BIM4EEB

BIM based fast toolkit for
Efficient rEnovation in Buildings

D9.2 Standardisation Approach

This project has received funding from European Union's H2020 research and innovation programme under grant agreement N. 820660

Programmes	H2020
Call for Proposal	LC-EEB-02-2018 Building information modelling adapted to efficient renovation
Project Title	BIM based fast toolkit for Efficient rEnovation in Buildings
Acronym	BIM4EEB
Project Grant Agreement	820660

Work Package	WP9 Exploitation and Standardisation
Lead Partner	Solintel
Contributing Partner(s)	All partners
Dissemination Level	Public
Type	R: Report
Due date	15/11/2019
Date	08/02/2021 (REVISION)
Version	3.0

DOCUMENT HISTORY

Version	Date	Comments	Main Authors
1.1	01.11.2019	First draft addressing review comments	Solintel
1.2	15.11.2019	Comments from Suite5, TUD, VTT	Suite5
1.3	09.12.2019	Comments from POLIMI, One Team	POLIMI
2.0 FINAL	16.12.2019	Final comments and editing integrated	Solintel
2.1	03/02/2021	M18 review comments addressed	Solintel
3.0	08/02/2021	Integration of plagiarism check and finalization of edits	Solintel

Statement of originality:
This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

BIM4EEB action has received funding from the European Union under grant agreement number 820660.

EXECUTIVE SUMMARY

This report presents the results of activities carried out for defining a preliminary standardization approach and strategy for the BIM4EEB project. The activities focus on the definition of relevant standardization bodies, technical committees and standards according to the identified Key Exploitable Results thus far with the aim of fostering increased market uptake of project results in the future through higher compliance with relevant market driven, regulatory, performance or safety requirements

For each identified project result the report will provide:

- The selection of standards bodies and forums that are developing the world leading standards in the identified technical areas
- List of relevant and prioritized standards affecting project results
- Which components or parts of research results is most affected by the identified standards
- Gap analyses and whether research results can constitute the basis for standards extensions
- The establishment of project internal processes for standards strategy and contribution development, alignment and review
- The identification of delegates for targeted standardization bodies in case of need for liaison for standards creation and extension

This report is a foundation for standards compliance throughout the BIM4EEB project in order to enhance exploitation potential of the project results that can swiftly be launched to market without any need for too many further adjustments. The report is tentative and may evolve during the course of the project, notably as a result of Innovation Management Board Seminars.

M18 Review comments

This report has been revised according to the comments received for the M18 review specifically in terms of standards in table 4 with the integration of more standards, and homogenization of standards tables for all KERs throughout the deliverable.

PUBLISHING SUMMARY

This report describes the main standards to be considered in the development of the main Key Exploitable Results and how they affect the project.

By segmenting the analysis according to the main research results envisioned at this stage, the reader is able to get a clear overview of the different standards that affect the BIM4EEB project, the partners most affected by them in the execution of project tasks and how the consortium plans on approaching standardization requirements in the project.

The methodology that is applied in this report is centred on four pillars:

1. The recognition of relevant standardization bodies, technical committees and standards
2. Definition of strategy in relation to the standards
3. Roadmaps and internal processes
4. Liaison and communication

Each of these steps is applied to the individual key exploitable results or research results that were identified during the preliminary phases of the BIM4EEB project with the objective of obtaining:

- Selection of standards bodies and forums that are developing the world leading standards in the identified technical areas
- List of relevant and prioritized standards affecting project results
- Which components or parts of research results is most affected by the identified standards with particular emphasis on specific project tasks
- Gap analyses of current standards and an assessment on whether or not research results can constitute the basis for standards extensions
- The establishment of project internal processes for standards strategy and contribution development, alignment and review
- The identification of delegates for targeted standardization bodies in case of need for liaison for standards creation and extension

This process will provide a development foundation for all research efforts with possibilities for benchmarking developments and outlining the different requirements that exploitable results are subject to. Moreover, it will help highlight the truly innovative areas of the project through the identification of potential standards extensions.

M18 Review comments

This report has been revised according to the comments received for the M18 review specifically in terms of standards in table 4 with the integration of more standards, and homogenization of standards tables for all KERs throughout the deliverable.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 Introduction

This document presents the results of activities carried out for defining a preliminary standardization approach and strategy for the BIM4EEB project. The main results are the identification of the relevant standards bodies and lists of standards relevant to the technical work packages or key exploitable results of the project. Moreover, strategies relevant to different standards, for instance whether contributions or extensions are envisioned, are explored along with the responsible partners. Finally, preliminary roadmaps and internal processes for standardization overview processes activities taking into consideration the project specific schedule and timeline of developments are delivered. At this stage of the project, the outputs of this deliverable from the point of view of responsible partners and action plans are suggestive and will have to be discussed in more depth during the Innovation Management Board sessions. Nevertheless, the identified standardization boards and relevant standards for each key exploitable result are fixed and will drive and influence initial research efforts.

Standardization is crucial in order for the BIM4EEB project results to comply with the relevant market driven, regulatory, performance or safety requirements as well as with standards for BIM implementation, resulting in KERs that can swiftly be launched to market without any need for too many further adjustments, accelerating industrial exploitation.

1.1 Objectives

The objectives of this task are:

- The **identification of technical subjects/items** for **standards** development for all involved WPs
- The selection of **standards bodies** and **forums** that are developing the world leading standards in the identified technical areas
- The establishment a project **internal process for standards strategy and contribution development**, alignment and review
- The identification of **delegates for targeted standardization bodies** in case of need for liaison for standards creation and extension

1.2 Relation with other tasks

This deliverable impacts all tasks of the project as it establishes development foundations for all the work packages and relevant Key Exploitable Results of the BIM4EEB project. Therefore, we consider this as an horizontal activity in line with the developments performed in the project.

1.3 Structure of the document

In terms of structure, the document first starts out by presenting the methodology that will be applied in order to develop standardization activities within the BIM4EEB project. It is separated into four main parts which will be described in the following section. Namely, the recognition of relevant standardisation bodies, technical committees and standards, the strategy in relation to identified standards, the creation of tentative roadmaps and internal processes taking into account project schedules and finally the liaison and communication with standardization bodies.

The next step will be a preliminary introduction of the Key Exploitable Results, identified and listed in the initial stages of the project and most generally aligned with the BIM4EEB Work Packages, which will be used as starting gates for identifying relevant bodies, technical committees and standards that must be observed during the project.

Each Key Exploitable Result will then be treated individually whereby relevant standardization bodies, technical committees, working groups and finally standards are identified, listed and described. It will be detailed what tasks standards apply to and whether the specific work produced during the project could lead to standard contributions or extensions.

Finally, a mapping of all listed standards will be offered according to the system architecture or Key Exploitable Results along with the envisioned possible responsible partners for standards compliance in each project component. At this stage, leading partners were generally selected along with the partners who are active members of relevant standardization boards and bodies.

It is important to understand that this document is not prescriptive but rather tentative and relevant activities will likely evolve over time, especially as a result of Innovation Management Board meetings and work.

1.4 M18 Review comments

This report has been revised according to the comments received for the M18 review specifically in terms of standards in table 4 with the integration of more standards, and homogenization of standards tables for all KERs throughout the deliverable.

2 Methodology

The BIM4EEB H2020 project is focused on creating a holistic BIM based toolkit for facilitating the fast renovation of existing buildings which encompasses a variety of different technical domains and applications which will be characterized by their own respective set of standards. In order for the project to create results and modules that are most aligned with current market standards and practices, facilitating integration with other technologies and accelerating general market uptake if results are eventually commercialized then it is necessary to implement internal processes and strategies in relation to standardisation. In order to establish the general approach to this deliverable and provide the basic introductory information, this section will be divided into three parts: the general methodology used for establishing standardization approaches in the BIM4EEB project, general information on standardisation and governing bodies and finally, a description of the system architecture and project results on which relevant standards depend.

2.1 General methodology

From a methodological point of view, standardization approaches are generally composed of the following main phases:

- Recognition of relevant standardisation bodies, technical committees and standards

This involves the recognition and listing of the most important standardization bodies, technical committees and standards related to a certain project result or component being developed. For the approach to be as comprehensive as possible, all types of standards will be included in the listing. Section 2.2 which follows will detail the types of standards and governing bodies in question.

- Strategy in relation to identified standards

Once the relevant standards are recognized, it is important to understand the strategy with respect to the said standard. Indeed, research & development can either yield results which have to comply with the specifications and guidelines set out by current standards or can also contribute to extending existing standards or even creating new ones if topics in the relevant domain are identified and not covered. Therefore, efficient standardization strategies will identify gaps, starting from the study of the existing situation and then collecting issues and problems that have still to be tackled, according to the most relevant stakeholders in the field.

The output of this section will be the determination of whether the project is to aim for compliance of the individually listed standards or provide extensions and updates according to the foreground being developed in the project.

- Roadmap and internal processes

The next step in the methodology is to establish a roadmap and internal processes for complying with the stated strategy or approach in the previous section. The roadmap will depend heavily on the deliverable and task schedules of the project.

If it is decided to contribute or extend existing standards (if possible), a set of possible deliverables or actions may be performed.

For ISO standardization process, six main steps are generally put in place (as described in their own documentation):

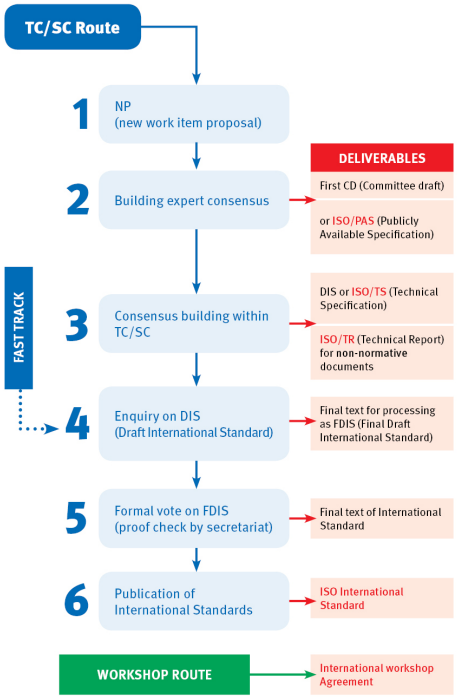


Figure 1 ISO standardization process and deliverables (International Organization for Standardization, n.d.)

“1) Proposal stage

The first step in the development of an International Standard is to confirm that a particular International Standard is needed. A new work item proposal (NP) is submitted for vote by the members of the relevant TC or SC to determine the inclusion of the work item in the programme of work.

The proposal is accepted if two thirds majority of the P-members (known as the participating members in a TC) of the TC/SC votes in favour and if at least five P-members declare their commitment to participate actively in the project.

2) Preparatory stage

Usually, a working group of experts, the chairman of which is the project leader, is set up by the TC/SC for the preparation of a working draft. Successive working drafts may be considered until the working group is satisfied that it has developed the best technical solution to the problem being addressed.

3) Committee stage

As soon as a first committee draft is available, it is registered by the ISO Central Secretariat. It is distributed for comment and, if required, voting, by the P-members of the TC/SC. Successive committee drafts may be considered until consensus is reached on the technical content. Once consensus has been attained, the text is finalized for submission as a Draft International Standard (DIS).

4) Enquiry stage

The draft International Standard (DIS) is circulated to all ISO member bodies by the ISO Central Secretariat for voting and comment within a period of five months. It is approved for submission as a final draft International Standard (FDIS) if a two-thirds majority of the P-members of the TC/SC are in favour and not more than one-quarter of the total number of votes cast are negative. If the approval criteria are not met, the text is returned to the originating TC/SC for further study and a revised document will again be circulated for voting and comment as a DIS.

5) Approval stage

The final draft International Standard (FDIS) is circulated to all ISO member bodies by the ISO Central Secretariat for a final Yes/No vote within a period of two months. If technical comments are received during this period, they are no longer considered at this stage, but registered for consideration during a future revision of the International Standard. The text is approved as an International Standard if a two-thirds majority of the P-members of the TC/SC is in favour and not more than one-quarter of the total number of votes cast are negative. If these approval criteria are not met, the standard is referred back to the originating TC/SC for reconsideration in light of the technical reasons submitted in support of the negative votes received

6) Publication stage

Once a final draft International Standard has been approved, only minor editorial changes, if and where necessary, are introduced into the final text. The final text is sent to the ISO Central Secretariat which publishes the International Standard.

All International Standards are reviewed at least every five years by all the ISO member bodies. A majority of the P-members of the TC/SC decides whether an International Standard should be confirmed, revised or withdrawn"

(International Organization for Standardization, n.d.)

ISO Deliverables

In terms of ISO deliverables which at this stage and within the standardization activities of BIM4EEB much more pertinent, the processes and options are much similar to those of CEN as described below:

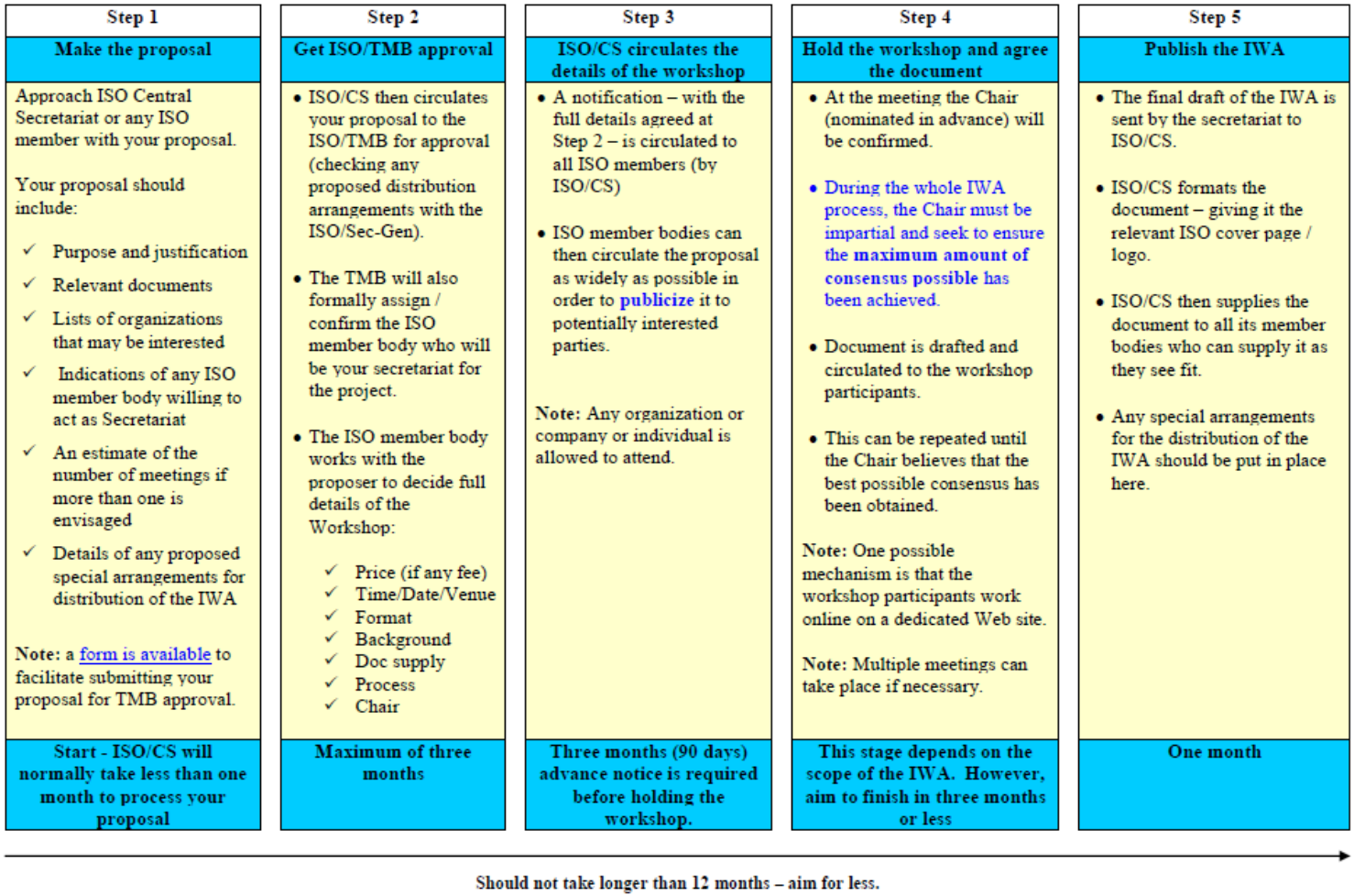
ISO deliverable	**Definition**	**Time to develop (idea to publication)**
International Standard	Provides rules, guidelines or characteristics for activities or for their results, aimed at achieving the optimum degree of order in a given context. Apart from product standards, other examples include: test methods, codes of practice, guideline standards and management systems standards.	Standardization process and typical delays described above.
Technical Specification	Addresses work still under	2-3 years

	technical development, or where it is believed that there will be a future, but not immediate, possibility of agreement on an International Standard. A Technical Specification is published for immediate use, but it also provides a means to obtain feedback. The aim is that it will eventually be transformed and republished as an International Standard.	
Technical Report	Contains information of a different kind from that of the previous two publications. It may include data obtained from a survey, for example, or from an informative report, or information of the perceived “state of the art”.	2-3 years
Publicly Available Specification	Published to respond to an urgent market need, representing either the consensus of the experts within a working group, or a consensus in an organization external to ISO. As with Technical Specifications, Publicly Available Specifications are published for immediate use and also serve as a means to obtain feedback for an eventual transformation into an International Standard. Publicly Available Specifications have a maximum life of six years, after which they can be transformed into an International Standard or withdrawn.	2-3 years

International workshop agreement	An International Workshop Agreement is a document developed outside the normal ISO committee system to enable market players to negotiate in an "open workshop" environment. International Workshop Agreements are typically administratively supported by a member body. The published agreement includes an indication of the participating organizations involved in its development. An International Workshop Agreement has a maximum lifespan of six years, after which it can be either transformed into another ISO deliverable or is automatically withdrawn.	Less than 12 months

Table 1 ISO deliverables (International Organization for Standardization, n.d.)

Within the framework of a research and development project such as BIM4EEB, the most logical avenue in the beginnning, similarly to with CEN, is the organization of IWAs due to it´s swiftness and evaluation potential. A specific description of it´s process is given in the following document:



Step 1	Step 2	Step 3	Step 4	Step 5
Make the proposal	**Get ISO/TMB approval**	**ISO/CS circulates the details of the workshop**	**Hold the workshop and agree the document**	**Publish the IWA**
Approach ISO Central Secretariat or any ISO member with your proposal. Your proposal should include: ✓ Purpose and justification ✓ Relevant documents ✓ Lists of organizations that may be interested ✓ Indications of any ISO member body willing to act as Secretariat ✓ An estimate of the number of meetings if more than one is envisaged ✓ Details of any proposed special arrangements for distribution of the IWA **Note:** a form is available to facilitate submitting your proposal for TMB approval.	• ISO/CS then circulates your proposal to the ISO/TMB for approval (checking any proposed distribution arrangements with the ISO/Sec-Gen). • The TMB will also formally assign / confirm the ISO member body who will be your secretariat for the project. • The ISO member body works with the proposer to decide full details of the Workshop: ✓ Price (if any fee) ✓ Time/Date/Venue ✓ Format ✓ Background ✓ Doc supply ✓ Process ✓ Chair	• A notification – with the full details agreed at Step 2 – is circulated to all ISO members (by ISO/CS) • ISO member bodies can then circulate the proposal as widely as possible in order to **publicize** it to potentially interested parties. **Note:** Any organization or company or individual is allowed to attend.	• At the meeting the Chair (nominated in advance) will be confirmed. • During the whole IWA process, the Chair must be impartial and seek to ensure the **maximum amount of consensus possible** has been achieved. • Document is drafted and circulated to the workshop participants. • This can be repeated until the Chair believes that the best possible consensus has been obtained. **Note:** One possible mechanism is that the workshop participants work online on a dedicated Web site. **Note:** Multiple meetings can take place if necessary.	• The final draft of the IWA is sent by the secretariat to ISO/CS. • ISO/CS formats the document – giving it the relevant ISO cover page / logo. • ISO/CS then supplies the document to all its member bodies who can supply it as they see fit. • Any special arrangements for the distribution of the IWA should be put in place here.
Start - ISO/CS will normally take less than one month to process your proposal	**Maximum of three months**	**Three months (90 days) advance notice is required before holding the workshop.**	**This stage depends on the scope of the IWA. However, aim to finish in three months or less**	**One month**

Should not take longer than 12 months – aim for less.

Figure 2 International Workshop Agreement (International Organization for Standardization, n.d.)

The CEN deliverables of relevance for researchers are:

- The European Standard (EN), leading to full implementation, as national standard, Europe wide, which may also serve the European regulatory purposes of the New Approach
- The Technical Specification (CEN/TS), that serves as normative document in areas where the actual state of the art is not yet sufficiently stable for a European Standard
- The Technical Report (CEN/TR), for information and transfer of knowledge
- The CEN Workshop Agreement (CWA), which aims at bringing about consensual agreements based on deliberations of open Workshops with unrestricted direct representation of interested parties

Within the framework or length of R&D projects, the most realistic deliverable from the point of view of CEN is a CWA which is quicker to implement and generally leads to non-binding results. CWAs are developed in a workshop, with secretarial support from a National Standardisation Body. The members of the workshop do not need to be registered experts and are chosen to best represent the relevant stakeholders.

The approximate times needed to develop the CEN deliverable from the first idea to publication of the document are listed in the table below:

CEN deliverable	**Time to develop (idea to publication)**
EN	Ca. 5 years (3y from first full draft)
CEN/TS	2-3 years
CEN/TR	2-3 years
CWA	<1 year

Table 2 CEN deliverables and time to develop (European Committee for Standardization, n.d.)

Moreover, it is highly probable that the partners of the project are affiliated to independent industry based standardization bodies unrelated to CEN which possess their own system for updating or extending current standards.

- Liaison and communication with standardization bodies

In terms of establishing liaison with the actual standardization bodies or national standardization bodies as well as independent industry bodies in case the project has the potential to advance standardization activities and topics, the most straight forward approach is to rely on partners that are already members of the relevant institutions such as their national TC´s and CEN boards. Otherwise, the partners in the relevant tasks affected by certain standards will be the logical players for establishing liaison.

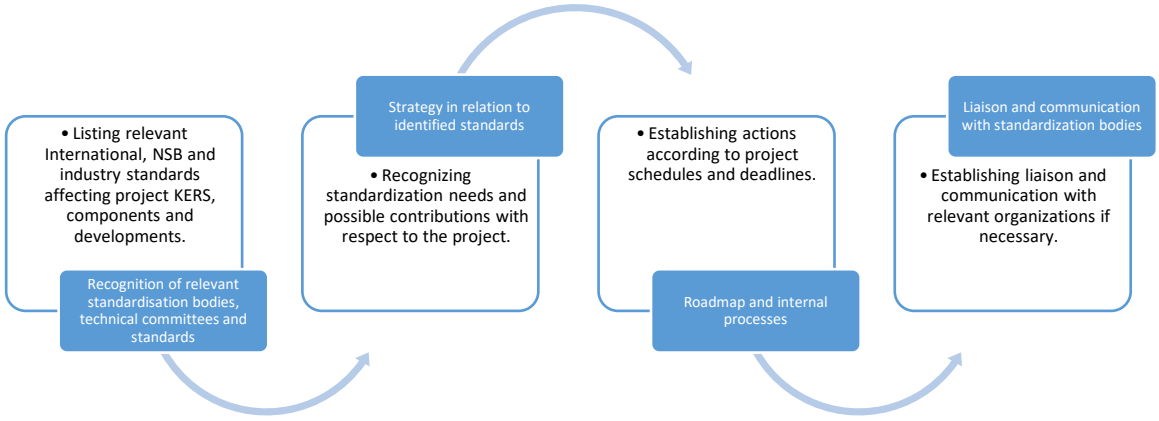


Figure 3 Standardisation approach methodology

It has been chosen to focus the bulk of the previously described work around the project Key Exploitable Results identified at the initial stage of the project as they correspond directly to relevant components, systems and solutions being developed within the BIM4EEB project. Inputs into each of the described sections within the methodology are the result of a process gathering feedback from partners for all relevant KERs.

2.2 Technical Standards and governing bodies

In order to lead to an optimal and full exploitation of BIM4EEB KERs, outputs and systems implementation, it is crucial to determine the European and industry wide standards that each relevant sub system must comply with so that commercialization or fruitful further research may take place effectively in the future. Generally, standards provide rules, guidelines or characteristics for activities or their results, for common and repeated use. Standards are created by bringing together all interested parties including manufacturers, users, consumers and regulators of a particular material, product, process or service. Everyone benefits from standardization through increased product safety and quality as well as lower transaction costs and prices.

- **Types of Standards**

In order to perform this task and identify exactly which standards and standardization processes will be referred to, as well as, the governing bodies and institutions that the project will be based on, it is first necessary to identify exactly where standards requirements and research projects intersect. The function of standardization in the research process has been extensively defined over the years. Blind and Jungmittag (Blind 2008) have broken down the research process into individual life cycle steps where different types of standards come into play. The following figure (figure 2) exemplifies this relationship.

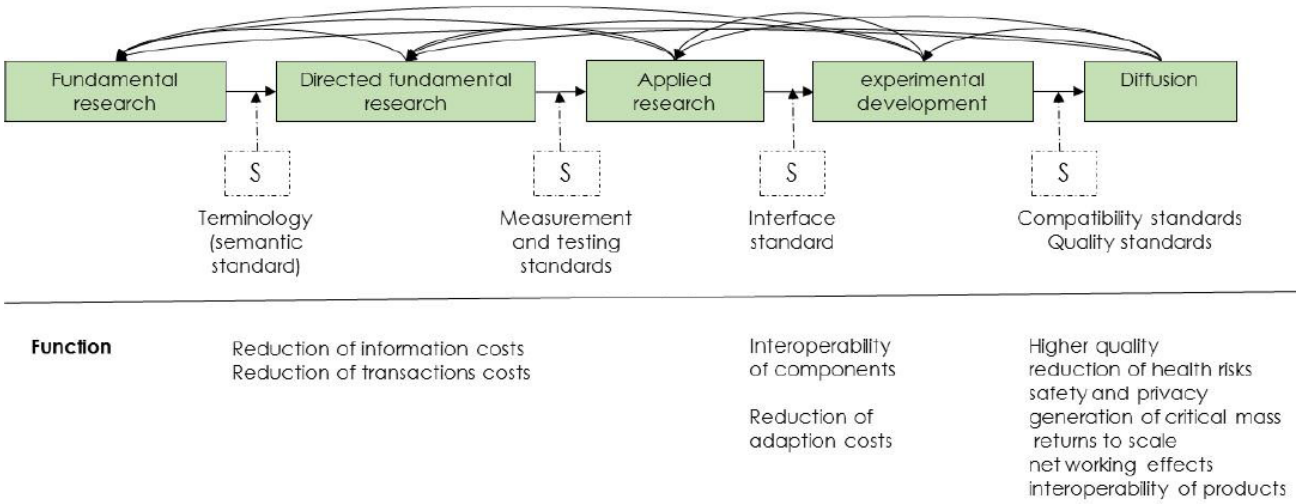


Figure 4 Standards in the Research and Innovation Process

As demonstrated by this life cycle figure, standardization enables fast and easier market exploitation of research results, as standards available in the area are usually already accepted by the possible end users. Moreover, on the technical side, standards can enhance interoperability, comparability and compatibility with what exists, facilitating market entrance and penetration. Project results taken up in a standard remain available beyond the project's life-time, are regularly revised and present a format for long-term exploitation of the project results.

In terms of deliverable and the BIM4EEB project as a whole, it seems that the most relevant standards will be what is qualified in the above figure as Interface Standards and Compatibility and Quality Standards. As an RIA project, many of the developments within the project aim a TRL level 6 and correspond to experimental developments that will not be directly diffused and taken to market. Therefore, the priority set on interoperability of components and the possibility for easy integration with existing components and solutions already present within the market. This will guarantee replicability of systems applied to the 3 pilot sites which stand for the experimental development phase.

- **Governing Bodies**

Beyond recognizing that we will be focusing on standards most relevant to applied research and experimental phases of research and innovation projects, it is also necessary to recognize which governing bodies and institutions will be studied and taken into consideration in order to then identify the necessary standards for BIM4EEB.

  - International standard setting

International standard setting is mainly taken on by the International Organization for Standardization (ISO). ISO has published 22843 international standards and related documents, covering almost every industry, from technology, to food safety, to agriculture and healthcare. ISO International Standards impact everyone, everywhere. The organization has members from 164 countries (national standardization bodies) and 779 technical committees and subcommittees to take care of standards development. ISO International Standards ensure that products and services are safe, reliable and of good quality. As will

be mentioned in the information provided on European standards, there is a high level of convergence between the European and international standards which is facilitated by the ongoing technical cooperation between CEN and ISO ensured by Vienna Agreement and between CENELEC and IEC ensured by the Frankfurt Agreement.

- Standard Setting in the European Union

Within the European Union, each European Standard is identified by a unique reference code which contains the letters 'EN'. A European Standard is a standard that has been adopted by one of the three recognized European Standardization Organizations (ESOs): CEN, CENELEC or ETSI. It is produced by all interested parties through a transparent, open and consensus based process.
“European Standards are a key component of the Single European Market. Although rather technical and mostly unknown to the public and media, they represent one of the most important issues for businesses. Often perceived as not particularly relevant to some organizations, they are actually crucial in facilitating trade and hence have high visibility among manufacturers inside and outside Europe. Standards provide individuals, businesses and all kinds or organizations with a common basis for mutual understanding. A standard represents a model specification, a technical solution against which a market can trade. It codifies best practice and is usually state of the art.
In essence, European Standards relate to products, services or systems. Today, however, standards are no longer created only for technical reasons but have also become enablers for greater social inclusiveness and engagement with technology, as well as convergence and interoperability within growing markets across industries.” (European Committee for Standardization, s.f.)

- CEN, the European Committee for Standardization, is an association that brings together the National Standardization Bodies of 33 European countries.
- CEN is one of three European Standardization Organizations (together with CENELEC and ETSI) that have been officially recognized by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at European level.
- CEN provides a platform for the development of European Standards and other technical documents in relation to various kinds of products, materials, services and processes.
- CEN supports standardization activities in relation to a wide range of fields and sectors including: air and space, chemicals, construction, consumer products, defence and security, energy, the environment, food and feed, health and safety, healthcare, ICT, machinery, materials, pressure equipment, services, smart living, transport and packaging.

CEN and CENELEC have dedicated agreements with the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), promoting the benefits of the international standards to international trade and markets harmonization. The high level of convergence between the European and international standards is facilitated by the ongoing technical cooperation between CEN and ISO (Vienna Agreement) and between CENELEC and IEC (Frankfurt Agreement).For this reason, many common ISO/CEN standards will be presented in this document.

- National Governing Bodies

CEN's National Members are the National Standardization Bodies (NSBs) of the 28 European Union countries, the Former Yugoslav Republic of Macedonia, Serbia and Turkey plus three countries of the

European Free Trade Association (Iceland, Norway and Switzerland). There is one member per country. A National Standardization Body is the one stop shop for all stakeholders and is the main focal point of access to the concerted system, which comprises regional (European) and international (ISO) standardization. It is the responsibility of the CEN National Members to implement European Standards as National Standards. The National Standardization Bodies distribute and sell the implemented European Standard and have to withdraw any conflicting national standards. In the next table, the list of the country organization devoted to the standardization process are listed.

Acronym	Country	Organization	Website
ASI	Austria	Austrian Standards International - Standardization and Innovation	www.austrian-standards.at
NBN	Belgium	Bureau de Normalisation/Bureau voor Normalisatie	www.nbn.be
BDS	Bulgaria	Bulgarian Institute for Standardization	www.bds-bg.org
HZN	Croatia	Croatian Standards Institute	www.hzn.hr
CYS	Cyprus	Cyprus Organization for Standardisation	www.cys.org.cy
UNMZ	Czech Republic	Czech Office for Standards, Metrology and Testing	www.unmz.cz
DS	Denmark	Dansk Standard	www.ds.dk
EVS	Estonia	Estonian Centre for Standardisation	www.evs.ee
SFS	Finland	Suomen Standardisoimisliitto r.y.	www.sfs.fi
AFNOR	France	Association Française de Normalisation	www.afnor.org
DIN	Germany	Deutsches Institut für Normung	www.din.de
NQIS/ELOT	Greece	National Quality Infrastructure System	www.elot.gr
MSZT	Hungary	Hungarian Standards Institution	www.mszt.hu
IST	Iceland	Icelandic Standards	www.stadlar.is
NSAI	Ireland	National Standards Authority of Ireland	www.nsai.ie
UNI	Italy	Ente Nazionale Italiano di Unificazione	www.uni.com
LVS	Latvia	Latvian Standard Ltd.	www.lvs.lv
LST	Lithuania	Lithuanian Standards Board	www.lsd.lt
ILNAS	Luxembourg	Organisme Luxembourgeois de Normalisation	www.portail-qualite.lu
MCCAA	Malta	The Malta Competition and Consumer Affairs Authority	https://mccaa.org.mt
NEN	Netherlands	Nederlands Normalisatie-instituut	www.nen.nl
SN	Norway	Standards Norway	www.standard.no/
PKN	Poland	Polish Committee for Standardization	www.pkn.pl
IPQ	Portugal	Instituto Português da Qualidade	www.ipq.pt
ISRSM	Republic of North Macedonia	Standardization Institute of the Republic of North Macedonia	www.isrm.gov.mk
ASRO	Romania	Romanian Standards Association	www.asro.ro
ISS	Serbia	Institute for Standardization of Serbia	www.iss.rs
UNMSSR	Slovakia	Slovak Office of Standards Metrology and Testing	www.unms.sk
SIST	Slovenia	Slovenian Institute for Standardization	www.sist.si
UNE	Spain	Asociación Española de Normalización	www.une.org
SIS	Sweden	Swedish Institute for Standards - SIS	www.sis.se
SNV	Switzerland	Schweizerische Normen-Vereinigung	www.snv.ch
TSE	Turkey	Turkish Standards Institution	www.tse.org.tr

BSI	United Kingdom	British Standards Institution	www.bsigroup.com

Table 3 Country standardization list (European Committee for Standardization, n.d.)

On top of taking into consideration European and international level standards as listed in the above sections, BIM4EEB partners will also focus on complying with some independent and industry specific level standards that are of special interest or are de facto standards.

- buildingSMART

In the case of BIM, one of the most important and dominant standardization boards is buildingSMART. This body promotes international consensus among stakeholders on specific standards to accelerate implementation and uptake of BIM. Some of the main aspects of the built environment covered by their standards are listed below and pertinent to the BIM4EEB project are listed below (buildingSMART, n.d.):

- "An industry-specific data model schema -Industry Foundation Classes [IFC]: This standard improves the sharing of information throughout the lifecycle of projects or assets."
- "A methodology for defining and documenting business processes and data requirements - Information Delivery Manual [IDM]: This standard has been developed by buildingSMART in order to have a methodology to capture and specify processes and information flow during the lifecycle of a facility."
- "Data model exchange specifications -Model View Definitions [MVD]: subset of the overall IFC schema to describe data exchange for a specific use or workflow. An IFC View Definition, or Model View Definition, MVD, defines a subset of the IFC schema, that is needed to satisfy one or many Exchange Requirements of the AEC industry."
- "Model-based, software-independent communication protocols -BIM Collaboration Format [BCF]: BCF was created for facilitating open communications and improving IFC-based processes to more readily identify and exchange model-based issues between BIM software tools."
- "A standard library of general definitions of BIM objects and their attributes -buildingSMART Data Dictionary [bSDD]: Shared library of objects and their attributes utilizing ISO 12006-3 ontology for the building and construction industry."

BuildingSMART also oversees formal reviews and publication of Technical Reports that result from technical activities in what are qualified as rooms (different chairs for different types of built environments such as airorts, infrastructure, construction, etc) that involve research, development or implementation and are of interest and benefit to the buildingSMART Community and the built asset industry. As a result of these activities, and potentially of interest to the BIM4EEB consortium in terms of potential standardization contributions during the project, a buildingSMART SPEC can be produced whereby an organisation wants to standardize best practice on a specific subject but is not yet ready to proceed with producing it as a bSI Standard.

2.3 System architecture and declared results

In order to establish the most important standards for the BIM4EEB project it is crucial to understand the architecture and structure of the envisioned project results and components being developed. Therefore,

this section will focus on providing a preliminary overview of the individual structural components and modules that form the BIM4EEB environment. This will serve as a preliminary description of the following respective sections of this deliverable which are separated according to Key Exploitable Results of the project.

As is now commonly accepted within the EE renovation industry, many barriers plague the successful implementation of swift and effective retrofits for existing buildings capable of reducing GHHG emissions and energy consumption of the EU´s aging building stock. These barriers are mainly related to fragmentation of the whole renovation value chain, difficulties in collecting data around existing buildings, large amount of time and cost for creating BIM models, difficulties in sharing information between different stakeholders or difficulties in updating information along the whole building lifecycle.

The objective of the BIM4EEB and the ensemble of products, components and services that are being created is to directly respond to these listed shortcomings with the introduction of a Linked Data Modelling and Sharing Framework that enhances current BIM-based approaches to ensure seamless collaboration and interoperable communication and data exchange among all actors involved in the renovation industry and intervening at different phases of the renovation process.

BIM4EEB will deliver a BIM management system, being an open integrated BIM-based collaboration environment, enabling the continuous updating, enhancement, improvement and enrichment of available models by the AEC industry stakeholders based on robust modelling guidelines that will be provided by the project, to ensure sustainability of the project developments and enhance its exploitation potential even after the end of the project.

The BIM4EEB tool is composed of a series of tools and solutions that will facilitate the work of a diversity of AEC stakeholders spread along the whole renovation value chain and process. The tools in question have been organized in a series of **Key Exploitable Results** representing the most interesting project results from an exploitation point of view and thus standardization activities will focus on these very elements in order to ensure that they are in line with the most adapted practices, processes and criteria for further research or commercial uptake and ventures. The segmentation of these research outputs has been rather straight forward as the different WPs of the project tend to stand for one element of the BIM4EEB modular structure.

Preliminary identification of KERS for BIM4EEB:

- Complete BIM4EEB Toolset (KER #1, All partners)

This project result relates to the integrated BIM4EEB solution containing all modules and services developed during the project. It will consist in a BIM based software environment offering interoperability between the different environments, data formats and types as well as developed tools and applications used and developed during the project.

- Linked data sharing framework for renovations/ BIM ontology for renovation (KER #2, Lead partner TUD)

This project result will focus on developing a framework with refinements and extensions and harmonization of existing ontologies in order to enable the integrated deployment of the developed tools in BIM4EEB.

- BIM management system (KER #3, Lead partner OneTeam)

Creation of an open source and interoperable platform based on the ontology developed in KER #2 with a specific toolkit to optimise the management of information (collection, share, update and exchange) during the different stages of a BIM-based renovation process for making it more efficient with respect to traditional processes.

- Fast mapping tools (KER #4, Lead partner RISE)

This project result relates specifically to the needs in easier and facilitated data gathering processes for the renovation of existing buildings. It focuses on developing a set of technologies and solutions for fast mapping of buildings regarding geometric parameters, heating- and water pipes, ventilation systems, electrical cords as well as materials.

- Digital tools for HVAC design, operation and efficiency management (KER #5, Lead partner UCC)

This section of the project aims at developing a set of solutions favouring the design, procurement, installation, post-renovation operation, user feedback and profiling of building automation systems for HVAC. This will be facilitated through the collection of BIM dimensional data as well as BAC factual and monitoring data. Retrofit decision making will also be supported through interaction with tenants and owners during the design, construction, and post-renovation operation phases and a retrofit assessment tool.

- Occupants´ energy profiling mechanisms and HMI applications and interfaces (KER #6, Lead partner Suite5)

This result will contribute to part of the previously described KER in terms of occupants profiling and enable the identification of occupants' actual comfort preferences in terms of HVAC and Lighting loads operation, considering, also, the health constraints imposed during building operation.

- Tools for planning & management of intervention and sites (KER #7, Lead partner VTT)

This project result is aimed at tackling issues related to the excessive length and complications of renovation processes by creating BIM-enabled methods and tools enabling effective planning and management of retrofit interventions.

- Applications for inhabitant interaction and information exchange related to the intervention (KER #8, Lead partner Suite5)

This KER feeds into the previous one with the development of an application to properly guide building occupants during on-site renovation works and, in that way, enhance security and safety on-site, reduce intrusiveness and consider individual needs and schedules, to optimise operational planning.

- Guidelines on BIM usage (KER #9, Lead partner Reg Lomb)

This result is not a component or software solution like the rest of the previously described KERs. It refers to the development of guidelines for innovative BIM-based efficient renovation uptake, outlining benefits and challenges, when adopting BIM for renovation processes. These guidelines will result from the experience in implementing the BIM4EEB toolkit in the relevant pilot sites.

Each relevant KER will be explored from the point of view of standardization through partner contributions in the following sections. Within these sections, more detailed descriptions will be offered when relevant in order to understand the component or aspect to which a specific standard may apply.

As the BIM4EEB toolkit (KER #1) refers to the consolidated set of all tools, solutions, results and services developed during the BIM4EEB project, it is dependent on the standardization activities of all its components and as such most of the approach and strategy relative to standards is focused on individual modular KERs. This explains why no specific section is dedicated to KER #1. The main enablers or enabling KERS for the realization of this consolidated tool kit are the BIM management system and the linked data and ontologies being developed which will enable the creation of a common data environment for the integration of all the developed modules within the project. For this particular reason, the main priority in terms of standardization for this KER relate to the standardization activities that pertain directly to these results.

The following figure provides an overview of the individual tools being developed and the stage at which they enter in the renovation process (KERS being treated appear in blue).

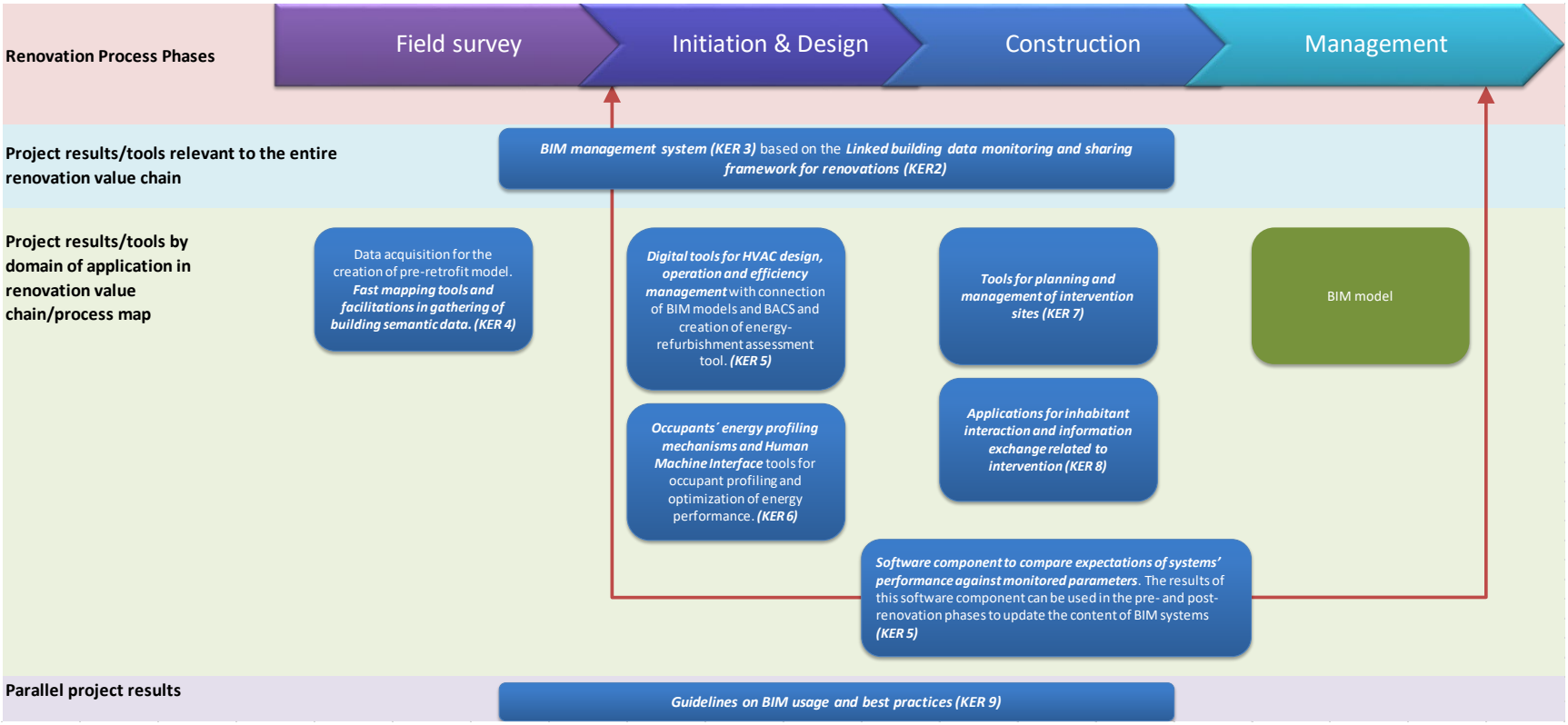


Figure 5 BIM4EEB Conceptual Overview

In the following sections, the detailed analysis of standardization for each KER is performed in line with the defined methodology as presented above.

3 BIM management system

As mentioned before when talking about the consolidated BIM4EEB toolkit (KER #1), the BIM Management system is the project KER which serves as a backbone for the integration of all solutions, modules, applications and tools as well as services developed during the project.
The BIM management system will have APIs and services specifically developed to give complete and interoperable access to the BIM4EEB project data. In order to reach these goals, this KER will be conceived as a web platform and in which all project partners can connect their tools and applications used and developed during the project.
The main components of the BIM management system will be composed of a **Common Data Environment (CDE)** so that BIM and GIS models along with linked data and IoT streaming data from sensors can be shared centrally. The main role of the CDE is to feed data to Tools, Applications and Services developed in the project that can of course be extended in order for potential users to have building related and syndicated data processed and treated with functionalities such as reporting systems, viewers, data sharing and analysis tools. In this sense, the BIM management system is a complete 3 layer platform with:

- **A data repository layer (CDE)**

The developed ontology within the BIM4EEB project investigated in the next section/KER will establish the relationships between data stored and linked in the CDE. The CDE will store BIM models generated during BIM4EEB (2D/3D Models, Point Clouds, and Analysis Models) and their representation as Linked Data and create relationships with other data repositories and sources identified within the project from internal and external sources (Regulations, Costs, Climate, Life-cycle Assessment, openData Repositories), Internet of Things (IoT) data-stream coming from sensors and environment, and finally from GIS data as schematic representation and location.

- **A CDE Service for Interoperability to exchange data from different authoring applications**

BIM Authoring applications will access the CDE with a set of application services for interoperability that will be used to upload data directly from applications.

- **A CDE Exchange Layer Services to connect the Semantic Web to give access to the users all necessary application frameworks for file sharing, data repository, visualisation, analysis and reporting.**

In the same way, an Exchange Layer with Services will be implemented to give to potential users the web access to the CDE to get reports and analysis, to share and visualise files and to implement frameworks and interfaces for other services and applications that could be implemented during the BIM4EEB project or later on.

3.1 Relevant technical standards

From the point of view of standardization, this is one of the most crucial and important elements of the

BIM4EEB project due to the complexities in terms of interoperability requirements and objectives and linking data. Moreover, as the objective of the consortium is to develop an open source platform with these characteristics, it is crucial for standardization to be at the heart of the relevant tasks. Finally, as this KER serves as a base for the other project implements and results and that it will be used as a potential platform for the integration of more applications and features down the line, it is crucial for its development to be in line with current market standards and practices for easier integration and diffusion from an exploitation point of view. In the following two sections, one can observe the standards identified by the relevant consortium partners as being crucial to the development of this KER.

Although standards relating to the linked data framework and ontologies could enter this section, they will be explored in a dedicated section after this one.

- ***International Standards***

Standardization board	Technical Committee	Standard
ISO	ISO/TC 59/SC 13 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)	ISO 19650-1:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles (https://www.iso.org/standard/68078.html)
		ISO 19650-2 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 2: Delivery phase of the assets (https://www.iso.org/standard/68080.html)
		ISO 19650-3:2020 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 3: Operational phase of the assets (https://www.iso.org/standard/75109.html)
		ISO 19650-5:2020 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 5: Security-minded approach to information management

		(https://www.iso.org/standard/74206.html)
		ISO 16739 – Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries buildingSMART Industry Foundation Classes (IFC) (https://www.iso.org/standard/51622.html)
		ISO 21597-1:2020 Information container for linked document delivery — Exchange specification — Part 1: Container (https://www.iso.org/standard/74389.html)
		ISO 21597-2:2020 Information container for linked document delivery — Exchange specification — Part 2: Link types (https://www.iso.org/standard/74390.html)

Table 4 International standards relevant to the BIM management system

ISO/TC 59/SC 13 is the technical committee dedicated to the Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Both relevant international standards recognized as being central to the development of this project implement are from this technical committee.

- **ISO 19650 Part 1: Concepts and principles; Part 2: Delivery phase of the assets; Part 3: Operational phase of the assets; Part 5: Security-minded approach to information management**

The ISO 19650 standard is an international standard for managing information over the whole life cycle of a built asset using building information modelling (BIM). This document/standard specifies requirements for information management, in the form of a management process, within the context of the delivery phase of assets and the exchanges of information within it, using building information modelling. This document can be applied to all types of assets and by all types and sizes of organizations, regardless of the chosen procurement strategy. The aim of this standard is to support all parties towards achieving their business objectives through the effective and efficient procurement, use and management of information during the delivery phase of assets. (ISO, ISO 19650-2, n.d.)

Within the framework of the BIM4EEB project and specifically the development of the BIM management system, this standard applies mainly towards the CDE component and the development of tasks T4.1 related to specifications and overall design of a BIM management system, task T4.3 related to the development of a platform as a CDE to support decision making, Task T4.4 related to the development of web interfaces to CDE and task T4.5 related to the development of a dedicated set of applications using the APIs of major BIM and GIS authoring platforms to manage the CDE.

“ISO 19650 standards define the need to have a common data environment (CDE) for collecting, managing and disseminating information throughout BIM projects. In accordance with ISO 19650, BIM is primarily concerned with managing information containers within the CDE. These information containers

are typically files or sub-directories, and can be structured or unstructured. Structured information containers include items such as geometric models, schedules and databases. Unstructured information containers include items such as documentation, video clips and sound recordings." (ISO, ISO 19650-2, n.d.)

With respect to the CDE workflow in BIM4EEB which is particularly pertinent to ISO 19650-2, information containers move between different states as the work progresses. "They will start as work in progress, and then they will be shared before being published. Finally, an information container may be archived. To move from one state to the next, there should be an agreed approval and authorization process. The standards state that each information container should have a unique ID that follows a documented convention and attributes to indicate the status/ suitability, the revision information and the classification." (ISO, ISO 19650-2, n.d.)

- **ISO 16739 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries**

The ISO 16739 standard relates directly to Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries. This standard is a data model developed by buildingSMART to facilitate interoperability between AEC practitioners and commonly used in BIM. It was ISO certified in 2013. The platform will be designed to incorporate typical IFC models and classes and further enhance them through coupling and establishing relationships with new modelling constructs, building acoustics, occupants' behaviour and comfort, economic, environmental, weather, GIS and regulatory data models. In this sense, this standard will be concerned with all the tasks related to this KER as it is the format of choice for data sharing of models.

The standard specifies a conceptual data schema and an exchange file format for Building Information Model (BIM) data. The conceptual schema is defined in EXPRESS data specification language. The standard exchange file format for exchanging and sharing data according to the conceptual schema is using the Clear text encoding of the exchange structure.

This is an open international standard for BIM data that is exchanged and shared among software applications used by the various participants in a building construction or facility management project. Therefore, it is extremely important for the integration of all tools and applications being developed by the BIM4EEB partners as well as guaranteeing further use and integration down the line beyond the project. (ISO, ISO 16739:2013, n.d.)

- **ISO 21597 Information container for linked document delivery — Exchange specification**

ISO 21597 refers to the development of an open container format to exchange different heterogenous files throughout the building lifecycle. It has been developed in order for all intervening parties in a project to exchange multiple documents and their interrelationships. The format uses data either included in the container such as documents or referenced remotely such as web resources. (ISO, ISO 21597 , 2020)

- ***National and industry specific standards***

Standardizatio	Technical	Standard

n board	Committe e	
UNI - Italian Standardization Body	CT 033	UNI 11337-4 Evolution and informative development of models, designs and objects (http://store.uni.com/catalogo/index.php/uni-11337-4-2017?josso_back_to=http://store.uni.com/josso-security-check.php&josso_cmd=login_optional&josso_partnerapp_host=store.uni.com)
		UNI 11337-5 Information flows in the digitized processes (http://store.uni.com/catalogo/index.php/uni-11337-5-2017)

Table 5 National and industry standards relevant to the BIM management system

From the point of view of national standards, the partners most pertinent to the development of this KER and the BIM management system as a whole have noted down the two standards above belonging to UNI which is the Italian national standardization body in charge of implementing the relevant CEN standards from TC 442. This is the technical committee in charge of standardization in the field of structured semantic life-cycle information for the built environment. The committee develops a structured set of standards, specifications and reports which specify methodologies to define, describe, exchange, monitor, record and securely handle asset data, semantics and processes with links to geospatial and other external data. As established in the BIM4EEB workplan, all components of the BIM management system developed by OneTeam/PoliMi, the main partners in charge of the development of the system, will be released as open source. It is therefore logical for them to operate in line with their national standardization board as often prescribed in common NSB R&D project standardization strategy protocols. Moreover, as OneTeam participates in UNI meetings for drafting of standards and guidelines regarding BIM for the construction sector, it will be easy for them to pursue standardization activities through their NSB.

Both standards from UNI that were listed as relevant by BIM4EEB partners are found within the CT 033 technical committee responsible for the standardization activities related to products, processes and systems for the organization of construction activities.

- **UNI 11337-4 Evolution and informative development of models, designs and objects**

This standard concerns the qualitative and quantitative aspects of the digitalized management of the information process in the construction sector, in support of the decision-making process, with the aim of:

- Specifying the objectives of each of the phases of a process (numbered from 0 to 7) introduced in UNI 11337-1. The model, the objects and the information documents are instrumental in achieving these objectives
- Defining a common scale of information development level of the objects related to the models
- Defining a common scale of processing and approval status of information content.

This standard is applicable to any type of product from the sector and any type of process (of conception, production or operation), for new construction and conservation, demolition and / or redevelopment of the environment or built heritage. (UNI Ente Italiano di Normazione, UNI 11337-4, n.d.)

Relevant partners have specified that this standard is mostly relevant to the work being carried out in task T4.3 Development of a platform as a CDE to support decision making, specifically in terms of the Level of Development (LOD) of the related models; and task T4.5 Development of a dedicated set of applications using the APIs of major BIM and GIS authoring platforms to manage the CDE, specifically in terms of the integration between BIM and GIS.

- **UNI 11337-5 Information flows in the digitized processes**

The standard defines the roles, rules and flows necessary for the production, management and transmission of information and their connection and interaction in digitized construction processes.
As stated by the partners, this will mostly apply to T4.4 and the development of web interfaces for the CDE. As this task implies the creation of CDE Services Interoperability and Exchange Layer Services for exchanging data between Applications and CDE it is important for the consortium to follow standardized information management and transmission protocols relevant to BIM and the built environment, all of which are embodied in this standard. (UNI Ente Italiano di Normazione, UNI 11337-5, n.d.)

3.2 Roadmap and internal process for standardization

Typical roadmaps for standardization activities generally involve a set of tasks where relevant standards are initially recognized, potential needs or gap analyses of current standards are performed if relevant to the activities being taken on and strategies for standards contributions, namely in terms of CEN deliverables, are developed. Moreover, internal processes for standards compliance and contribution must be set about at key points in the project´s main developments. Finally, for situations where actual contributions to current standards, working groups or even new standardization are envisioned through deliverables described in Table 1 CEN deliverables and time to develop; liaison and communication must be established with relevant standardization bodies and NSBs in due time respecting delays.

In addition to this, as we have focused all of our KERs on specific WPs of the BIM4EEB project, it is possible to establish a tentative roadmap which is coherent with task and deliverables development.

The following figure represents a tentative roadmap for the standardization approach and strategy for the BIM Management System, reflecting partner intentions and wishes, project schedules and development as well as general consortium feedback.

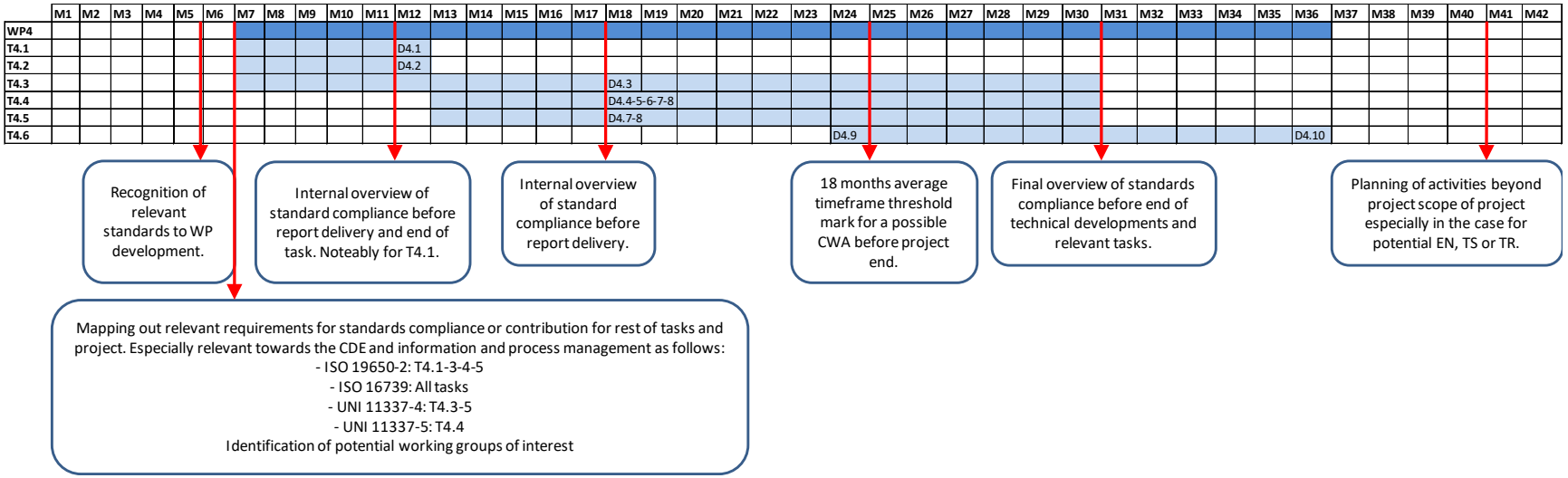


Figure 6 Tentative standardization roadmap BIM Management System

D4.1	Technical specifications for the design of a BIM management system
D4.2	Users' profiles for accessing the BIM management system
D4.3	CDE Database, Core DB functionalities, Ontological representation, BIM data translation engine to ontology
D4.4	CDE Services, Interoperability Services, Exchange Layer Services, I/O Protocols and Data specification
D4.5	Technical configuration of the platform
D4.6	Guidelines for the implementation of the BIM management system
D4.7	API, Master end user front end
D4.8	Guidelines for the integration of new tools in the BIM Management system
D4.9	Tested version of the platform
D4.10	Testing and validation results on demonstration sites

Table 6 WP4 deliverable

4 Linked data sharing framework for renovations / BIM ontology for renovation

The linked data sharing framework for renovations and new ontologies refers to the enhacement of current BIM-based approaches to ensure seamless collaboration and interoperable communication and data exchange among all actors involved in the renovation industry spanning from AEC professionals to finance parties. As the exchange of information in the form of designs, models and supply information amongst others is hampered by organizational boundaries, cross disciplinary cooperation and different company standard operating procedures and modus operandis, interoperability is a central issue in order to fluidify renovation and construction processes. Indeed, relevant information is not yet properly shared among stakeholders and there is often a duplication of efforts required for using it in the different tools involved.

BIM offers a collaborative environment among all stakeholders involved in the design and construction process and, as such, interoperability (syntax, visualization and semantic) is one of the crucial enabling factors for the successful diffusion of BIM processes and for software packages manipulating the models to be able to interoperate reliably and without necessitating significant human intervention.

Until now, Industry Foundation Classes (IFC) models for data sharing in the construction and facility management industries have ensured interoperability and the exchange of information. This has lead to certain limitations as several barriers are still encountered in the adoption of IFC (e.g. static representation of information, incomplete information structure considering the specificities of renovation processes). For this reason, BIM4EEB will rely on semantic interoperability based on ontologies and linked data harmonising and orchestrating existing ontologies in the construction domain, while investigating intermodal and inter-ontology relationships to address concepts that are currently absent from building-relevant ontologies and very much relevant to specific developments within this project such as human centric and behavioral profiling implements (e.g. comfort, occupancy, energy performance, workflow and process management, materials).

Ontologies (i.e. ‘semantically consistent, meta-data dictionaries’) are identified as one “enabling technology” for the integrated, holistic, seamless deployment of attractive toolkits operated as components of a BIM-platform using the “linked data paradigm”. BIM4EEB will analyse existing ontologies relevant to the renovation domain, propose refinements and extensions and harmonise them. Further inter-model and inter-ontology relationships will be investigated to integrate concepts which are currently absent or underdeveloped in current ontologies and that will be relevant according to the objectives of the proposal for instance in terms of behavioral profiles of occupants and such (e.g. comfort, occupancy, energy performance, workflow and process management, materials, equipment).
As a result, project relevant data will be shared through a flexible and easily adaptable data interface enabling the use of available data generated or residing in external systems and utilise it in several renovation and construction tools and for different.

This KER is an integral development for the execution and completion of the BIM management system as whole since the CDE will use the developed ontology as a basis for the sharing of relevant information.

4.1 Relevant technical standards

From the point of view of standardization, this KER is central to the BIM4EEB project as it feeds into the BIM management system and actually enables the functional interoperability of all applications and tools that are developed in parallel, creating a unified environment truly capable of tackling the coordination and information exchange barriers that currently plague the renovations market. Moreover, as this KER will first investigate existing ontologies and information exchange formats, it will be crucial for the relevant partners to examine the standards governing these. In the following two sections, one can observe the standards identified by the relevant consortium partners as being crucial to the development of this KER.

- **International Standards**

Standardization board	Technical Committee	Standard
ISO	ISO/TC 59/SC 13 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)	ISO 16739 – Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries buildingSMART Industry Foundation Classes (IFC with specific focus on ifcOWL and W3C standards) (https://www.iso.org/standard/51622.html)
	ISO/TC 159/SC 5 Ergonomics of the physical environment	ISO 7730:2005 Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria https://www.iso.org/standard/39155.html
		ISO 10551:2019 Ergonomics of the physical environment — Subjective judgement scales for assessing physical environments https://www.iso.org/standard/67186.html
	ISO/TC 283 Occupational health and safety management systems	ISO 45001 OCCUPATIONAL HEALTH AND SAFETY https://www.iso.org/iso-45001-occupational-health-and-safety.html
	ISO/TC 59/SC 13 CEN TC 442 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)	ISO 12006-2:2015 Building construction — Organization of information about construction works — Part 2: Framework for classification https://www.iso.org/standard/61753.html
		ISO 12006-3:2007 Building construction — Organization of information about construction works — Part 3: Framework for object-oriented information https://www.iso.org/standard/38706.html
	ISO/TC 59/SC 2 Terminology	ISO 6707-1:2017

	and harmonization of languages	Buildings and civil engineering works — Vocabulary — Part 1: General terms https://www.iso.org/standard/69426.html
		ISO 6707-2:2017 Buildings and civil engineering works — Vocabulary — Part 2: Contract and communication terms https://www.iso.org/standard/70040.html
	ISO/TC 301 Energy management and energy savings	ISO 50001:2018 Energy management systems — Requirements with guidance for use https://www.iso.org/iso-50001-energy-management.html
	ISO/TC 43/SC 2 Building acoustics	ISO 12354-1:2017 Building acoustics — Estimation of acoustic performance of buildings from the performance of elements — Part 1: Airborne sound insulation between rooms https://www.iso.org/standard/70242.html
		ISO 12354-2:2017 Building acoustics — Estimation of acoustic performance of buildings from the performance of elements — Part 2: Impact sound insulation between rooms https://www.iso.org/standard/70243.html
		ISO 12354-3:2017 Building acoustics — Estimation of acoustic performance of buildings from the performance of elements — Part 3: Airborne sound insulation against outdoor sound https://www.iso.org/standard/70244.html
		ISO 12354-4:2017 Building acoustics — Estimation of acoustic performance of buildings from the performance of elements — Part 4: Transmission of indoor sound to the outside https://www.iso.org/standard/70248.html
ISO/DIS	ISO/TC 59/SC 13 CEN TC 442 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM)	ISO/FDIS 23386 Building information modelling and other digital processes used in construction — Methodology to describe, author and maintain properties in interconnected dictionaries https://www.iso.org/standard/75401.html
		ISO/DIS 23387 Building Information Modelling (BIM) — Data templates for construction objects used in the life cycle of any built asset — Concepts and

		principles https://www.iso.org/standard/75403.html
IEA	Energy in Buildings and Communities Programme	IEA-EBC Annex 66 Definition and Simulation of Occupant Behavior in Buildings
		IEA EBC - Annex 79 - Occupant-Centric Building Design and Operation http://annex79.iea-ebc.org/

Table 7 International standards relevant to the building data monitoring and sharing framework

As can be seen in the above table, many standards come from the same technical comittees and as such, we will distinguish the different technical committees in question and then the standards that are relevant to the project that are published by them.

- **ISO/TC 59/SC 13**

As already explored in previous WP/KER section, ISO/TC 59/SC 13 is the technical committee dedicated to the Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) and active participation of buildingSMART. (ISO, ISO 16739:2013, n.d.)

  - **ISO 16739 and ifcOWL**

The ISO 16739 standard relates directly to Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries. As mentioned in the previous section, this standard is important as the platform will be designed to incorporate typical IFC models and classes and further enhance them through coupling and establishing relationships with new modelling constructs, building acoustics, occupants' behaviour and comfort, economic, environmental, weather, GIS and regulatory data models.
ifcOWL provides a Web Ontology Language (OWL) representation of the Industry Foundation Classes (IFC) schema. It is specifically important to this KER as the ifcOWL ontology enables the representation of building data using semantic web and linked data technologies. IFC data becomes available according to W3C´s Resource Description Framework (RDF) specifications. This standard model for data interchange on the Web, allows building data to be easily linked to material data, GIS data, product manufacturer data, sensor data, classification schemas, social data, and so on. The result is directly related to the ensemble of tasks in WP3 with the creation of a web of linked building data that brings major opportunities for data management and exchange in the construction industry and beyond. (buildingSMART, n.d.)

- **ISO/TC 59/SC 13 CEN TC 442**

This is the TC responsible for the organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) as already observed in the section on the BIM management system. The following standards from this TC pertain to this KER.

  - **ISO 12006-2/3**

“ISO 12006-2:2015 defines a framework for the development of built environment classification systems. It identifies a set of recommended classification table titles for a range of information object classes according to particular views, e.g. by form or function, supported by definitions. It shows how the object classes classified in each table are related, as a series of systems and sub-systems, e.g. in a building information model.”

“ISO 12006-2:2015 does not provide a complete operational classification system, nor does it provide the content of the tables, though it does give examples. It is intended for use by organizations which develop and publish such classification systems and tables, which may vary in detail to suit local needs. However, if this part of ISO 12006 is applied in the development of local classification systems and tables, then harmonization between them will be facilitated.” (ISO, ISO 12006-2:2015, n.d.)

Within the framework of BIM4EEB, this standard is specifically relevant towards the classification of information and provide a framework in order to classify existing built environment information object classes.

“On the other hand, ISO 12006-3 specifies a language-independent information model which can be used for the development of dictionaries used to store or provide information about construction works. It enables classification systems, information models, object models and process models to be referenced from within a common framework.” (ISO, ISO 12006-3:2007, n.d.)

These standards tend to be relevant towards tasks 3.1, 3.3, 3.4, 3.6 and 3.7.

- **ISO/DIS 23386 and ISO/DIS 23387**

ISO/DIS 23386 is currently under development, with the aim of providing a methodology to describe, author and maintain properties in interconnected dictionaries. For the future of BIM it is important to ensure that these dictionaries can be interoperable in tools and applications. (ISO, ISO/FDIS 23386, n.d.)

—"The elements of the dictionaries, for instance, the properties, need to be described by the same attributes. If this is agreed and done by all dictionary providers, then it is quite simple to map properties in one dictionary to properties in other dictionaries which can lead to reuse of properties and to harmonization of properties across dictionaries. In addition, this is an important step to allow BIM applications to use a set of dictionaries in a common way.”

—"The governance of the dictionaries has to follow the same rules with respect to the building and development of the dictionaries’ content.”

“The assumption is that the dictionaries are independent from each other, but that they are connected in a coordinated network of dictionaries (again, there may exist several of these networks). Within the network, the dictionaries are related, which is visible, for instance, by the use of a specific attribute which maps properties and groups of properties of different dictionaries to each other. Any dictionary in the network of coordinated dictionaries is independent, i.e. it has its own processes and committees to control the development and evolution of the dictionary, they all follow the same description and governance rules defined in this standard.”

“This standard defines the attributes to define properties and group of properties of the single dictionaries as well as the processes and committees / roles for the governance of the single dictionary in a network

of coordinated dictionaries. In the governance processes, it is described how the single dictionary deals with queries and change requests, and the extension of queries to other connected dictionaries, information of other connected dictionaries regarding change is an integral part of this process."

As BIM4EEB will develop ontologies while investigating intermodal and inter-ontology relationships to address concepts that are currently absent from building-relevant ontologies and relevant to specific developments within this project, investigating such standards is important in order to obtain feedback and indications as to connect the different dictionaries and data and enable their use in the developed applications during the project.

Similarly, ISO/DIS 23387 is also under development, with the aim of creating data templates for construction objects used in the life cycle of built assets. (ISO, ISO/DIS 23387, n.d.)

These standards tend to be relevant towards tasks 3.1, 3.3, 3.4, 3.6 and 3.7.

- **ISO/TC 59/SC 2**

This TC is dedicated towards the terminology and harmonization of languages. It develops common vocabulary on areas relevant to the built environment with working groups dedicated to topics such as sustainability in buildings and civil engineering works.

  - **ISO 6707-1/2**

ISO 6707-1:2017 contains the terms and definitions of general concepts to establish a vocabulary applicable to buildings and civil engineering works. (ISO, ISO 6707-1:2017, n.d.)

It comprises:

- fundamental concepts, which can be the starting point for other, more specific, definitions;
- more specific concepts, used in several areas of construction and frequently used in standards, regulations and contracts.

ISO 6707-2:2017 defines terms applicable to contracts and communication in relation to buildings and civil engineering works. (ISO, ISO 6707-2:2017, n.d.)

Within the framework of BIM4EEB, this standard will be observed in order to respect standardized terminology for relevant construction and civil engineering processes as well as contracts and other forms of communication in order to cover all phases of asset renovation, construction and delivery.

This standard tends to be relevant towards tasks 3.1, 3.3, 3.4, 3.6 and 3.7.

- **ISO/TC 283 Occupational health and safety management systems**

  - **ISO 45001**

ISO 45001 is a standard focused on the domain of occupational health and safety management procedures with the definition of the requirements for a management system as well as giving guidance

on its use. An ISO 45001 management system provides a framework to establish OH&S management policies, objectives, processes and governance, and facilitates an organization's achievement of its strategic goals. (ISO, ISO 45001, n.d.)

BIM4EEB will mainly focus on the IEQ aspect of this standard supporting the evaluation of indoor hygienic and health/well-being conditions according to the standards prescriptions on contamination of air with compounds, such as carbon dioxide (CO2), carbon monoxide (CO), nitrogen dioxide (NO2) and volatile organic compounds (VOCs). All of these aspects are once again mainly addressed in T3.2 on the Refined domain ontology for occupants, building services, building energy and acoustics.

- **ISO/TC 159/SC 5**

This TC relates to standardization in the field of ergonomics. It is most relevant to BIM4EEB in terms of ergonomics of human system interaction and ergonomics of the physical environment, addressing human characteristics and performance, and methods for specifying, designing and evaluating products, systems, services, environments and facilities.

  - **ISO 7730**

"ISO 7730 presents methods for predicting the general thermal sensation and degree of discomfort (thermal dissatisfaction) of people exposed to moderate thermal environments. It enables the analytical determination and interpretation of thermal comfort using calculation of PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) and local thermal comfort, giving the environmental conditions considered acceptable for general thermal comfort as well as those representing local discomfort." (ISO, ISO 7730, n.d.)

Within the BIM4EEB project, this standard will once again be applied to T3.2 on the Refined domain ontology for occupants, building services, building energy and acoustics in the creation/definition of KPIs and boundaries associated with IEQ and comfort levels for occupants' comfort modelling.

  - **ISO 10551:2019**

This standard presents principles of practical application for the construction of appropriate subjective scales for use in the assessment and evaluation of the physical environment.

"It considers scales of perception, comfort, preference, acceptability, expression form and tolerance, and environmental components such as thermal, visual, air quality, acoustic and vibration." (ISO, ISO 10551:2019, n.d.)

Within the BIM4EEB project, this standard will be applied to T3.2 on the Refined domain ontology for occupants, building services, building energy and acoustics in the creation/definition of KPIs and boundaries associated with IEQ and comfort levels for occupants' comfort modelling. This standard can be used to evaluate IAQ conditions in building premises.

- **ISO/TC 301**

Standardization in the field of energy management and energy savings.

  - **ISO 50001:2018**

"ISO 50001 is based on the management system model of continual improvement also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organizations to integrate

energy management into their overall efforts to improve quality and environmental management." (ISO, ISO 50001:2018, n.d.)

ISO 50001:2018 provides a framework of requirements for organizations to:

- "Develop a policy for more efficient use of energy"
- "Fix targets and objectives to meet the policy"
- "Use data to better understand and make decisions about energy use"
- "Measure the results"
- "Review how well the policy works, and"
- "Continually improve energy management."

This standard can be used for determining systems requirements specifically with regard to energy management.

- **ISO/TC 43/SC 2**

This technical committee is in charge of standardization in the field of acoustics, including methods of measuring acoustical phenomena, their generation, transmission and reception, and all aspects of their effects on man and his environment.

The four following standards will be used to tackle issues related to acoustic analysis and how to incorporate them in the BIM4EBB project. Specifically, the ISO 12354 framework will be used as a methodology to incorporate building acoustics parameters in the extended BIM ontology.

  - **EN ISO 12354-1:2017**

"This standard specifies calculation models designed to estimate the airborne sound insulation between adjacent rooms in buildings, primarily using measured data which characterize direct or indirect flanking transmission by the participating building elements, and theoretically-derived methods of sound propagation in structural elements. Two models are provided within the standard describing principles of the calculation scheme. One of them is A detailed model described in frequency bands, in the frequency range 1/3 octave 100 Hz to 3 150 Hz in accordance with ISO 717-1, possibly extended down to 1/3 octave 50 Hz if element data and junction data are available while the simplified model with a restricted field of application is deduced from this, calculating directly the single number rating, using the single number ratings of the elements." (ISO, ISO 12354-1:2017, n.d.)

  - **ISO 12354-2:2017**

This standard specifies calculation models designed to estimate the impact sound insulation between rooms in buildings, primarily using measured data which characterize direct or indirect flanking transmission by the participating building elements and theoretically-derived methods of sound propagation in structural elements. Impact noise in buildings is made according to EN ISO 16283-2 and evaluated according to EN ISO 717-2. (ISO, ISO 12354-2:2017, n.d.)

  - **ISO 12354-3:2017**

"This standard specifies a calculation model to estimate the sound insulation or the sound pressure level difference of a façade or other external surface of a building. The calculation is based on the sound reduction index of the different elements from which the façade is constructed and it includes direct and

flanking transmission. Measurement of the sound insulation of facades could be made according to EN ISO 16283-3 and evaluated according to EN ISO 717-1". (ISO, ISO 12354-3:2017, n.d.)

- **ISO 12354-4:2017**

"This standard specifies a calculation model to estimate the sound power level radiated by the envelope of a building due to airborne sound inside that building, primarily by means of measured sound pressure levels inside the building and measured data which characterize the sound transmission by the relevant elements and openings in the building envelope." (ISO, ISO 12354-4:2017, n.d.)

- **IEA-EBC**

The International Energy Agency has established an Implementing Agreement on Energy in Buildings and Communities (EBC). The function of EBC is to undertake research and provide an international focus for building energy efficiency. Tasks are undertaken through a series of 'Annexes', so called because they are legally established as annexes to the EBC Implementing Agreement. (Energy in Buildings and Communities Programme, IEA, n.d.)

- **Annex 66 and 79**

"Annex 66 aims to set up a standard occupant behavior definition platform, establish a quantitative simulation methodology to model occupant behavior in buildings, and understand the influence of occupant behavior on building energy use and the indoor environment. The IEA - Annex 66 working group was established with the following subtasks" (Energy in Buildings and Communities Programme, IEA, Annex66, n.d.):

- Subtask A - Occupant movement and presence models.
- Subtask B - Occupant action models in residential buildings.
- Subtask C - Occupant action models in commercial buildings.
- Subtask D - Integration of occupant behavior definition and models with current building energy modeling programs. A framework in XML schema and a software module with occupant behavior models will be the main outcome of this subtask.
- Subtask E - Applications in building design and operations.

Subtask D will be used as one of the main inputs towards the definition of occupant's behaviors and comfort model in BIM4EEB.

Annex 79 is a follow up on Annex 66 addressing withstanding issues through enhanced sensing and modelling techniques. This is an ongoing working group with many overlaps with the occupant comfort and behavior modelling being performed in BIM4EEB. For this reason, outcomes must be monitored. (Energy in Buildings and Cumminities Programme, IEA, Annex79, n.d.)

- **European Standards**

Standardization board	Technical Committee	Standard
CEN	TC 156 Ventilation for buildings	EN 15251: Indoor Environmental Criteria https://www.rehva.eu/rehva-journal/chapter/revision-of-en-15251-indoor-environmental-criteria
		SAREF ontology and extensions

European Commission/ ETSI	N/A	https://ec.europa.eu/digital-single-market/en/news/etsi-releases-three-new-saref-ontology-specifications-smart-cities-industry-40-and-smart
		Directive 2008/50/EC https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32008L0050

Table 8 European standards relevant to the building data monitoring and sharing framework

- **TC 156 Ventilation for buildings**

The scope of this TC is the standardization of terminology, testing and rating methods, dimensioning and fitness for purpose of natural and mechanical ventilation systems and components for buildings subject to human occupancy.

  - **EN 15251**

EN 15251 is concerned with the indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.

In terms of the BIM4EEB project, it is mainly concerned with occupants´ behaviours and comfort models and the definition of KPIs and boundaries associated with indoor environmental quality (IEQ). This is mainly contained in task T3.2 led by Suite5 on the Refined domain ontology for occupants, building services, building energy and accoustics. (Federation of European Heating, Ventilation and Air Conditioning Associations, n.d.)

- **Directive 2008/50/EU of the European Parliament and of the Council**

IAQ KPIs within the BIM4EEB project will mainly be a product of and comply with Directive 2008/50/EU, which sets standards in air quality taking into account relevant World Health Organisation standards, guidelines and programmes. (European Union Law, n.d.)

The directive established health based objectives for a number of pollutants present in the air which will influence IAQ KPI setting for T3.2.

The following table is an overview of these threshold limits (European Union Law, n.d.):

Pollutant	*Concentration*	*Averaging period*	*Legal nature*	*Permitted exceedences each year*
Fine particles (PM2.5)	25 µg/m3	1 year	Target value to be met as of 1.1.2010 Limit value to be met as of 1.1.2015	n/a
Sulphur dioxide (SO2)	350 µg/m3	1 hour	Limit value to be met as of 1.1.2005	24
	125 µg/m3	24 hours	Limit value to be met as of 1.1.2005	3
Nitrogen dioxide (NO2)	200 µg/m3	1 hour	Limit value to be met as of 1.1.2010	18
	40 µg/m3	1 year	Limit value to be met as of 1.1.2010 *	n/a
PM10	50 µg/m3	24 hours	Limit value to be met as of 1.1.2005 **	35
	40 µg/m3	1 year	Limit value to be met as of 1.1.2005 **	n/a
Lead (Pb)	0.5 µg/m3	1 year	Limit value to be met as of 1.1.2005 (or 1.1.2010 in the immediate vicinity of specific, notified industrial sources; and a 1.0 µg/m3 limit value applied from 1.1.2005 to 31.12.2009)	n/a
Carbon monoxide (CO)	10 mg/m3	Maximum daily 8 hour mean	Limit value to be met as of 1.1.2005	n/a
Benzene	5 µg/m3	1 year	Limit value to be met as of 1.1.2010**	n/a
Ozone	120 µg/m3	Maximum daily 8 hour mean	Target value to be met as of 1.1.2010	25 days averaged over 3 years
Arsenic (As)	6 ng/m3	1 year	Target value to be met as of 31.12.2012	n/a
Cadmium (Cd)	5 ng/m3	1 year	Target value to be met as of 31.12.2012	n/a
Nickel (Ni)	20 ng/m3	1 year	Target value to be met as of 31.12.2012	n/a
Polycyclic Aromatic Hydrocarbons	1 ng/m3 (expressed as concentration of Benzo(a)pyrene)	1 year	Target value to be met as of 31.12.2012	n/a

Table 9 Directive 2008/50/EU standards

- **SAREF - Smart Appliances REFerence (SAREF) ontology**

This standard has been developed by the European Commission in and ETSI, the European Telecommunications Standards Institute. It consists in a reference ontology for smart appliances, which has become a new European standard. The standard, creates a new reference language for energy-related data. This new language will be used by the devices in the home and will allow them to exchange information with any energy management system (which could physically be in the home or in the cloud). (European Commission, SAREF, n.d.)

This standard will be important for T3.2 and T3.5 with the use of sensor and metering data for comfort and behavioural profiling, energy systems modelling and the definition of data models for energy systems.

Existing gaps have been identified in the current standard with BIM4EEB specific attributes not yet defined in the existing ontologies specifically associated with the M&V protocol that will be developed in T3.5.

- **National and industry specific standards**

Standardization board	Technical Committee	Standard
ANSI/ASHRAE	N/A	ANSI/ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy https://www.ashrae.org/technical-resources/bookstore/standard-55-thermal-environmental-conditions-for-human-occupancy
		Guideline 14 https://www.techstreet.com/ashrae/standards/guideline-14-2014-measurement-of-energy-demand-and-water-savings?gateway_code=ashrae&product_id=1888937

Table 10 National and industry standards relevant to the BIM management system

- **ANSI/ASHRAE**

In terms of industry specific standards affecting this KER, Suite5 have identified ASHRAE standards as potentially relevant for developments in IEQ KPIs in BIM4EEB. ASHRAE, the American Society of Heating, Refrigerating and Air Conditioning Engineers, is a non-profit organization that develops and publishes standards for the heating, ventilating and air conditioning industry, with over 50,000 members. ASHRAE also serves as the administrator for the U.S. TAGs (United States Technical Advisory Group) to ISO/TCs 86, 142, 180 and 205 (International Organization for Standardization/Technical Committee) and to many of the subcommittees for ISO/TCs 86 and 180.

- **ANSI/ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy**

"ANSI/ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy is an American National Standard published by ASHRAE that establishes the ranges of indoor environmental conditions to achieve acceptable thermal comfort for occupants of buildings. The standard addresses the four primary environmental factors (temperature, thermal radiation, humidity, and air speed) and two personal factors (activity and clothing) that affect thermal comfort. It is applicable for healthy adults at atmospheric pressures in altitudes up to (or equivalent to) 3,000 m (9,800 ft), and for indoor spaces designed for occupancy of at least 15 minutes." (ANSI-ASHRAE, Standard 55, n.d.)

- **ASHRAE Guideline 14**

"ASHRAE Guideline 14: Measurement of Energy, Demand and Water Savings, is a reference standard for calculating energy and demand savings associated with performance contracts using measurements. Therefore, this standardization effort is in line with the project mandate for the definition of a measurement and verification framework in the project.
In addition, it sets forth instrumentation and data management guidelines and describes methods for accounting for uncertainty associated with models and measurements. The ASHRAE guideline specifies three engineering approaches to M&V. Compliance with each approach requires that the overall uncertainty of the savings estimates be below prescribed thresholds. The three approaches presented are closely related to and support the options provided in IPMVP presented in the following sections." (ANSI-ASHRAE, GUIDELINE 14-2014, n.d.)

- **International Performance Measurement and Verification Protocol (IPMVP)**

The IPMVP is a standardized approach for measurement and verification in buildings divided into the following three volumes:

- Volume I - Concepts and Options for Determining Energy and Water Savings. In this document the basic concepts are included and the methodology to be carried out is developed. It is, therefore, the most important volume since it includes most of the information needed to apply the IPMVP.
- Volume II - Concepts and practices for improved indoor environmental quality (2002). This document addresses the environmental aspects of indoor air that are related to the design, implementation and maintenance of Energy Efficiency Measures EEMs
- Volume III. It provides details for the M&V methods in the construction of new buildings and in renewable energy systems

The IPMVP framework, used to estimate energy/demand savings, and delivered as the basis for the definition of the Performance Measurement and Verification Protocol as defined in the project.

In line with IPMVP the International Organization for Standardization (ISO) published the standard ISO 50015:2014 "Energy management systems - Measurement and verification of energy performance of organizations - General principles and guidance", which complements the previous ISO 50001:2011 "Energy Management System", in the context of M&V, key point for the energy management systems based on this standard.

- **EN 16212:2012**

Although it was possible to apply the EVO's IPMVP protocol, in 2012 the European Committee for Standardization (CEN) publishes the standard EN 16212:2012: "Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods". The main objective of this regulation is to harmonize the methods for monitoring and evaluating energy savings considering the numerous policies and actions carried out in recent years within the framework of the European Union in the field of reducing greenhouse gas emissions and energy efficiency. The document presents a general approach for the calculation of energy savings in final energy consumption in buildings, cars, equipment and industrial processes, among others, to carry out ex ante and ex post evaluations in any chosen period. (BSI, EN 16212:2012, n.d.)

The two proposed methods, top-down and bottom-up, were designed within the framework of the European Directive 2006/32/EC on energy end-use efficiency and energy services (currently replaced by the European Directive 2012/27/EU on energy efficiency). The top-down method proposes the estimation of savings from indicators calculated with statistical data while the ascending method is based on actions of end users to improve energy efficiency. Also the key principles of this standardization effort will be considered as part of the work for the measurement and verification framework of the project

4.2 Roadmap and internal process for standardization

The following figure represents a tentative roadmap for the standardization approach and strategy for the Linked data and sharing framework for renovations and new ontologies, reflecting partner intentions and wishes, project schedules and development as well as general consortium feedback. One of the important

aspects of standardization activities for this KER is the envisioned extension towards SAREF standards in terms of the extension to ontologies. If liaison is required according to the obtained results it shall be established in due time. Since this KER is an integral part of the CDE and the BIM management system as a whole, this task has already started with three preparatory deliverables already having been given in.

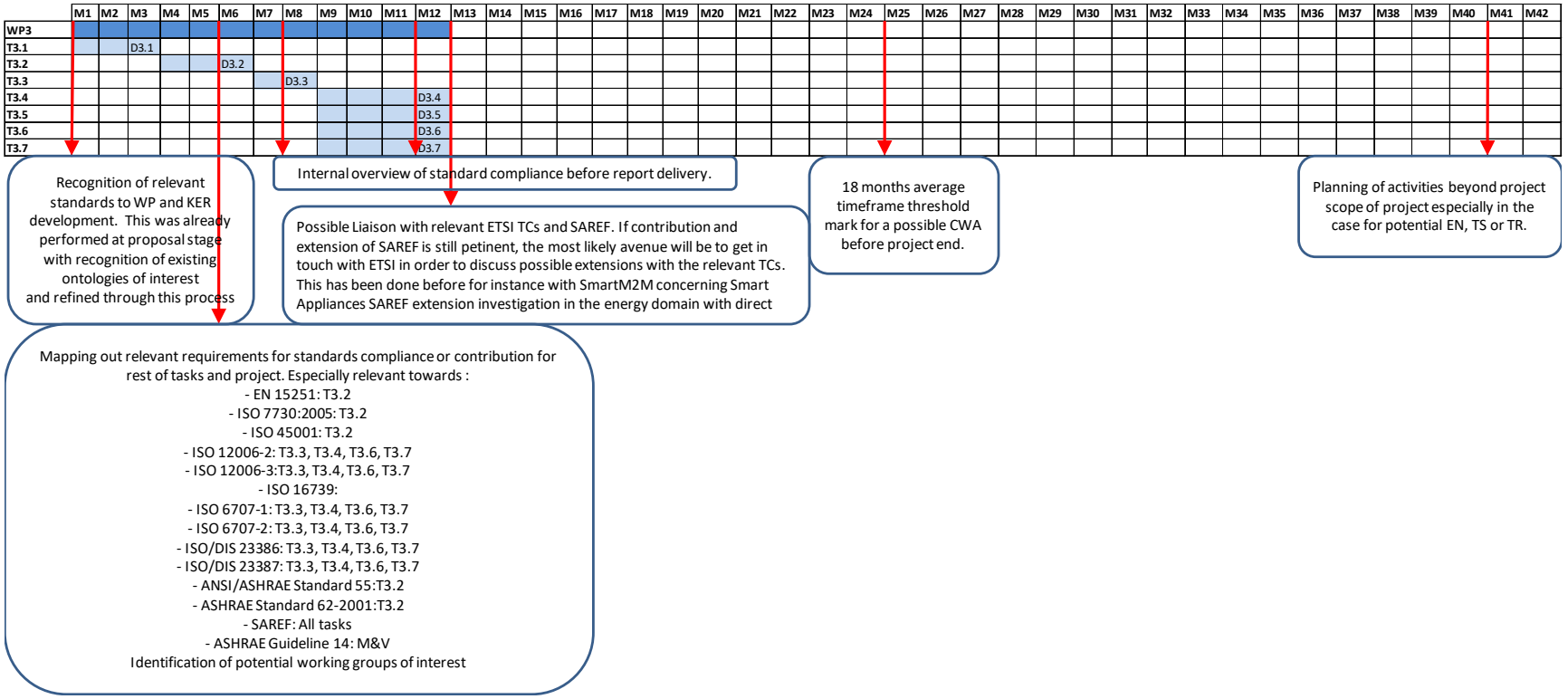


Figure 7 Tentative standardization roadmap Linked data

D3.1	A BIM-based framework for building renovation using the linked data approach and ontologies
D3.2	A refined, integrated domain ontology for occupants, building services, building energy and acoustics
D3.3	An ontology for representing data and information stored in BIM models at different levels of detail
D3.4	An Ontology to represent renovation workflows including BIM change management Services, I/O Protocols and Data specification
D3.5	Measurement and Verification protocol
D3.6	Integrated Linked Data Modelling and Sharing framework
D3.7	Harmonised common data exchange formats

Table 11 WP3 Deliverables

5 Fast mapping tools

As the BIM4EEB project aims to reduce intervention time and facilitate the collection and processing of data for the renovation of existing buildings, it is important to develop methodologies, tools and technologies capable of reproducing 3D models of buildings with geometric parameters as well as more complex and "hidden" information which generally are subject to undocumented changes over the life cycle of a building such as heating and water pipes, ventilation systems, electrical cords as well as materials. In order to tackle this challenge, the BIM4EEB project aims to develop a digital tool for fast mapping of buildings encompassing the previously mentioned types of information. The development in question will be based around an augmented reality tool designed for two purposes: to speed up the mapping process and to visualize the building as a help for quality assurance in the building process. It will combine different monitoring techniques for identification of the buildings geometric lay out, installations and materials. It is planned to connect the developed AR tool to the BIM model in order to upload information and retract updates when used to visualize.

5.1 Relevant technical standards

From the point of view of standardization, this KER differentiates itself from the previous ones as it is less BIM focused and thus priority is not so much set on interoperability standards and the like. The following table contains the identified standards by the relevant WP leader RISE.

- **International Standards**

Standardization board	Technical Committee	Standard
ISO-IEC	ISO/IEC JTC 1/SC 24 - Computer graphics, image processing and environmental data representation	ISO/IEC 18039:2019 Information technology — Computer graphics, image processing and environmental data representation — Mixed and augmented reality (MAR) reference model https://www.iso.org/standard/30824.html
		ISO/IEC 18520:2019 Information technology — Computer graphics, image processing and environmental data representation — Benchmarking of vision-based spatial registration and tracking methods for mixed and augmented reality (MAR) https://www.iso.org/standard/66281.html

Table 12 International standards relevant to the Fast mapping tools

- **ISO/IEC JTC 1/SC 24**

Both standards relevant to the fast mapping tools come from the same TC within the CEN. This TC is responsible for standards related to computer graphics, image processing and environmental data representation

The current area of work for JTC 1/SC 24 consists of:

- standardization of interfaces for information technology-based applications relating to computer graphics and virtual reality,
- image processing,
- environmental data representation,
- support for Mixed and Augmented Reality (MAR), and
- interaction with, and visual presentation of, information

The two relevant standards are:

- **ISO/IEC 18039:2019**

" This standard defines the scope and key concepts of mixed and augmented reality, the relevant terms and their definitions and a generalized system architecture that together serve as a reference model for mixed and augmented reality (MAR) applications, components, systems, services and specifications. This architectural reference model establishes the set of required sub-modules and their minimum functions, the associated information content and the information models to be provided and/or supported by a compliant MAR system.

The MAR reference model is designed to apply to MAR systems independent of specific algorithms, implementation methods, computational platforms, display systems and sensors or devices used.

This document does not specify how a particular MAR application, component, system, service or specification is designed, developed or implemented. It does not specify the bindings of those designs and concepts to programming languages or the encoding of MAR information through any coding technique or interchange format. This document contains a list of representative system classes and use cases with respect to the reference model." (ISO, ISO/IEC 18039:2019, n.d.)

- **ISO/IEC 18520:2019**

"This standard identifies the reference framework for the benchmarking of vision-based spatial registration and tracking (vSRT) methods for mixed and augmented reality (MAR).

The framework provides typical benchmarking processes, benchmark indicators and trial set elements that are necessary to successfully identify, define, design, select and apply benchmarking of vSRT methods for MAR. It also provides definitions for terms on benchmarking of vSRT methods for MAR.

In addition, this document provides a conformance checklist as a tool to clarify how each benchmarking activity conforms to this document in a compact form by declaring which benchmarking processes and benchmark indicators are included and what types of trial sets are used in each benchmarking activity." (ISO, ISO/IEC 18520:2019, n.d.)

Both of these standards are directly related to tasks T5.3 Development of an AR tool and T5.4 development of a visualization tool for the installations as a help in renovation process. It seems as though these standards will be used indicatively for benchmarking during the development of the AR tools as they do not determine the actual specific algorithms, implementation methods, computational platforms, display systems and sensors or devices used.

5.2 Roadmap and internal process for standardization

The following figure represents a tentative roadmap for the standardization approach and strategy for the Fast Mapping Tools. As the approach towards the listed standards is more of an indicative or compliancy nature no standards extensions or contributions are envisioned at this stage undermining the need for liaison with NSBs or other standardization bodies.

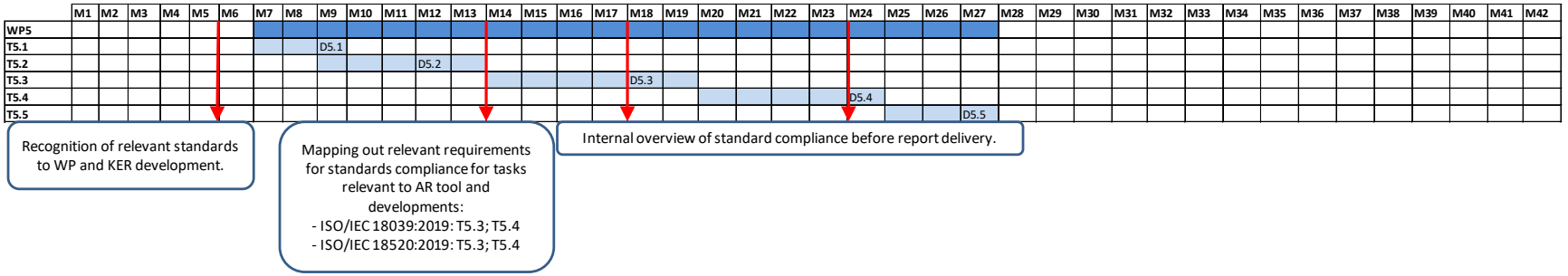


Figure 8 Tentative standardization roadmap Fast Mapping Tools

D5.1	Report of existing techniques and recommendation of mapping technique approach and ontologies
D5.2	Report of output from metering devices and their translation in BIM models services, building energy and acoustics
D5.3	Augmented reality tool in BIM models at different levels of detail corresponding to renovation process modelling representation, BIM data translation engine to ontology
D5.4	Visualisation tool in the AR tool
D5.5	Technical report on testing and validation results

Table 13 WP5 Deliverable

6 Digital tools for HVAC design, operation and efficiency management

This KER corresponds to the implements being developed in work package 6 of the BIM4EEB project. The objective is to develop a set of digital tools to support the design, procurement, installation, post-renovation operation, user feedback and profiling of building automation systems for HVAC. Moreover, the objective is to implement a feedback process whereby tenants and owners interact during the design, construction, and post-renovation operation phases.

The portfolio of digital tools planned for this KER are listed as follows and interdependent:

- A software component supporting the automatic generation of the layout for control systems emphasizing on user preferences and including constraint checking of BAC-topologies against selected building codes. Data and information stored in BIM models are used to generate the initial recommendations and constraints and to deliver the final installation instructions.
- A software component allowing the seamless specification and evaluation of user comfort and systems performance. The underpinning information model will “amalgamate” data sources from BIM (dimensional data) and BAC (factual data).
- An energy-refurbishment assessment tool, for bridging the gap between commercial simulators and the BIM management system.
- A user-profiling component allowing to compare expectations of tenants and owners with regard to comfort and systems’ performance against monitored parameters. The results of this software component can be used in the pre- and post-renovation phases to update the content of BIM systems and thus to improve their accuracy and to reduce efforts for data acquisition and verification.

6.1 Relevant technical standards

This KER characterizes itself on one side through the bridging of data exchange between BIM models and Building Automation Control Systems (BACS) as well as HVAC based implements. Therefore, it comes as no surprise that most relevant standards recognized by the partners pertinent to the execution of these tasks are mostly centered either on specification and implementation of BACS and HVAC control.

- **International Standards**

Standardization board	Technical Committee	Standard
ISO	ISO/TC 205 - Building environment design	ISO 16484-1:2010 Building automation and control systems (BACS) — Part 1: Project specification and implementation https://www.iso.org/standard/37300.html

Table 14 International standards relevant to the Digital tools for HVAC design, operation and efficiency management

- **ISO/TC205 Building environment design**

This TC is responsible with the standardization in the design of new buildings and retrofit of existing buildings for acceptable indoor environment and practicable energy conservation and efficiency. Building environment design addresses the technical building systems and related architectural aspects, and includes the related design processes, design methods, design outcomes, and design-phase building commissioning. Indoor environment includes air quality, and thermal, acoustic, and visual factors.

- **ISO 16484-1:2010**

"ISO 16484-1:2010 specifies guiding principles for project design and implementation and for the integration of other systems into the BACS.

This standard specifies the phases required for the BACS project, including:

- design (determination of project requirements and production of design documents including technical specifications),
- engineering (detailed function and hardware design),
- installation (installing and commissioning of the BACS), and
- Completion (handover, acceptance and project finalization).

ISO 16484-1:2010 also specifies the requirements for as-built documentation and training.

ISO 16484-1:2010 is not applicable to operation and maintenance, nor is it applicable to retro or continuous commissioning, including a commissioning authority." (ISO, ISO 16484-1:2010, n.d.)

This standard will affect results and integration processes and methodologies where tools are being developed through the integration of BACS data and whereby new layer features and systems are being implemented on top of BACS. These correspond mainly towards T6.4 "Performance Evaluation System", whereby data exchange mechanisms between BIM models and BACS are envisioned in order to amalgamate projected vs monitored data in the pre and post renovation phases.

- **European Standards**

Standardization board	Technical Committee	Standard
CEN	CEN/TC 247	EN 15232 Impact of Building Automation, Controls, and Building Management https://www.buildup.eu/en/explore/links/overview-en-15232-standard-impact-building-automation-controls-and-building-manageme-0

Table 15 European standards relevant to the Digital tools for HVAC design, operation and efficiency management

- **CEN/TC 247**

Standardisation of building automation, controls and building management systems and services for residential and non-residential buildings. These standards include the definitions, requirements, functionality and test methods of building automation products and systems for automatic control of building services installations.

- **EN 15232**

This standard is focused on the impact of BACS and Building Management on the energy performance of buildings. It describes methods for evaluating the influence of building automation and technical building management on the energy consumption of buildings.

Four efficiency classes A to D have been introduced to this purpose. After a building has been equipped with building automation and control systems, it will be assigned one of these classes. The potential savings for thermal and electrical energy can be calculated for each class based on the building type and building purpose. In the annexes you can find diagrams of the different classes, expected savings relative to base class C and the functions list per class assigned to every performance class (ABB; The European Standard EN 15232, n.d.).
This standard is mainly pertinent to T6.1 “Formalized requirements specification for procurement” where it will be used to determine desired system specifications through a targeted energy class. (Build Up, EN 15232, n.d.)

- **National and industry specific standards**

Standardization board	Technical Committee	Standard
VDI (Verein Deutscher Ingenieure) (Association of German Engineers)	technical building equipment department	VDI 3814 https://www.vdi.de/richtlinien/unsere-richtlinien-highlights/vdi-3814
	N/A	VDI 3805 Electronic product data exchange in the TGA https://www.vdi3805.eu/

Table 16 National and industry standards relevant to the Digital tools for HVAC design, operation and efficiency management

Two standards from VDI have been listed as being important for the development of this KER. Verein Deutscher Ingenieure (VDI) or the Association of German Engineers is an organization with over 150,000 engineers and natural scientists. More than 12,000 honorary experts process the latest findings every year to promote the advancement of technology and represent the interests of engineers and of engineering businesses in Germany. They are the third largest technical standardization body in Germany, More than 200 new or revised VDI Standards based on the latest technical developments are published by VDI’s technical divisions every year.

- **VDI 3814**

The guideline VDI 3814 was developed in the technical building equipment department of the Association of German Engineers. It describes in several sheets the state of the art in planning and construction of building automation. Under the main heading "Building Automation (GA)", the current pages describe: - Requirements for equipment, software and services - Presentation of tasks for automatic control and regulation, monitoring, optimization and operation and - Management of building services. In recent

decades, the guideline has been continuously expanded and parts of it have been incorporated into the worldwide standard ISO 16484. (VDI, VDI 3814 "Gebäudeautomation (GA)", n.d.)

The standard will apply to most tasks within WP6 relevant towards BACS specification and HVAC algorithms. Moreover, it is potentially envisioned to contribute or extend this standard with the more detailed HVAC algorithms developed in BIM4EEB.

- **VDI 3805**

In the VDI 3805 standard, the product data exchange for components and systems of heating, ventilation and sanitary technology is regulated in the computer-aided planning process. For this purpose, the collection of the required data via the VDI 3805 is standardized in order to cover a wide variety of tasks with access to only one product database. Parts of the VDI 3805 have been extended towards ISO 16757. (VDI, VDI 3805, n.d.)

This standard will mostly be concerned with database management systems and algorithms in T6.5 “Population with Monitoring Data and Evaluation” and the digital twins of HVAC components, and HVAC algorithms in embedded controllers. Moreover, this standard can be used for T6.4 in terms of data exchange between BACS and BIM.

6.2 Roadmap and internal process for standardization

The following figure represents a tentative roadmap for the standardization approach and strategy for the Digital tools for HVAC design, operation and efficiency management. One of the important aspects for this KER is the fact that partners have expressed the goals of contributing towards potential standards extensions with VDI implying the need for liaison and communication in due time.

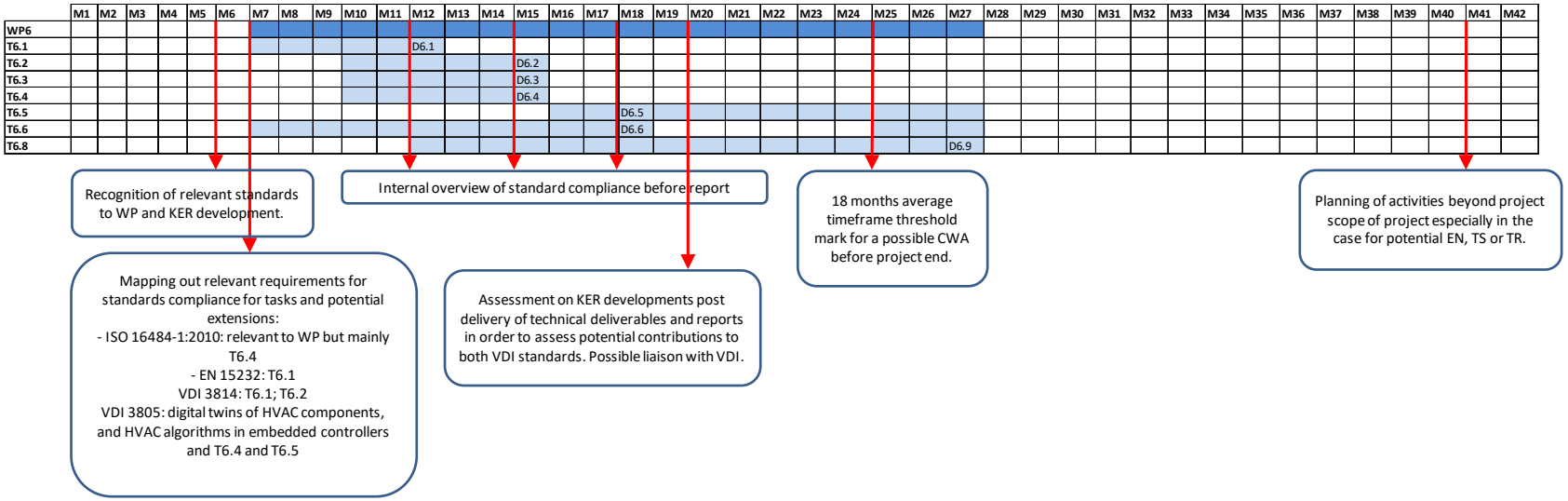


Figure 9 Tentative standardization roadmap Digital tools for HVAC design, operation and efficiency management

D6.1	Open format and formalised requirements specification for procurement
D6.2	Methods and tools for selecting devices and linking them to the generic model
D6.3	Tool for constraint checking BAC topologies VS building codes
D6.4	Tool for connecting BIM and BAC
D6.5	Database management system
D6.6	Decision-support tool
D6.9	Report on adoption of BIM-assisted Energy refurbishment assessment tool

Table 17 WP6 Deliverables

7 Occupants´ energy profiling mechanisms and HMI applications and interfaces

This specific KER is a component of the more generalized “Digital tools for HVAC design, operation and efficiency management” project results previously detailed. However, due to its exploitation potential as a modular component especially for Suite5 it has also been treated as an individual KER and component.

The main goal of the Occupants’ Profiling Mechanism is to enable the identification of occupants’ actual comfort preferences in terms of HVAC and Lighting loads operation, considering, also, the health constraints imposed during building operation. The BIM4EEB occupants’ profiling mechanism will perform a continuous monitoring of ambient/ occupancy conditions and interact with the occupants via user-friendly interfaces in order to extract context-aware user preferences and understand comfort (dis)satisfaction zones, while considering health boundaries and **set-points based on the modelling work and enhanced models provided in WP3**. As a result, Context-Aware Energy Behaviour Profiles will be produced, reflecting occupants’ energy behaviour as a function of multiple parameters, such as time, environmental context/conditions, energy costs, occupant comfort preferences and health/ hygienic constraints. The BIM4EEB behaviour profiling mechanism will be complemented with appropriate Ambient User Interfaces.

7.1 Relevant technical standards and roadmap

As this specific project result relies on the developments of the data models WP3, it is no surprise that the technical standards relevant towards this module are the same as the ones listed in the section on “Linked data sharing framework for renovations / BIM ontology for renovation”, specifically in terms of IEQ boundaries and KPIs definition as follows:

- International standards:
  - ISO 7730:2005: Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria
  - ISO 12354 framework: Accoustic modelling:
  - IEA EBC Annex 66 and 79: Methodologies for modelling occupant behavior in buildings
- European standards:
  - EN 15251 “Indoor Environmental Criteria”
  - Directive 2008/50/EC
- Industry specific
  - ANSI/ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy
  - ASHRAE Guideline 14

Also, to point out that the standardization in CR 1752 is considered towards setting the boundaries for ventilation operation in line with IAQ conditions in premises.

While not considered for the modelling work in WP3, we consider the standardization of EN 13779 as relevant to this task. EN 13779: Performance requirements for ventilation and room-conditioning systems defines the indoor air quality on the basis of the amount of outside air per person, per m2 or on the basis of the increase in the CO2 value (as an indicator for the emission of gas by organic substances). The concentration of certain undesirable, volatile pollutants, which can be released into the air (paint, carpeting, glue, chipboard, photocopiers, etc.), such as total volatile organic components (TVOC), can also be a

decisive factor (see EN 15251).

Review of the local legislation about indoor environmental conditions (e.g. LVI 05- 10440 for the Finnish pilot) is a decisive aspect to be considered also during the work in the alignment with existing standards

Since the modelling work in question is performed at an earlier stage in the project with consideration given to the listed standards (WP3 ends at M12), and T6.7 “Occupants’ context-aware energy behaviour profiling and ambient interfaces for Human-Machine Interaction” starts at M18, the final product should align meaning that most of the standardization work relevant to this KER will already be performed and mapped.

7.2 Roadmap and internal process for standardization

The following figure represents a tentative roadmap for the standardization approach and strategy for the KER. As the approach towards the listed standards is more of an indicative and compliancy nature with no standards extensions or contributions, there will be no need for liaison with NSBs or other standardization bodies and the process should be relatively simple. Moreover, detailed overview of one of these standards will already have been performed in the earlier stages of the project during the execution of WP3 tasks, which should facilitate the tasks related to this KER in WP6.

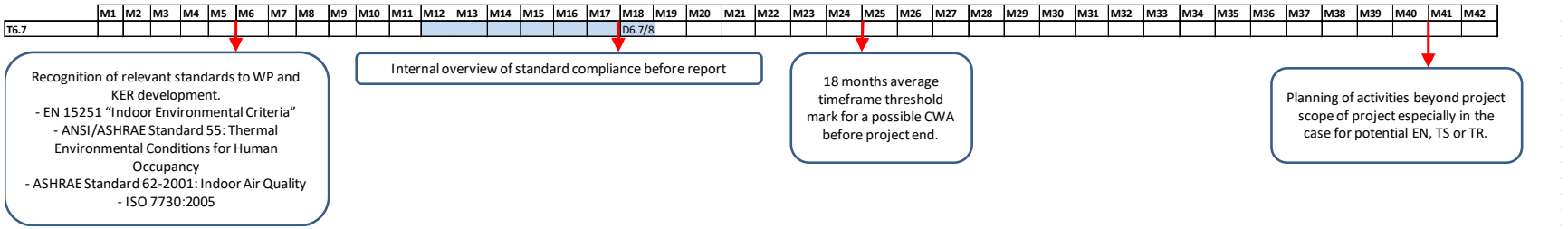


Figure 10 Tentative standardization roadmap Digital tools for HVAC design, operation and efficiency management

D6.7	Report on BIM4EEB Occupants' Profiling Mechanism
D6.8	Ambient User Interface

Table 18 Deliverables on Occupants Energy Profiling Mechanisms and HMI applications and Interface

8 Tools for planning & management of intervention and sites & Applications for inhabitant interaction and information exchange related to intervention

This section relates to two recognized KERs, the general Tools for planning and management of intervention sites with the aim of easing the renovation process as well as the occupant focused applications for inhabitants which is a sub component of the latter. Due to the high exploitation potential of the individual application for inhabitants' interaction as a modular component especially for Suite5 it has also been treated as an individual KER and component within the project. Nevertheless, both are treated jointly in this deliverable as the standards affecting both are aligned.

The main objective of the tools for easing interventions is to enhance construction planning and tracking methods and provide valuable information to all stakeholders with web-service and mobile applications to achieve positive network effects. In doing so, the relevant tasks will seek to establish BIM based tools that overview construction production management with planning and tracking of site operations features, enable communication and information exchange between the intervening AEC professionals/stakeholders and building occupants for enhanced security, guidelines and reduced intrusiveness, facilitate facility management with log books for maintenance planning and finally leverage the short intervention times implied by prefabricated implements by potentiating BIM based design in this respect.

It is crucial to involve building occupants and clients in order to communicate project progress data reliably along with guidance and safety instructions. The application is meant to guide building occupants during on-site renovation works and consequently enhance security and safety on-site, reduce intrusiveness and consider individual needs and schedules, to optimise operational planning. The application will be shaped around a BIM-based mobile interface allowing building occupants to receive notification and alerts on on-going works, receive safety hints and information (e.g.to avoid specific areas where works have not yet been finished), while on the other hand, enabling them to upload information that might be requested ad-hoc by contractors or any other relevant input they may consider useful, thus contributing to the constant and collaborative updating of BIM and as-built documentation. Furthermore, occupants will have access to information about on-site work planning and schedules, communicate with contractors their individual needs and preferences and jointly decide on the optimal schedules without affecting the overall duration of projects.

8.1 Relevant technical standards

As both these KERs are specifically focused on data and information exchange and delivery between the relevant stakeholders of a renovation project via BIM technologies, the standards that most affect them are standards that relate to processes in information delivery and specifications during construction works in general and the built environment. Below are the standards that have been identified by relevant partners as being most important to the appropriate development of these tasks and KER.

- **International Standards**

Standardization board	Technical Committee	Standard
ISO	ISO/TC 59/SC 13	ISO 29481-1:2016 – buildingSMART Information Delivery Manual (IDM)

		https://www.iso.org/standard/60553.html
		ISO 16739 – buildingSMART Industry Foundation Classes (IFC) https://www.iso.org/standard/51622.html

Table 19 International standards relevant to the Tools for planning & management of intervention sites & Applications for inhabitant interaction and information exchange related to intervention

- **ISO 16739**

ISO 16739 has already been listed for the KERs related to BIM management system and the development of the Linked data for renovations framework. It refers to IFC for data sharing standards.

- **ISO 29481-1:2016**

" This standard has been developed by buildingSMART (Information Delivery Manual – IDM) in order to have a methodology to capture and specify processes and information flow during the lifecycle of a facility. It is related to information delivery in construction works and specifies a methodology that links the business processes undertaken during the construction of built facilities with the specification of information that is required by these processes, and a way to map and describe the information processes across the life cycle of construction works." (ISO, ISO 29481-1:2016, n.d.)

" The intended objective is to facilitate interoperability between software applications used during all stages of the life cycle of construction works, including briefing, design, documentation, construction, operation and maintenance, and demolition. It promotes digital collaboration between actors in the construction process and provides a basis for accurate, reliable, repeatable and high-quality information exchange."

8.2 Roadmap and internal process for standardization

The following figure represents a tentative roadmap for the standardization approach and strategy for these two KERs. As the approach towards the listed standards is more of an indicative and compliancy nature with no standards extensions or contributions, there will be no need for liaison with NSBs or other standardization bodies and the process should be relatively simple. Moreover, detailed overview of one of these standards will already have been performed in the earlier stages of the project during the execution of WP3 tasks, which should facilitate the tasks related to this KER in WP7.

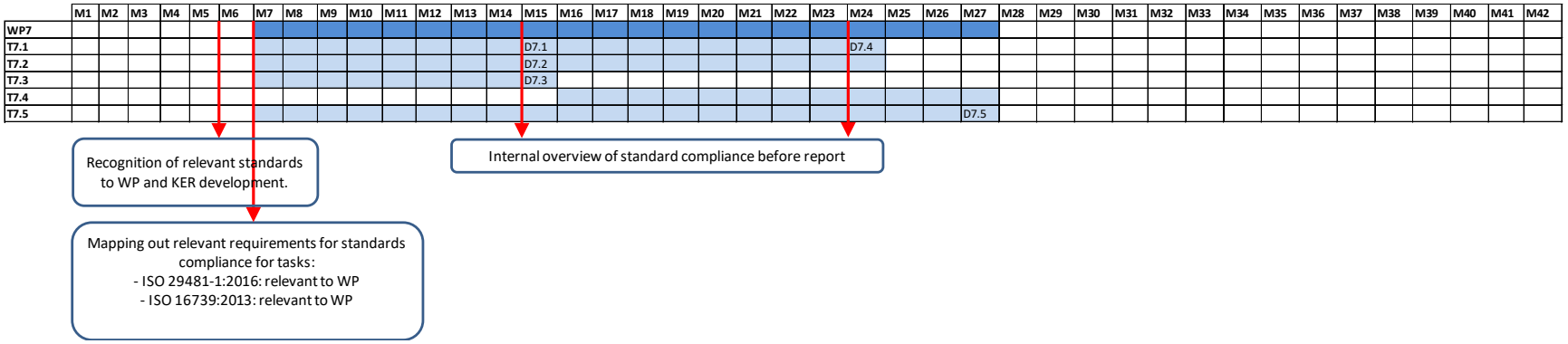


Figure 11 Tentative standardization roadmap Tools for planning & management of intervention sites & Applications for inhabitant interaction and information exchange related to intervention

D7.1	Server software to manage interlinked BIM-workflow data for construction production management
D7.2	Web-based responsive user-interfaces
D7.3	Report on methods to record as-built data for implementing digital maintenance manuals
D7.4	Report on BIM implementation for prefabrication of exhaust air heat pumps in renovation
D7.5	Guideline on BIM implementation for the design of prefabricated thermal insulation components

Table 20 WP7 deliverable

9 Guidelines on BIM Usage

This result is not a component or software solution like the rest of the previously described KERs. It refers to the development of guidelines for innovative BIM-based efficient renovation uptake, outlining benefits and challenges, when adopting BIM for renovation processes. These guidelines will result from the experience in implementing the BIM4EEB toolkit in the relevant pilot sites.

As a result, two separate sets of guidelines will be developed. One for the public sector with active cooperation of Regione Lombardi and one for the private sector through the experience of industrial and SME partners.

9.1 Relevant technical standards

The guidelines in question will have to respect and take into consideration standards and guidelines having been developed mainly in the realm of information management and sharing in BIM as well as standards applying towards digital solutions in the construction industry.

- **International Standards**

Standardization board	Technical Committee	Standard
ISO	ISO/TC 59/SC 13	ISO 29481-1:2016 – buildingSMART Information Delivery Manual (IDM) https://www.iso.org/standard/60553.html
		ISO/TS 12911:2012 Framework for building information modelling (BIM) guidance https://www.iso.org/standard/52155.html
		ISO 19650-1:2018 Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles https://www.iso.org/standard/68078.html

Table 21 International standards relevant to the Guidelines on BIM Usage

All international or European level standards are contained within the same TC, ISO/TC 59/SC 13 CEN TC 442. As seen previously throughout other KERs, this is the TC responsible for the organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). The following standards from this TC pertain to this KER.

- **ISO 29481-1:2016**

“ This standard has been detailed in the section just before. It was developed by buildingSMART and is related to information delivery in construction works and specifies a methodology that links the business

processes undertaken during the construction of built facilities with the specification of information that is required by these processes, and a way to map and describe the information processes across the life cycle of construction works."

- **ISO/TS 12911:2012**

" This standard establishes a framework for providing specifications for the commissioning of building information modelling (BIM). It is applicable to any asset type, including most infrastructure and **public works**, equipment and material. The main user of the framework is the information manager, who utilizes the framework to **assist in structuring an international, national-project- or facility-level BIM guidance document**." (ISO, ISO/TS 12911:2012, n.d.)

- **ISO 19650-1**

As explored in standards relative to the development of the BIM4EEB BIM management system, ISO 19650 is a standard for managing information over the whole life cycle of a built asset using building information modelling (BIM). It specifies requirements for information management, in the form of a management process, within the context of the delivery phase of assets and the exchanges of information within it, using building information modelling. The aim of this standard is to support all parties towards achieving their business objectives through the effective and efficient procurement, use and management of information during the delivery phase of assets.

Both ISO 19650 standards define the need to have a common data environment (CDE) for collecting, managing and disseminating information throughout BIM projects which sends back to the BIM Management system.

- **European Standards**

Standardization board	Technical Committee	Standard
EU BIM Task Group	Handbook for introduction of BIM by European public sector	Guidelines introducing BIM in public works for big public appointing party http://www.eubim.eu/wp-content/uploads/2017/07/EUBIM_Handbook_Web_Optimized-1.pdf

Table 22 European standards relevant to the Guidelines on BIM Usage

- **EU BIM Task Group**

The EU BIM Task Group has produced the "Handbook for the introduction of Building Information Modelling by the European Public Sector" in order to respond to the growing challenges faced by governments and public clients to stimulate economic growth and competitiveness while delivering value for public money through the wider introduction of BIM. It brings insight on why governments should implement BIM, what benefits can be expected, how can government and public institutions be leaders in the implementation and wide diffusion of BIM and how to involve industry and relevant stakeholders. (EU BIM Task Group, 2017)

BIM4EEB must take into consideration these initial guidelines when producing their own as well as the country level diffusion strategies contained in this guide. The project will be able to observe the potential additions that can be brought; especially as it focuses on BIM based renovation approaches that are more specific than these more general guidelines.

- **National and industry specific standards**

Standardization board	Technical Committee	Standard
UNI - Italian Standardization Body	CT 033	UNI 11337-1 Construction and civil engineering works - Digital management of construction information processes - Part 1: Models, documents and information objects for products and processes http://store.uni.com/catalogo/uni-11337-1-2017?josso_back_to=http://store.uni.com/josso-security-check.php&josso_cmd=login_optional&josso_partnerapp_host=store.uni.com

Table 23 National and industry standards relevant to the Guidelines on BIM Usage

- **UNI 11337-1**

UNI 11337 concerns the qualitative and quantitative aspects of the digitalized management of the information process in the construction sector, in support of the decision-making process.
The standard proposes a structured sequence of stages, in turn consisting of phases, which concern the production and management of information contents with defined maturity levels. This standard has already been detailed in the section on Linked data and ontologies. (UNI Ente Italiano di Normazione, UNI 11337-1:2017, n.d.)

9.2 Roadmap and internal process for standardization

The following figure represents a tentative roadmap for BIM guidelines. Most of the work will be pertinent towards verifying standards compliance and bringing additional insight on top of EU BIM Task Group guidelines specifically in terms of renovations rather than general construction processes.

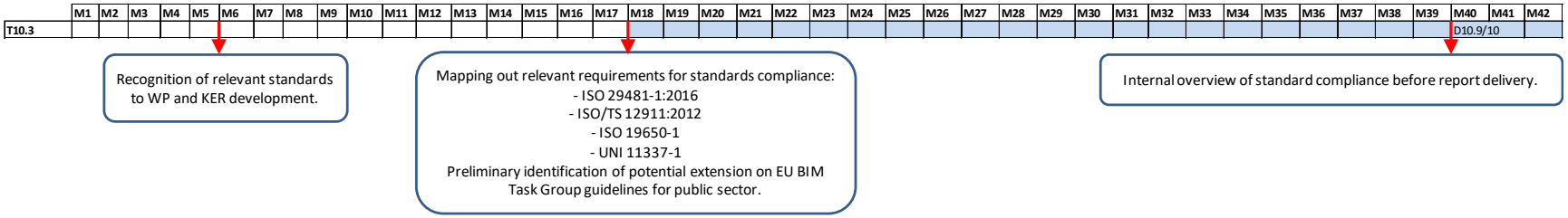


Figure 12 Tentative standardization roadmap guidelines on BIM usage

D10.9	Guidelines for BIM implementation for public administration
D10.10	Guidelines for BIM implementation for private stakeholders

Table 24 WP10 deliverables

10 Mapping of standards in system architecture and partners responsible for overview and liaison

This section provides an overview of the previously explored standards by mapping them in the whole BIM4EEB system architecture in order for readers to get a more direct and immediate look at the different standards intervening in different key elements, components or developments of the project.

Moreover, it is possible to observe in the following figure which standards partners are using for benchmarking or with which they want to comply in the development of the tools and applications they are working on and which standards they believe could be extended as a result of BIM4EEB KER development.

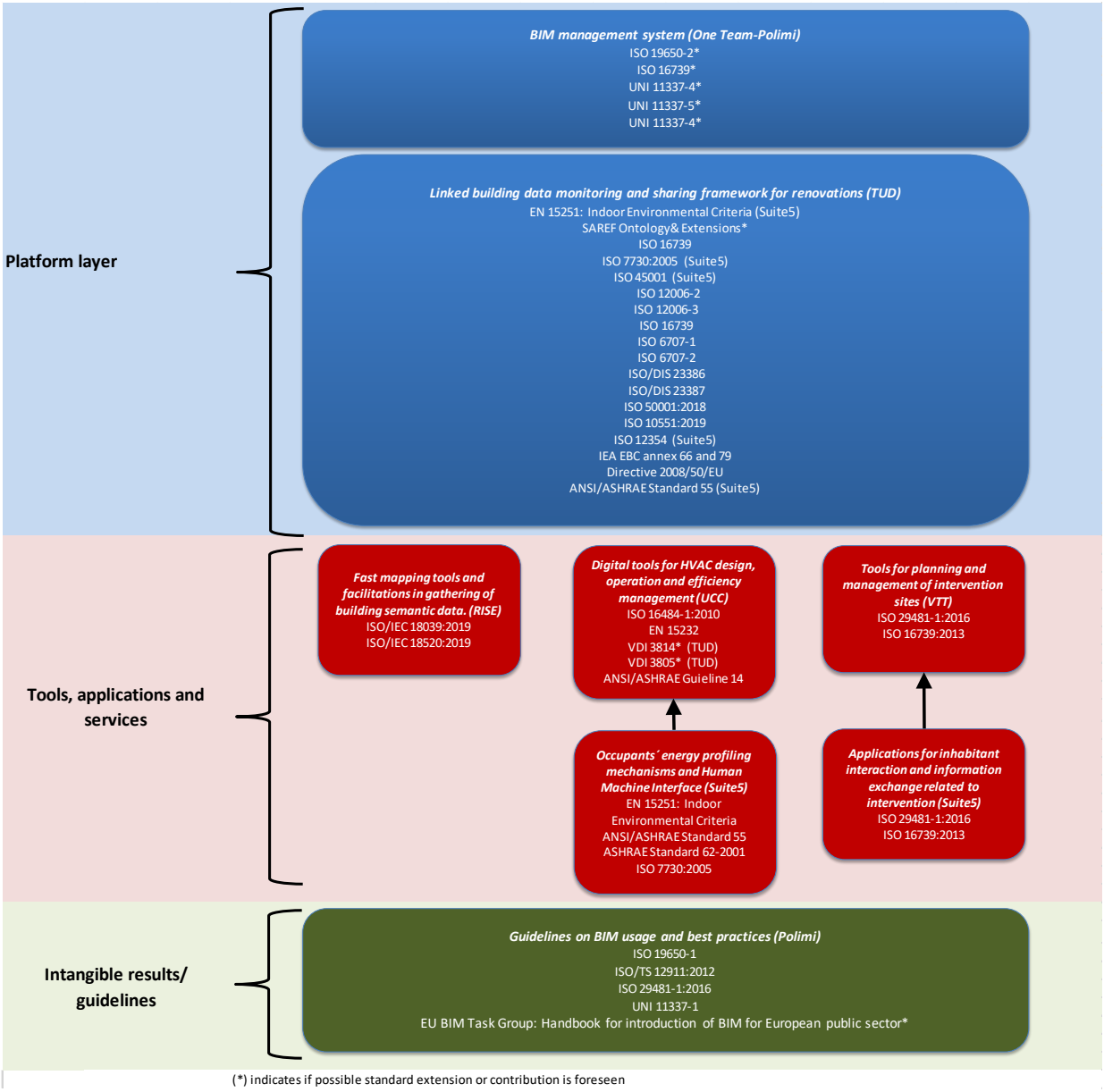


Figure 13 Standards mapping

In addition to this, this section provides observations on the partners that are most ideally positioned for overviewing standards compliance and contributions during the project lifetime in every KER as seen in the figure. At this stage, these are indicative and will have to be further discussed in Innovation Management Board (IMB) seminars.

Analysis of potential responsible partners is broken down by KER as follows:

The following section analyses the potential breakdown of responsibilities per KER within the project. The responsibilities in question are relevant towards standards compliance and benchmarking or possible extensions implying technical work. Nevertheless, it is important for R&D projects to be able to communicate with standardization bodies swiftly and have an internal liaison or point of contact for such duties. Before introducing the KER breakdown in responsibilities, the report provides information on the party responsible for communicating with potential NSBs and other standardization bodies.

- **Overall standardization delegate and project liaison**

Generally, R&D projects aiming for efficient standards compliance and contribution processes should put in place a party or organization that can serve as a main liaison or point of contact for standardization bodies or anything to do with such matters as well as overview general standardization processes. BIM4EEB has the particularity of having an Innovation Management Board (IMB) in charge of maximizing exploitation potential of the project. The IMB will do its best to support communication initiatives with standardization boards considering the importance of standards in accelerating market acceptance and facilitating integration with other already commercialized solutions. In addition to this, the IMB contains members with extensive experience in standardization processes and interacting with standardization bodies; namely One Team being an active contributor to BIM committees and associations in Italy (AssoBIM), participating in UNI meetings for drafting of standards and guidelines regarding BIM for the construction sector. The main point of contact for the BIM4EEB project in terms of standardization falls onto the project coordinator, POLIMI, especially as they will conduct important standardization activities in relation to the project, namely the open source BIM management system. Furthermore, most activities with foreseen standards extensions that require liaison with NSBs and other standardization bodies are mainly all related to the work to be performed around the BIM management system. For this reason, it is specifically important to establish who will work as a project liaison with the following TCs, NSBs and Standardization Boards:

- ISO TC 59 SC 13
- CEN TC 442
- buildingSMART
- UNI CT033

Considering the following table whereby partners involved with the latter entities are listed, POLIMI will function as the main liaison partner in BIM4EEB for these standardization activities. Moreover, TUD has been listed as liaison with VDI considering their potential interest in contributing towards standards extensions of the listed standards and their past work and relationship with the organization.

Standardization body /TC	**Standards/topics**	**Partners involved with standardization body or TC**	**Liaison partner in BIM4EEB**
ISO TC 59 SC 13	Building Information Modeling (BIM)	POLIMI, OneTeam	POLIMI

CEN TC 442	Building Information Modeling (BIM)	POLIMI, OneTeam	POLIMI
buildingSMART	IFC, openBIM	Visualynk, POLIMI, OneTeam	POLIMI
UNI CT033	UNI 11337-4,5	POLIMI, OneTeam (AssoBIM)	POLIMI
VDI	VDI 3814, VDI 3805	TUD	TUD

Table 25 Envisioned BIM4EEB liaison partners for main standardization bodies

- **BIM Management system**

As mentioned above, POLIMI will be most active in overlooking the standardization activities and processes for this WP. More specifically, Alberto Pavan will serve as a reference contact for standardization as he is the chair of UNI Committee for BIM, linked with CEN TC 442 and ISO TC59 SC13. Most liaison and communication with external standardization institutions will be performed with regard to this WP whereby standards contributions are envisioned. One Team will support in this task given that they are members of UNI and AssoBIM and have extensive experience in standardization workshops, extensions and contributions. The outcome of these tasks are even embodied in *T9.3 Validation of harmonised open-BIM standards for sharing information* where a three level validation will be set in place. The first level will involve experts in the field of ontology definition, external to the previous phases, that can analyse the proposed results with the objective of highlighting critical points and/or other possible issues. The second level will be the discussion of the contents in one of the major working tables of UNI (possible support from IMB member One Team) where the main stakeholders of the Italian context are involved (public administrations, associations, construction companies, engineering firms, etc.). Furthermore, the advancements proposed in standards will be shared publicly to allow the entire market reading the standard itself and comment it. This step will allow validating the standard with the needs of the market. The third and final step is based on the analysis of the obtained results at European level through the presentation of the standard at CEN TC 442. The output of this task will be a *Report on the validation of harmonised open-BIM standards D9.7*. The nature of the possible CEN deliverables which were described at the beginning of this report will be determined as the project advances

- **Linked Data sharing framework for renovations/**

As TUD is the lead partner of the relevant work package for the development of this task it would be most logical to have them overview compliance and potential contributions relevant to this KER if deemed necessary closer towards the end of the tasks and WP for instance with ETSI.

Furthermore, given Suite5´s expertise and control of tasks related to comfort and behavioural models, it is most logical that they overview the standards compliance in this area, though this contribution will be aligned with the work performed under the development of the respective components to follow

- **Fast Mapping Tools**

As WP5 leading partner and leader of most tasks, RISE seems ideally positioned to overview the standardization approach for this work package. Considering that no standards extensions have been foreseen at this stage, liaison with NSBs and standardization bodies in general are unlikely meaning that the majority of the work for this KER is simply overseeing compliance and benchmarking with current relevant standards.

- **Digital tools for HVAC design, operation and efficiency management**

As the lead partner for the WP related to the development of the software components of this KER, UCC will most likely be involved in standardization activities related to these tasks at the very least from a compliance and evaluation point of view.
Moreover, in terms of potential liaison with VDI, TUD is deeply involved in several standardization committees, such as CEN TC247 WG4, VDI, VDE, DKE, Building Smart, LonMark, and IEEE IES TC BACM and TC Smarter Cities and can therefore assist in this regard.

- **Occupants´ energy profiling mechanisms and HMI applications and interfaces**

Being that Suite5 is developing this solution and the partner that intends to exploit the results, it seems logical for them to overview standardization activities for this tool. Moreover, as seen in the relevant section, this should be a straight forward activity considering the overlap with WP3.

- **Tools for planning & management of intervention and sites & Applications for inhabitant interaction and information exchange related to intervention**

As the lead partner for the WP and considering their extensive work in WP3 with overlapping standards, VTT will most likely be involved in ensuring standards compliance for this KER.

- **Guidelines on BIM Usage**

Taking into cconsideration their involvement with similar standards in the development of the BIM Management System and their role in this development, Polimi is ideally positioned to overview activities related to standards for this project result and assist Regione Lombardia.

11 Conclusions

Including standardiszation approaches and activities within research projects brings many benefits. Indeed, building upon standards ensures compliance with market conditions and increases the transparency for prospective customers and being involved in standardization and shaping future standards helps to translate your research and innovation findings, including intellectual property rights, into marketable solutions.

Moreover, with the increasing complexity and interdisciplinarity of today's products and services combined with customers' expectations of new and innovative solutions after increasingly shorter periods of time, standards come into play as they can allow faster uptake of innovative solutions and enhance the economic value of research and innovation projects or facilitate further research down the line bringing TRLs close to commercializable levels.Finally, participating in standardization, increases your visibility and you will be part of a recognized and reputable worldwide platform.

Through the work reflected in this deliverable, namely the identification of technical subjects/items for standards development for all involved WPs, the selection of standards bodies and forums that are developing the world leading standards in the identified technical areas, the establishment a project internal process for standards strategy and contribution development, alignment and review, the identification of delegates for targeted standardization bodies in case of need for liaison for standards creation and extension, the BIM4EEB consortium is able to foresee the generalized basic requirements in the products, tools and services they are developing as well as anticipate any potential standardization working groups they must contact in the case of extended standardization activities for certain research topics and establish project liaisons.

This document must be seen as a first building block to be used in aligning project results adequately towards market expectations and requirements and facilitating further research which is particularly relevant in the case of a Research and Innovation Action project with TRL 6 objectives for the enemble of KERs.

Finally, considering the fact that partners have expressed the will to extend standards according to project developments in certain areas which have been detailed throughout the report, this work is also pertinent towards the wider dissemination of project results. Dissemination of project's results through standards bodies in general brings projects higher international recognition, collaboration opportunities, and the ability to cooperate with a variety of specialists, thus benefiting from their collective expertise.

12 Bibliography

- ABB; The European Standard EN 15232, n.d. *abb.com.* [Online] Available at: http://www04.abb.com/global/seitp/seitp202.nsf/0/d0bbe587cf46edc6c125777500401d30/$file/extract_from_ABB_brochure_2CDC500060M0201_p_6_7.pdf
- ANSI-ASHRAE, GUIDELINE 14-2014, n.d. *ashrae.org.* [Online] Available at: https://www.techstreet.com/ashrae/standards/guideline-14-2014-measurement-of-energy-demand-and-water-savings?gateway_code=ashrae&product_id=1888937
- ANSI-ASHRAE, Standard 55, n.d. *ashrae.org.* [Online] Available at: https://www.ashrae.org/technical-resources/bookstore/standard-55-thermal-environmental-conditions-for-human-occupancy
- BSI, EN 16212:2012, n.d. *bsigroup.com.* [Online] Available at: https://shop.bsigroup.com/en/ProductDetail/?pid=000000000030260661
- Build Up, EN 15232, n.d. *buildup.* [Online] Available at: https://www.buildup.eu/en/explore/links/overview-en-15232-standard-impact-building-automation-controls-and-building-manageme-0
- buildingSMART, n.d. *buildingsmart.org.* [Online] Available at: https://www.buildingsmart.org/standards/bsi-standards/
- Energy in Buildings and Communities Programme, IEA, Annex66, n.d. *annex66.org.* [Online] Available at: https://annex66.org/?q=Publication
- Energy in Buildings and Communities Programme, IEA, n.d. *iea-ebc.org.* [Online] Available at: https://www.iea-ebc.org/
- Energy in Buildings and Cumminities Programme, IEA, Annex79, n.d. *http://annex79.iea-ebc.org/.* [Online] Available at: http://annex79.iea-ebc.org/
- EU BIM Task Group, 2017. *eubim.eu.* [Online] Available at: http://www.eubim.eu/wp-content/uploads/2017/07/EUBIM_Handbook_Web_Optimized-1.pdf
- European Commission, SAREF, n.d. *ec.europa.eu.* [Online] Available at: https://www.rehva.eu/rehva-journal/chapter/revision-of-en-15251-indoor-environmental-criteria
- European Committee for Standardization, n.d. *cen.eu.* [Online] Available at: https://boss.cen.eu/reference%20material/guidancedoc/pages/del.aspx
- European Committee for Standardization, n.d. *cen.eu.* [Online] Available at: https://standards.cen.eu/dyn/www/f?p=CENWEB:5:0:::::
- European Union Law, n.d. *eur-lex.europa.eu.* [Online] Available at: https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32008L0050
- Federation of European Heating, Ventilation and Air Conditioning Associations, n.d. *rehva.eu.* [Online] Available at: https://www.rehva.eu/rehva-journal/chapter/revision-of-en-15251-indoor-environmental-criteria
- International Organization for Standardization, n.d. *ISO.* [Online] Available at: https://www.iso.org/deliverables-all.html
- International Organization for Standardization, n.d. *isotc.iso.org.* [Online] Available at: https://isotc.iso.org/livelink/livelink/fetch/2000/2122/15507012/20695258/iwa.pdf?nodeid=20683323&vernum=-2

- ISO, https://www.iso.org/standard/38706.html, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/38706.html
- ISO, ISO 10551:2019, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/67186.html
- ISO, ISO 12006-2:2015, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/61753.html
- ISO, ISO 12006-3:2007, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/38706.html
- ISO, ISO 12354-1:2017, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/70242.html
- ISO, ISO 12354-2:2017, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/70243.html
- ISO, ISO 12354-3:2017, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/70244.html
- ISO, ISO 12354-4:2017, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/70248.html
- ISO, ISO 16484-1:2010, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/37300.html
- ISO, ISO 16739:2013, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/51622.html
- ISO, ISO 19650-2, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/68080.html
- ISO, ISO 21597 , 2020. *iso.org.* [En línea] Available at: https://www.iso.org/standard/74389.html
- ISO, ISO 29481-1:2016, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/60553.html
- ISO, ISO 45001, n.d. *iso.org.* [Online] Available at: https://www.iso.org/iso-45001-occupational-health-and-safety.html
- ISO, ISO 50001:2018, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/69426.html
- ISO, ISO 6707-1:2017, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/72244.html
- ISO, ISO 6707-2:2017, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/70040.html
- ISO, ISO 7730, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/39155.html
- ISO, ISO/DIS 23387, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/75403.html
- ISO, ISO/FDIS 23386, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/75401.html
- ISO, ISO/IEC 18039:2019, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/30824.html
- ISO, ISO/IEC 18520:2019, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/66281.html
- ISO, ISO/TS 12911:2012, n.d. *iso.org.* [Online] Available at: https://www.iso.org/standard/52155.html
- UNI Ente Italiano di Normazione, UNI 11337-1:2017, n.d. *uni.com.* [Online] Available at: http://store.uni.com/catalogo/uni-11337-1-

2017?josso_back_to=http://store.uni.com/josso-security-check.php&josso_cmd=login_optional&josso_partnerapp_host=store.uni.com

- UNI Ente Italiano di Normazione, UNI 11337-4, n.d. *uni.com.* [Online] Available at: http://store.uni.com/catalogo/index.php/uni-11337-4-2017?josso_back_to=http://store.uni.com/josso-security-check.php&josso_cmd=login_optional&josso_partnerapp_host=store.uni.com
- UNI Ente Italiano di Normazione, UNI 11337-5, n.d. *uni.com.* [Online] Available at: http://store.uni.com/catalogo/index.php/uni-11337-5-2017
- VDI, VDI 3805, n.d. *VDI.* [Online] Available at: https://www.vdi3805.eu/
- VDI, VDI 3814 "Gebäudeautomation (GA)", n.d. *VDI.* [Online] Available at: https://www.vdi.de/richtlinien/unsere-richtlinien-highlights/vdi-3814

13 Annex

13.1 EN 15232:2007 BACS efficiency classes description

The following diagram shows the differences in energy consumption for three building types in the energy efficiency classes A, B and D relative to the basis values in rating C. For example, by using class A, 30 % of the thermal energy can be saved in offices.

Building Automation and Control (BAC) efficiency classes to EN 15232	Efficiency factor for thermal energy			Efficiency factor for electrical energy		
	Office	School	Hotel	Office	School	Hotel
A High energy performance building automation and control system (BACS) and technical building management (TBM)	0.70	0.80	0.68	0.87	0.86	0.90
B Advanced BACS and TBM	0.80	0.88	0.85	0.93	0.93	0.95
C Standard BACS	1	1	1	1	1	1
D Non energy efficient BACS	1.51	1.20	1.31	1.10	1.07	1.07

Function list and assignment to energy performance classes (section from table 1 of the EN 15232:2007 [D])

	Heating / Cooling control	Ventilation / Air conditioning control	Lighting	Sun protection
A	– Individual room control with communication between controllers – Indoor temperature control of distribution network water temperature – Total interlock between heating and cooling control	– Demand or presence dependent air flow control at room level – Variable set point with load dependant compensation of supply temperature control – Room or exhaust or supply air humidity control	– Automatic daylight control – Automatic occupancy detection manual on / auto off – Automatic occupancy detection manual on / dimmed – Automatic occupancy detection auto on / auto off – Automatic occupancy detection auto on / dimmed	– Combined light/blind/ HVAC control
B	– Individual room control with communication between controllers – Indoor temperature control of distribution network water temperature – Partial interlock between heating and cooling control (dependent on HVAC system)	– Time dependent air flow control at room level – Variable set point with outdoor temperature compensation of supply temperature control – Room or exhaust or supply air humidity control	– Manual daylight control – Automatic occupancy detection manual on / auto off – Automatic occupancy detection manual on / dimmed – Automatic occupancy detection auto on / auto off – Automatic occupancy detection auto on / dimmed	– Motorized operation with automatic blind control
C	– Individual room automatic control by thermostatic valves or electronic controller – Outside temperature compensated control of distribution network water temperature – Partial interlock between heating and cooling control (dependent on HVAC system)	– Time dependent air flow control at room level – Constant set point of supply temperature control – Supply air humidity limitation	– Manual daylight control – Manual on/off switch + additional sweeping extinction signal – Manual on/off switch	– Motorized operation with manual blind control
D	– No automatic control – No control of distribution network water temperature – No interlock between heating and cooling control	– No air flow control at room level – No supply temperature control – No air humidity control	– Manual daylight control – Manual on/off switch + additional sweeping extinction signal – Manual on/off switch	– Manual operation for blinds