementation of the legal procedure to set the ground for suggesting a new indicator for expectable future development of the PEF for a selected district heating network.

- **EN 15316-4-5:2017** [132]

This standard provides a general framework for factors, which weights various parts of the district heating network (in principle also for district cooling networks) corresponding to their part of energy in the system. This formula for example can be used to calculate the PEF (and the corresponding carbon emission factor and renewable energy factor) for a district heating network that has several different heat supply units and exports energy. The exported energy could be in the form of electricity from a combined heat and power (CHP) unit.

$$f_{we;des} = \frac{\sum_{cr} E_{in;cr} * f_{we;cr} - E_{exp} * f_{we;exp}}{\sum E_{del}}$$

where

- $f_{we;des}$ weighting factor of the energy system
- $E_{in;cr}$ energy content of the energy carrier supplied to the system (cr)
- $f_{we;cr}$ weighting factor of the energy carrier (cr)
- E_{exp} energy emitted to an external system or external network
- $f_{we;exp}$ weighting factor of external energy
- E_{del} total delivered energy

In addition to this weighting formula, the standard provides formulas for evaluating a renewable energy factor, an excess heat factor and a CHP portion. On the supply side most of the data in the standard is dedicated to diverse types of CHP technologies. In addition, there is a small portion of handling excess heat and waste incineration plants. Appendix B in EN 15316-4-5:2017 offers key data for the calculation such as emission factors, renewable energy factors and some values for identifying the network losses, such as a heat loss value for new and old networks and electrical energy used by the pumps.

- **Calculation and reporting of PEFs in Poland**

In Poland, where district heating is used to supply the heat in a building, the primary energy resource factor (PRF) of the district heating system must be integrated in the EPC. The PRF is equivalent to the PEF as used in this document. The value of the PRF should be provided by the district heating company to calculate primary energy consumption of a building connected to the network. In theory, district heating companies are obliged to publish a PRF value each year on the basis of the previous year's consumption of fuels and sales of heat. However, not all district heating companies fulfil this requirement. A methodology for calculation of the PRF from district heating is given in the Regulation of the Minister of Energy of October 5, 2017 [133] regarding the detailed scope and method of preparing an energy efficiency audit and methods of calculating energy savings.

The PRF, marked with the symbol "$W_{P,c}$", for the heating network, regardless of the amount and type of heat sources and technologies used to generate and supply heat to the final customer, is calculated according to the following formula:

$$W_{P,i} = \frac{\sum_i(w_{P,i} * H_{ch,i}) - \sum_l(w_{el} * E_l)}{\sum Q_{K,i}}$$

where

- $w_{P,I}$ coefficient of non-renewable primary energy input, appropriate for the final energy carrier concerned, as appropriate fuel or energy source used
- $H_{ch,I}$ amount of energy introduced in the fuel, including biomass or biogas, up to heat sources supplying heat to a given heating network, both for boilers of the heating part and cogeneration units, calculated as the product of the amount of this fuel and its calorific value, as well as the amount of heat waste from industrial installations or the amount of heat generated in renewable energy installations (excluding biomass or biogas sources already used to supply heat to the network) per calendar year preceding the year in which the assessment is made, expressed in *MWh / year*
- w_{el} coefficient of non-renewable primary energy input for electricity from mixed production, as specified in the table in the Regulation of the Minister of Energy
- E_l the sum of the gross amount of electricity measured at the generators, generated annually from a cogeneration system, per calendar year p preceding the year in which the assessment is made, expressed in *MWh / year*
- $Q_{K,I}$ amount of heat delivered from the heating network to consumers in the calendar year preceding the year in which the assessment is made, expressed in *MWh / year*

Calculation and reporting of PEFs in Italy

If the building (or the building unit) is connected to a district heating network, the annual amount of energy deriving from district heating calculated in standard use conditions is indicated on the EPC. The primary energy performance index, based on which the building energy class is determined, depends on this energy calculation. The building's thermal energy needs are calculated according to the Italian National Technical Standard UNI/TS 11300-1/2014 [134], independently of the heat generation system. With a connection to a district heating system, energy loss factors related to the customer substation are calculated according to the Italian National Technical Standard UNI/TS 11300-4/2016 [135] and applied. In this way, the thermal energy supplied, in standard use conditions, by the district heating system to the customer substation is calculated. Consequently, with the application of the PEF of the thermal energy distributed by the district heating network, the annual primary energy is calculated. The PEF must be provided by the district heating utility.

According to the Decree of the Minister of Economic Development "DM 26/06/2015", concerning the application of the methodologies for calculating the energy performance of buildings [136], district heating and district cooling utilities need a certification for the PEF of the thermal energy supplied to buildings. The certification must be issued by an accredited certification body.

The certification procedure is not yet available and, as regards the national legislation, it is possible for district heating and district cooling utilities to use the current technical standards for the calculation of the primary energy conversion factor: UNI EN 15316-4-5/2008, which is the transposition for Italy of EN 15316-4-5/2007. The more recent Standard UNI EN 15316/2018 (transposition for Italy of EN 15316/2017) is not yet applicable in Italy, as the national annexes and modules are under development. If the utility is not providing the PEF for the thermal energy delivered at the building substation, a "reference" value (fixed at 1.5 by DM 26/06/2015 [136]) has to be considered.

⦿ Calculation and reporting of PEFs in Germany

In Germany, the calculation of the PEF is performed according to regulation FW 309 published by the German District Heating Association AGFW [137]. The calculation follows the power bonus approach principle. The calculation of the PEFs of the different supply plants can be modelled in a process chain using life-cycle data from various sources. Alternatively, such factors are given in the regulation. However, for each district heating network a primary energy factor must be calculated based on the supply technologies used in the network and the split of energy supplied by these technologies.

The calculation of the PEF for each network must be performed by a certified expert. Experts are certified by the AGFW according to regulation FW 609 [136]. They must have a finished engineering degree or technical career and several years of working expertise in the field of (district) heating and cooling and must pass an exam to become certified. The certification for each expert must be renewed regularly. In order to do so, different options are stated in regulation FW 609, e.g. repeating the exam or taking part in regular experience exchange. Also, the expert calculating the PEF for a specific network must prove their independence from the network utility.

For calculating the PEF the district heating utility sends data on the heat, fuel and electricity balance of the network to the certified expert. The expert then calculates the PEF according to regulation FW 309. All data as well as the calculation is then sent to AGFW, which proofs the data and the calculation. If the calculation is approved the certificate is issued and sent to the utility as well as published on the DESI website [138].

Certificates have a validity of three years in general. If the calculation is based on balancing data of a period of at least three years, the validity of the certificate can be prolonged to 10 years. While the PEF is calculated within the FW 309 framework, no renewable or carbon emission factors are included. Also, potential future development of the PEF for the district heating network under consideration is not included in the procedure.

Calculation and reporting of PEFs in the Netherlands

In the Netherlands, district heating and cooling companies have to calculate their primary energy and carbon emission factors according to the method stated in the standard NEN 7125:2017 [139]. All the following calculations are done periodically and normally once a year.

The PEF of the distribution grid is determined with the following formula, if all of the incoming and outgoing energy flows are measured values.

$$f_{P;XD;tot} = \frac{\sum_{ci}\left(E_{XD;in1;ci} * f_{P;del;ci}\right) - E_{XD;exp1;el} * f_{P;exp;el} + \sum_{ci}\left(E_{XD;in2;ci} * f_{P;del;ci} * \Delta\varepsilon_{chp;el} * f_{P;exp;el}\right)}{Q_{XD;out;tot}}$$

If the values for the incoming and outgoing energy flows are calculated and possibly measured the following formula is applied:

$$f_{P;XD;tot} = \frac{f_{XD;gen;tot}}{\eta_{XD;dis}} + \frac{W_{XD;aux;tot}}{Q_{XD;out;tot}} * f_{P;del;el}$$

where

- $f_{P;XD;tot}$ primary energy factor of the district heating or cooling grid.
- $E_{XD;in1;ci}$ energy consumption by the energy system per energy carrier c_i on an annual basis, for all generators with the exception of CHP, *in MJ*
- $f_{P;del;ci}$ primary energy factor for the relevant energy carrier
- $E_{XD;exp1;ci}$ supply of electricity by the energy system for all generators with the exception of CHP, *in MJ*
- $f_{P;exp;el}$ primary energy factor for exported electricity
- $E_{XD;in2;ci}$ energy consumption by the energy system per energy carrier c_i on an annual basis, exclusively for CHP, *in MJ*
- $\Delta\varepsilon_{chp;el}$ annual average loss of the electrical conversion number of the CHP installation
- $Q_{XD;out;tot}$ total annual customer demand for heat or cold in the network, *in MJ*
- $f_{XD;gen;tot}$ primary energy factor of the heat or cold supply by the joint heat or cold generators through the network
- $\eta_{XD;dis}$ distribution efficiency of the distribution network per year
- $W_{XD;aux;tot}$ annual amount of purchased electrical auxiliary energy for the collective energy system, *in MJ*
- $Q_{XD;out;tot}$ heat or cold supply from the energy system to the customer I on an annual basis, *in MJ*

- $f_{P;del;el}$ primary energy factor for energy purchased on one's own plot for electricity

The calculation of the CO_2 emission coefficients also differs depending on whether all energy flows are measured, or are available as a mix of measured and calculated values.

If all of the energy flows are measured the CO_2 emission coefficients can be determined by two methods. In method A, the reference plant supplies the fossil share of the lost electricity. This means that the required fuel and emissions are allocated to the heat supplied by CHP.

$$K_{CO2;XD;until} = \frac{\sum_{ci}\left(E_{XD;in1;ci} * K_{CO2;del;ci}\right) - E_{XD;exp1;el} * K_{CO2;exp;el} + \sum_{ci}(E_{XD;in2;ci} * f_{p;del;ci} * \Delta\varepsilon_{chp;el} * K_{CO2;exp;el})}{Q_{XD;out:until}}$$

In method B, the efficiency of the reference plant is only used to determine which part of the fossil fuel and emissions from the CHP is attributed to the heat supply.

$$K_{CO2;XD;tot} = \frac{\sum_{ci}\left(E_{XD;in1;ci} * K_{CO2;del;ci}\right) - E_{XD;exp1;el} * K_{CO2;exp;el} + \sum_{ci}(E_{XD;in2;ci} * K_{CO2;del;ci} * \Delta\varepsilon_{chp;el} * f_{P;exp;el})}{Q_{XD;out:until}}$$

If the values of the incoming and outgoing energy flows are calculated and possibly measured the following formula is used.

$$K_{CO2;XD;until} = \frac{K_{CO2;XD;gen;tot}}{\eta_{XD;dis}} + \frac{W_{XD;aux;tot}}{Q_{XD;out;tot}} * K_{CO2;del;el}$$

where the new symbols mean:

- $K_{CO2;del;ci}$ CO_2 emission coefficient for purchased energy for the relevant energy carrier c_i
- $K_{CO2;exp;el}$ CO_2 emission coefficient for exported electricity
- $K_{CO2;XD;gen;tot}$ CO_2 emission coefficient of the heat or cold supply by the joint heat or cold generators through the network. Where XD stands for HD, WD, CD (heat distribution network, hot tap water distribution network, and cold distribution network)

The standard provides different calculations of the energy factor and carbon emission factor for the three types of distribution networks (heat, hot tap water, cold). Each of these calculations is separated into three main parts: the calculation of distribution losses of the network, the calculation of the energy factor for the supply and the calculation of the auxiliary energy. The calculation of the renewable energy, primary energy and carbon emission factors for a network can be determined when knowing the supply of heat/cold to the network via different technologies together with the auxiliary energy and the heat/cold supplied to the customers. Where the heat supplied to the customers is not known or measured, e.g. if the district heating system is under construction, the heat/cold supplied to the customer is calculated via estimating the distribution losses in the network.

⦿ Distribution losses in the network

If measured data on the total amount of heat delivered to the customers and the total amount of heat fed into the network is available, this can be used. Otherwise, a standard calculation is provided. This calculation is based on the monthly average temperature of the water in the distribution network and the monthly average ambient temperature. With these values and several other parameters regarding the pipes, such as heat resistance, the monthly heat losses are calculated and summed for the yearly total heat loss according to the following formula:

$$Q_{net;total} = \sum_{mo} t_{mo} * \sum_{j} \left(\frac{L_j * (T_{net;mo} - T_{amb;mo}}{R_{net}} \right)$$

where

- $Q_{net;total}$ total distribution losses in the network over one year, *in MJ*
- t_{mo} number of days in the respective month *mo*
- L_j length of the pipes in network part *j*, *in m*
- $T_{net;mo}$ average temperature of the water in the distribution network in month *mo*, *in °C*
- $T_{amb;mo}$ average ambient temperature around the distribution pipes in month *mo*, *in °C*
- R_{net} specific thermal resistance of the pipes in the network part *j*, *in Km/W*

⦿ Energy factor heat generation for collective heat supply

The calculation of the PEF and CO_2 emission coefficient is divided into two temperature levels (low and high temperature). The standard [139] also provides different calculations for different heat supply technologies such as gas or oil-fired boilers, heat pumps, cogeneration installations, residual heat, geothermal energy, intermediate collective heat supply and collective solar collectors.

⦿ Auxiliary energy

The auxiliary energy is modelled in three parts: the annual amount of purchased electrical auxiliary energy for the distribution network (for pumps), the annual amount of used auxiliary electrical energy from solar energy systems for space heating and hot water (which can also be calculated with formulas given in the standard) and the annual amount of purchased auxiliary electrical energy for the generators. These three sources are summed to give the overall auxiliary energy demand.

2.3.2 Indicators related to supply line and expectable return temperatures in the heat distribution system of the building

In the following we discuss different indicators related to the temperatures in the building's heat distribution systems that could be integrated into EPCs.

⊙ Flow and return temperature of the heat distribution system in the building

The required heat load of a given building with its technical properties (e.g. average thermal resistance of envelope, airtightness, compactness, etc.) and site-specific properties (orientation, solar gains, etc.) varies over time depending on different factors, most importantly the outdoor/ambient temperature and the share of the floor area that needs to be heated at a certain moment. This implies that the temperature levels (supply and/or return line temperature) of the heat distribution systems typically vary over time. While the supply line temperature level might be controlled by more recent boiler technologies, heat pumps or district heating networks, it remains constant or needs to be set manually for older boiler technologies. The return line temperature, on the other hand, is defined by supply line temperature, the thermal energy that is transferred by radiators and pipes to the indoor environment and the flow rate through the piping system. In contrast to the supply line temperature, the return line temperature is more difficult to control. Additional sensors and processing units are needed, which are available from a technical point of view, but not yet implemented in most buildings. In theory, the resulting return line temperature could also be calculated, e.g. by considering the logarithmic mean temperature difference. However, suboptimal configuration and control strategies and missing hydraulic balance of the heat distribution system in apartments, in combination with individual temperature levels in different rooms and different apartments, dominate the actual return line temperatures, making theoretical calculations almost complete defective. Thus, in order to analyse the temperature level (average, maximum, minimum) of a heat distribution system in a building, measurement over a longer time period (days or a few weeks) during the heating season is necessary.

Usually, information on the actual temperature level or the temperature difference between the return and supply line of the heat distribution system is gathered when a building is connected to a district heating system. In such case, the energy transferred from the district heating to the building in the heat transfer station is measured. This is usually done by measuring the volume flow together with the temperature difference[2] between supply and return side. These measurements are done continuously but cannot be accessed directly. In order to get any information on the return line temperature, either direct information on the temperature level or the volume flow and the transferred energy needs to be stored. Since heat transfer stations usually accumulate the measured data, the volume flow, next to transferred energy, is the most available information on the return line temperature. Because the data is accumulated in these stations, it can be accessed only as the sum over a certain period. A typical resolution for buildings with old heat transfer stations (10-30 years, depending on country) is annual data. More recent technologies store monthly data on the energy demand and the associated volume flow.

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[2] Actually, the absolute temperatures of supply and return line are measured. However, as this data is used to charge the customers for the transferred heat, it needs to be calibrated. In order to reduce the error margins, the calibration of typical heat transfer stations is done for the temperature difference and not for the absolute temperature levels, and the temperature differences are stored instead of temperature levels. The transferred heat is then calculated by multiplying volume flow and temperature difference.

The most recent technologies allow for storing daily data up to real-time data that is automatically transferred to grid operators.

Although the temperature levels of the heat distribution system could be measured even if the building is not connected to district heating, such a measurement is usually not undertaken. This is also because such a measurement is expensive, and a technician must visit the building at least two times for installing and removing the measurement instruments. The gathered data must then be analysed, and the results reported.

- Type of heat distribution system in the building

Besides measuring the temperatures of the heat distribution system in the building, a look at the installed technologies themselves can give an indication about the temperature level of the system. Relevant indications in this respect can be given by both the type of heat transfer system (e.g. radiators) as well as the type of regulation (e.g. control of valves and control of circulation pumps). Regarding the heat transfer system, different types can be distinguished with respect to their effective heat transmission area (types, age and size of radiators, floor heating). Since the different technologies are associated with distinctive temperature levels, they allow a quick and easy estimation of the temperature levels.[3]

Besides the control technology (e.g. thermostat valves) of the individual heat transmission systems (radiators), the following systems are commonly used to control the circulation pump and thus the volume flow through the heat distribution pipes: not regulated and/or manually controlled (on/off, manually switched between different rotation speeds), pressure regulated and temperature regulated. The latter is sometimes combined with a signal processing unit that considers the outdoor air temperature and calculates the return line temperature that is needed to ensure that the required heat can be transferred to the rooms. With such temperature-regulated heat distribution systems, low return line temperature levels (compared to what is possible with the existing heat radiation system and the heat demand of the building) can be achieved throughout the year. This is not easy to ensure with other control systems such as pressure-regulated systems, let alone unregulated or manually regulated systems.

- Existing standards

In the Netherlands, the energy performance standard for provisions at district level [139] provides a method for classifying distribution networks in the buildings. The networks for the distribution of heat, cold and hot tap water are distinguished. Also, two different temperature levels for the heat distribution systems are distinguished. However, it is not clearly stated how these temperature levels are to be obtained.

In Austria, the type of heat distribution system has to be defined in the EPC; the heat transfer area (small/large) as well as the system temperature (min/max) is stated. The

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[3] The actual indicator derives from a non-linear relation between the temperature differences against the indoor temperature on the one hand and the effective heat transmission surface area and the heat load of the room/building on the other.

regulation for the calculation of energy savings in buildings provides reference systems to be used in the EPC if no information is obtained on site. Reference values are given for different types of heat supply systems as well as types of buildings [140].

2.4 Application of assessment methods for the indicator

2.4.1 Voluntary or mandatory methods for EPCs

- Primary energy, renewable energy and carbon emission factors

In all countries, it is mandatory to state the primary energy demand and the CO_2 emissions of the building in its EPC. Thus, where a building is connected to district heating, a PEF and a CO_2 factor must be used in order to calculate the related primary energy demand and CO_2 emissions. For different countries, different methods for deriving these factors are used and implemented in national legislation (see Section 2.3 for further details). These methods are mandatory to be used in EPCs. In none of the countries has an approach been found that needs to state the future expectable development of the primary energy or carbon emission factors of district heating.

- Necessary supply line and expectable return flow temperatures in the distribution system

No country's EPC integrates indicators that show the necessary supply line temperature or the expectable return flow temperature.

2.4.2 Applicability of methods to different building typologies

- Primary energy, renewable energy and carbon emission factors

There is no difference in the calculation between new or existing buildings because the calculation is related to the network and not to the building. For new buildings, if the network is nearby and the values are calculated, these can be used in the EPC. If the district heating/ cooling system is yet to be built, a different approach must be taken; the calculation of the factors cannot then be based on a relation between the energy supply to the network from the different technologies and the supply from the network to the customers. In this case the calculation must be done via estimating the supply from the network to potential customers via calculating the losses in distribution. An approach for how this can be done is given e.g. in the calculation standard for the Netherlands [139].

The main aim of integrating indicators on the future development of PEF, REF and carbon emission factors is to drive the development of the district heating supply towards low-carbon and efficient supply technologies. This is not dependent on the type of building

- Necessary supply line and expectable return flow temperatures in the distribution system

The necessary supply line temperature and the expectable return flow temperature can be developed for both existing and new buildings. For existing buildings, it is necessary to visit the building and measure the heat transfer area and check the type of regulation of the distribution system. For a new building, this information is usually determined in the planning phase. Thus, it should be easily possible to calculate these indicators for both existing and new buildings.

The main aim of these indicators is to detect the building's suitability to be supplied by district heating systems working at lower distribution temperatures. This also is not related to the type of building supplied by a (potential) district heating system.

2.4.3 Presentation of the indicator

- **Primary energy, renewable energy and carbon emission factors**

PEF and REF are unit-less; the carbon emission factor is usually in $kgCO_2$/MWh. This would also apply for the proposed indicators on potential future factors. It is possible then to also calculate the ratio between the current values and the expected future values to visualise the level of ambition of the district heating system to increase energy efficiency and decrease CO_2 emissions. This could be ranked in the EPC. Both the absolute values and the ratios could be shown in the EPC against the average values of all district heating systems in the country. With this a type of benchmarking figure could be included, making it easy for EPC user to see and understand the current state as well as the level of ambition to change.

- **Necessary supply line and expectable return flow temperatures in the distribution system**

These proposed indicators are both temperatures. Thus, the unit would be °C or K. A categorisation into different temperature classes would be possible for these indicators.

2.5 Linking the assessment methods to energy performance and EPCs

- **Primary energy, renewable energy and carbon emission factors**

In general, the indicators in this field are related to the district heating system. Thus, they only indirectly reflect the energy performance of the building. The higher the useful energy demand of the building, the higher the absolute values of primary energy consumption, renewable energy consumption and CO_2 emissions. At the same time the primary energy consumption and the CO_2 emissions of the building are indicators directly related to the rating of the building and expressed very prominently in the EPCs of many countries. Also, the primary energy consumption of a building is considered in several national regulations. Thus, the lower the value the easier it is to fulfil building law requirements. This is e.g. the case for Poland where primary energy consumption is explicitly stated in building laws.

These indicators are not linked to other features within X-tendo. However, they have a strong link to existing EPC schemes in different countries and how the primary energy consumption, the use of renewable energy and the CO_2 emissions are currently derived. The approach to be developed in the course of X-tendo must therefore consider the differences in calculations in the different Member States.

- **Necessary supply line and expectable return flow temperatures in the distribution system**

The necessary supply line temperature is related to the potential efficiency of heat supply systems. This is especially relevant for renewable energy supply on the one hand and for efficient heat distribution in district heating systems. For several renewable energy supply technologies, efficiency decreases significantly with higher supply line temperatures. This is especially relevant for the supply from solar thermal systems as well as from heat pumps. Both technologies can be used in district heating systems as well as inside buildings. The distribution losses in district heating systems also depend on the temperatures in the heat distribution pipelines. The higher the supply line and the return flow temperatures in the district heating pipelines, the higher the losses in the system. Thus, lower necessary supply line temperatures and expectable return flow temperatures decrease potential losses in the district heating system. This again reduces the primary energy consumption as well as the CO_2 emissions in the district heating system and the building.

2.6 Legal boundaries or requirements of assessment methods

- Primary energy, renewable energy and carbon emission factors

The balance data for calculating the PEF, REF and CEF must be provided by the network utilities. The same applies to the estimated balancing values for future points in time as needed for the calculation of the proposed indicator.

- Necessary supply line and expectable return flow temperatures in the distribution system

The necessary input information and data must be determined by entering the building and apartment. Thus, the same legal issues apply as for the overall EPC development.

2.7 Ranking of methods for assessing the feasibility for the feature

Table 2 presents a qualitative assessment of the feasibility of integrating the described methods for calculating PEF, REF and CEF as well as the necessary supply line and expectable return temperatures in the EPC calculation process.

Table 2: Ranking of methods for district energy feature

Method	Ranking	Comment on feasibility/ Explanation
Indicators related to the district heating/cooling system		
PEF, REF, CEF (integration of potential future development)	***	Indicator for the current PEF is already integrated in the EPC schemes of nearly all EU countries Method would rely on a certification scheme of measures and the calculation of related indicators; this might be a challenge in countries where no certification schemes for calculating the PEF of individual district heating systems currently exist

Necessary supply line and expectable return temperature of the heat distribution system in the building	****	Indicators can be easily calculated after on-site visits. Calibration might be a challenge and depends on discussions with building experts in countries
Likert scale used for suitability: not at all (*), slightly (**), moderately (***), very (****), extremely (*****)		

2.8 SWOT analysis of the assessment methods

The following two tables present a qualitative estimation of the strengths, weaknesses, opportunities and threats related to a potential adoption of the methods to calculate and include future PEF, REF and CEF (Table 3) and to estimate necessary supply line and expectable return flow temperatures in the distribution system (Table 4) in EPCs.

Table 3: SWOT analysis of primary energy, renewable energy and carbon emission factors

Strengths	Weaknesses
For PEF, REF and CEF, standards and calculation methods exist in nearly all countries in the EU. The calculation for the current state indicators is already included in existing EPC schemes. Regular updates of the standards may allow for the integration of further adaptations.	The proposed indicator would incur further work for the district heating utility as well as for the certification expert.
Some countries already have certification schemes for calculating values of each district heating system in place. These could be forerunner countries.	
Opportunities	**Threats**
District heating utilities could show their ambition with an indicator in the EPC. The feature would build up the need for district heating utilities to develop and publish a strategy on how to improve these indicators in the mid-term future. Public authorities would have information about the future development plans of the district heating utilities in their region.	The proposed indicator could be relevant for district heating utilities when it comes to national regulation, so their interest might be low and even negative.

Table 4: SWOT analysis of necessary supply line and expectable return flow temperatures in the distribution system

Strengths	Weaknesses
The proposed indicators could be easily calculated from on-site visits, which usually have to be performed anyway.	Calibration of correction factors is not straightforward and needs an intensive stakeholder discussion process with building experts.
The theoretical concept of calculating these values is well defined.	
Opportunities	**Threats**

The potential of having this information for the planning of district heating supply systems is very relevant.	It might be difficult to find an agreement on the correction factors in the stakeholder discussion process.

2.9 Proposed approach to develop the feature

- Expected future performance of district heating

  - Calculation in a nutshell

The estimated future performance of each district heating system should be expressed via the PEF, REF and CEF for a future point in time. Based on estimated future balancing data (plant capacities, full load hours, CO_2 factors of electricity) and a roadmap for implementation, these values should be calculated by certified experts according to national or EU standards (e.g. EN 15316-4-5:2017). The calculation should then be approved by a recognised association or authority. In the EPC, these values can be used to express future primary energy, renewable energy and CO_2 emissions of the building or for calculating tailored recommendations.

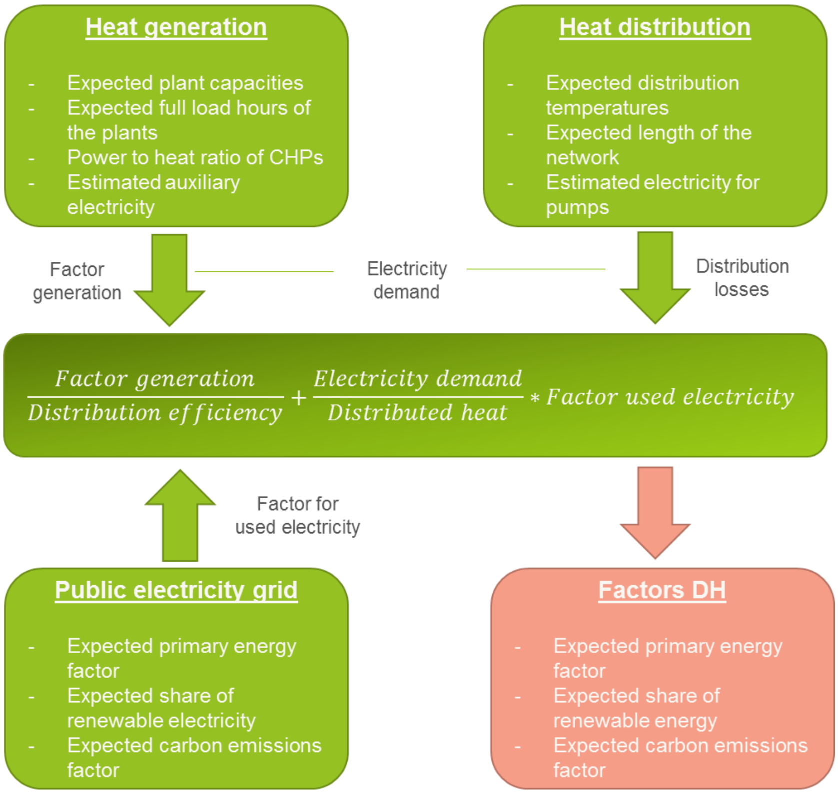

Figure 4: Calculation flow for first method

Figure 4 shows the input data and information needed for the calculation distinguishing between heat generation, heat distribution and the public electricity grid. Assumptions have to be made for all of these values reflecting a predefined future year.

  - Difficulties / Questions to be answered
    - Estimation of data for future years for a district heating system (mainly plant capacities and full load hours)

- Estimation of data for future years for the public electricity grid so that it is accepted by the district heating utilities and authorities
- Method for verification between roadmap of district heating utility and estimated data

Heat distribution and transfer system

Calculation in a nutshell

The heat distribution and transfer system of a building should be characterised by the necessary supply line temperature and the expectable return temperature. Both values should represent temperatures at the supply side for a central heat supply system, even if such a system is not currently in place. The basis for the calculation is the necessary heat load of the building. Via the available heat transfer area in the building, the maximum temperature at the end of the supply line is calculated. The temperature losses in the heat distribution system are then estimated via the isolation, length and location of the supply lines. The temperature reduction in the return line, on the other hand, is estimated based on the existing control system of the heat distribution system.

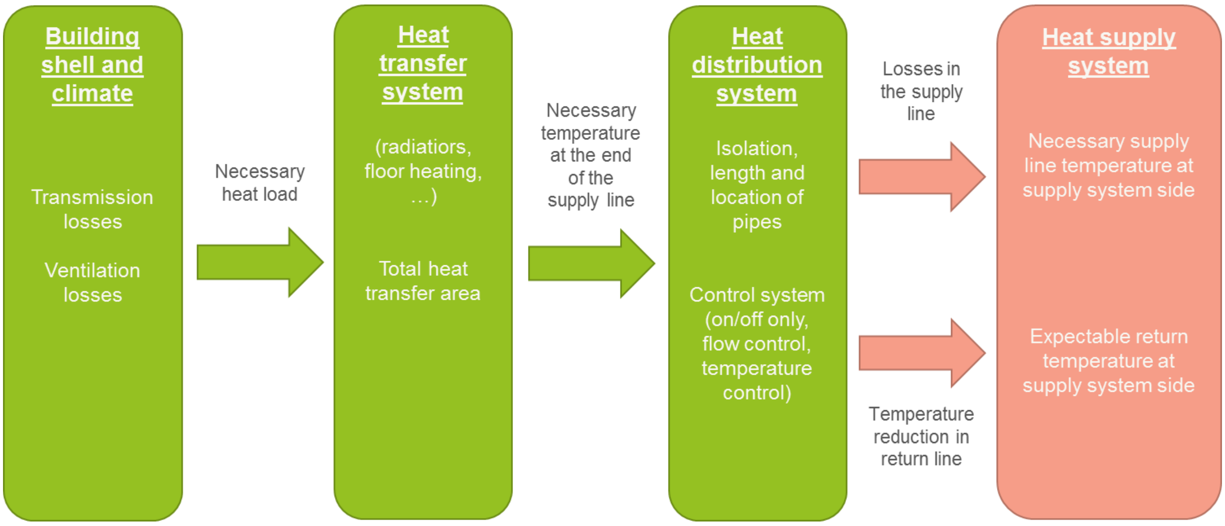

Figure 5: Calculation flow for second method

Figure 5 shows the input data and information needed for the calculation distinguishing between the building shell and climate, the transfer system and the heat distribution system. While some of the needed input data is already used in current EPC calculations, other parts are new, like heat transfer area or control systems for temperature reduction in the return line.

Difficulties / Questions to be answered

- Estimation of the correlation between the control system type and the temperature reduction in the return line
- Estimation of suitable correction factors between theoretical and practical values in general

3 FINDINGS

This section presents a summary of key findings (Table 5) related to the indicators that will be developed for the five innovative features in the X-tendo toolbox. This summary will be a precursor for further work in WP3. The findings have been categorised into key barriers, challenges, limitations, delivery actors, presentation, target audience and link with energy performance.

Table 5: Key findings of the scoping and analysis of all features

	Feature 1: smart readiness	Feature 2: comfort	Feature 3: outdoor air pollution	Feature 4: real energy consumption	Feature 5: district energy
Key barriers					
Technical/ methodological	Dealing with differences in building services (heating, EV presence, etc.) and characteristics (age, type or geographical location) Weighted measures and theoretical building maximums need to be developed	Assessment methodology for different building typologies	Proper definition of outdoor air quality	Length of the monitoring duration	Implementation of a certification scheme for calculating future PEF, REF and CEF could be a major barrier for some countries
Financial /economic	Existence of several schemes (market saturation)	-	-	Normalisation for user behaviour financially	-
Legislative/ governance	Differences across MS in smart readiness levels	Various standards at MS level	-	Enforcement frame Accounting for bulked quantities	-
Social	Novelty of the indicator requires the presence of useful information for the majority of	Benefits are not well understood by public	-	Landlord/tenant split	-

	the public				
Environmental	ICT technology might have a significant environmental impact	-	-	Monitoring infrastructure cost in relation to benefits	Additional efforts and committing to values stated in EPCs might be a reason for district heating utilities to oppose these indicators
Industry	Potential lack of readiness of the industry to satisfy the demand of new ICT	Application of industry-based solutions in building sector	-	Strict enforcement is difficult or even not feasible	Implementation of a certification scheme for calculating future PEF, REF and CEF could be a major barrier for some countries
Key challenges					
Technical/ methodological	Quick assessment -> Method A is created to reduce assessment time	Provision of single rank/score Accuracy of methods with or without measurements	Estimation of filter classification for each county Proper definition of reference values of emission rates Scale of indexes and weights for each country	Development of suitable models for missing data (e.g. DHW energy consumption) Differentiation of method for various functions (especially non-residential) Normalisation versus maintaining the link with actual measured energy consumption Normalisation for indoor environmental quality and service provision	Variable definitions of PEF, REF and CEF

Financial/ economic	Low cost and easy-to-use option	Developing cost-effective assessment criteria	-	Cost/accuracy or effectiveness balance	Estimation of data for future years for a district heating system (mainly plant capacities and full load hours)
Legislative/ governance	Universal methodology applicable to all MS (in contrast to EPC)	No reference for EPCs available from MS	Multiple standards and regulations in different MS	Minimising fraud GDPR (especially in the case of individual dwellings or buildings with low number of users) Citizen security and data privacy	Estimation of data for future years for the public electricity grid so that it is accepted by the district heating utilities and authorities
Social	Acceptability and appropriation	-	-	User acceptance; maintaining the link with energy billing/metering information	Method for verification between roadmap of district heating utility and estimated data
Environmental	Benefits vs. costs understudied	Integration in decision-making for renovation measures	Integration of variable sources of emissions in different MS	Positive balance of environmental benefits of EPC method effectiveness improvement versus environmental impact	-
Industry	Demand satisfaction	Quantified benefits not well integrated in assessments	-	-	-
Limitations	Might work at the level of	Reduction of measuremen	AQI data is required	For the design, calculation is	-

	some MS but not all Higher smartness levels should reflect better quality of life for occupants and building performance	ts for cost-effectiveness Limited complexity to simplify training of experts		still required; duration of measurement period (relevant for new/renovated buildings) Monitoring infrastructure roll-out may not be supported in all MS	
Presentation	Well-developed presentation approach	Few examples of presentation available	Existing colourful scale exists	As part of EPC, printed, digital, as part of building logbook, complementary to current EPC information or replacing it.	-
Delivery actors	EPC assessors, qualified experts but also owners (self-assessment)	EPC assessors, qualified building professionals	EPC assessors, energy auditors	EPC assessors, qualified building professionals/ experts Depending on data availability, potentially fully automated	EPC assessors, district heating utilities
Target audience	Whole building ecosystem: property owners, buyers, renters, tenants, facility managers, public authorities	Property owners, buyers, renters, tenants, facility managers	End-users, owners, occupants	Same as current EPC target audience, although focus is more user-oriented.	Property owners, buyers, renters, tenants, facility managers, research, public authorities responsible for planning heating and cooling
Link with energy performance	Monitoring and operation at the building level and improved interoperability with the grid	Thermal comfort and indoor air quality have a strong link with energy performance	Pollutant emission and indoor air purity have a strong link with building thermal and	Real energy consumption directly links with energy performance and additional operational (energy) performance	All indicators have a strong link to the energy performance of the building

			installation characteristi cs	Potentially contributes to mitigation of energy performance gap	

4 CONCLUSIONS

This report provides useful and crucial insights into working out the indicators for the five features during the X-tendo project. For all features, we have outlined details of the existing assessment/calculation methods in the context of EPCs. Their application domain, legal boundaries, and links with energy consumption and EPCs were also studied and evaluated. A SWOT analysis and ranking of methods were presented highlighting the best fits for each of the indicators. However, further work and adjustments to these methods would be required to make them available for real testing. A proposed approach for the development of each feature based on a preliminary concept for the indicator is also presented. Finally, across all features, key findings have been presented, leading to the following conclusions in two groups:

Indicators

- 'Smart readiness' approach presents a potential method for assessing the smartness of buildings with nine domains (e.g. lighting, ventilation, envelope, monitoring and control etc.)
- 'Comfort' approach incorporates four key indicators – thermal, visual and acoustic comfort and indoor air quality – to be assessed through checklists, on-site measurements and surveys
- 'Outdoor air pollution' approach addresses a building's impact on air by two methods: an outdoor air pollution contribution index and indoor air purity index
- 'Real energy consumption' approach outlines an assessment method based on operational ratings, with options for normalisation to allow for better inter-building comparison
- 'District energy' approach focuses on predicting the potential for future development for buildings via two methods: expected future performance of district heating and heat distribution and transfer system

Cross-cutting issues

- Technical challenges that constrain the application of existing methods such as assessment time, accuracy, normalisation process, variable definitions and emission factors could be overcome by certain modifications in approach
- Features should be aligned financially to increase market acceptance and cost-effective assessments during the development
- Legal and governance issues should be addressed by dealing with challenges such as development of universal methodologies, presence of multiple standards at Member State level, control of citizen data and privacy, and acceptance of future estimations by public authorities
- From a social perspective, user acceptance and public understating of the features are key issues and should be considered in feature development
- If these indicators are well integrated within EPCs, significant environmental benefits are anticipated
- Future implementation of indicators can be strengthened by addressing lack of industry readiness, understanding of anticipated benefits and enforcement issues

Certain limitations need to be overcome to implement these innovative indicators, such as variable levels of implementation in the Member States due to different local requirements and regulations. Some indicators require extensive monitoring and measurements, and a lack or absence of data is a barrier in the development and acceptance of these features within EPC schemes.

A range of delivery actors was identified for all the features, including EPC assessors, qualified experts, building professionals, and auditors. It is especially important to focus on them while developing the features as they will directly affect the outcomes of the assessments. While developing the features, links with energy performance are being explored and studied with reference to interoperability with the grid, energy consumption, and operational energy performance. To successfully develop the indicators and their implementation in the EPC schemes of the Member States, the features should ensure compliance with the requirements of the target audience and the framework principles of the cross-cutting criteria in X-tendo.

GLOSSARY OF TERMS

Term/words	**Meaning/definition**
Air Quality Index (AQI)	Index used by government agencies to communicate to the public how polluted the air currently is or how polluted it is forecast to become
Building smartness	A building's capacity to communicate with its occupants and the grid and to monitor and regulate efficiently the use of energy and other resources. It exemplifies the ability of the building to adapt to internal and external situations, relies on information and connectivity, and requires an appropriate level of cybersecurity.
Carbon emission factor (CEF)	A coefficient which allows conversion of activity data (process/processes) into CO_2 emissions
Emission rate	The emission intensity of a given pollutant relative to the intensity of a specific activity, or an industrial production process; for example grams of carbon dioxide released per megajoule of energy produced, or the ratio of greenhouse gas emissions produced to gross domestic product (GDP)
Energy Performance of Buildings Directive (EPBD)	The EPBD covers a broad range of policies and supportive measures that will help national EU governments boost energy performance of buildings and improve the existing building stock
Expectable return temperature (ERT)	Average temperature to be expected in the return of a building's heat distribution system
Filtration	A physical, biological or chemical operation that separates solid matter and fluid from a mixture with a filter medium that has a complex structure through which only the fluid can pass
Final energy consumption	Final energy consumption is the total energy consumed by end users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door and excludes that which is used by the energy sector itself.
Indoor environmental quality (IEQ)	IEQ encompasses the conditions inside a building – air quality, lighting, thermal comfort, acoustic conditions, ergonomics – and their effects on occupants or residents
Information and communication technologies (ICT)	Infrastructure and components that enable modern computing
Internet of Things (IoT)	Enabling of everyday devices to send and receive data through the internet
Low emission	Emission of combustion products of solid, liquid and

	gaseous fuels to the atmosphere from emission sources (emitters) located at a height of not more than 40 m
Nearly zero energy building (nZEB)	nZEBs have very high energy performance, and the low amount of energy they require comes mostly from renewable sources
Necessary supply line temperature (NST)	Maximum temperature that is necessary to be supplied to a building's heat distribution system in order to ensure that the heat load can be supplied to each part of the building on the coldest day of the year
Overheating risk	Situations where the indoor temperature of a home becomes uncomfortably or excessively warm
PM2.5/PM10	Particles with an aerodynamic diameter smaller than respectively 2.5 and 10 μm
Pollutant	A substance or energy introduced into the environment that has undesired effects, or adversely affects the usefulness of a resource
Primary energy factor (PEF)	A PEF connects primary and final energy by indicating how much primary energy is used to generate a unit of electricity or a unit of useable thermal energy
Primary energy consumption	Primary energy consumption measures the total energy demand of a country. It covers consumption of the energy sector itself, losses during transformation (for example, from oil or gas into electricity) and distribution of energy, and the final consumption by end users. It excludes energy carriers used for non-energy purposes (such as petroleum not used not for combustion but for producing plastics).
Primary resource factor (PRF)	The ratio between fossil energy supply and energy used in a building
Renewable energy factor (REF)	The share of renewable energy in the heat supplied by the district heating system
Sick building syndrome (SBS)	A condition affecting office workers, typically marked by headaches and respiratory problems, attributed to unhealthy or stressful factors in the working environment such as poor ventilation
Smart readiness indicator (SRI)	Measure of the capability of buildings to adapt their operation to the needs of the occupant, optimising energy efficiency and overall performance, and to adapt their operation in reaction to signals from the grid (energy flexibility)
Smog	An atmospheric phenomenon resulting from the mixing of fog with smoke and exhaust fumes

Volatile organic compounds (VOCs)	Organic chemicals that readily produce vapours at ambient temperatures and are therefore emitted as gases from certain solids or liquids. All organic compounds contain carbon, and organic chemicals are the basic chemicals found in all living things.

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