Built2Spec

Built to Specifications – Tools for the 21st Century Construction Site

D1.3 Integrated Self-Inspection Quality Check Framework

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DISCLAIMER

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The **Deliverable D1.3** entitled ***"Report on Integrated Self-Inspection Quality Check Framework"*** is a public document delivered in the context of WP1, Task 1.5: Integrated building design and construction management framework, which encompasses and promotes Integrated Design, Self-Inspection and Quality Checks.

This work is part of the project on Tools for the 21st Century Construction Worksite (BUILT2SPEC) and is financed by the European Union in the context of the Horizon 2020 Programme.

This **Deliverable D1.3** describes the requirements of the VCMP and the basis from which the requirements are derived.

This document is structured as follows:

The methodology and sources from which the VCMP requirements were developed and are described in section.

These sources are mainly:
1) the BIM integration (the background is briefly explained in section 4.1.[1]);
2) the self-inspection technologies (thermal inspection, indoor air quality tools, airtightness test tools, acoustic tools, 3D imagery tools, smart materials, PHPP, DesignPH and interlinkage with the Passive House Certification platform) (section 4.2.1 – 4.2.8)[2]
3) the user needs identified in D1.1;
4) the most frequent causes of a performance gap (D1.2) and ;
5) the quality checks in the construction process (section 4.3).

The VCMP requirements are described in section 4.4 commencing with a short description of the already existing Refurbify platform (4.4.1), the general requirements (4.4.2) and BIM as a very important part (4.4.3). Built2Spec assessed the following additional general program parts/functions as 'musts' (4.4.4): providing information (e.g. component details, installation, commissioning and maintenance guidelines, etc. with information about the related quality checks), communication facilities, a documentation section which is closely related to the reporting and the help function.

In addition **'change management'** (4.4.5) was also identified as a very important factor particularly with a view to avoiding or at least reducing the so-called performance gap.

The quality checks will be organised as a matrix (4.4.6) which follows 3-step approach (4.4.7) and integrates the certifications (4.4.8) and national adaptations (4.4.9).   Additional useful apps which are conceivable are presented in 4.4.10 and the requirements of the VCMP related to the project stages in 4.4.11.

The innovative processes IDDS, IPD, IDP, Lean are introduced briefly and it is explained how they have influenced the workflow of the VCMP. This is described under 4.5, and the quality checks with the highest impact on energy efficiency are described in 4.6.

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[1] The technical details of BIM can be found in D1.4.

[2] The self-inspection technologies are more described more in detail in D1.1 and D1.4.

In Section 4.7 the certification **schemes of Passive House certification**, BREEAM, HQM and LEEDS are described briefly and in Section 4.8 we will take a brief look at the national construction specifics in Italy, France, Germany, UK, Spain, Ireland and the Netherlands.

In the **Annex 1** there is a list of quality checks covering the entire construction process. Annex 2 visualizes how the general requirements of the VCMP were derived from the user needs and Annex 3 shows the assessment of the impact of the platform on the performance gap.

1 CONTENT

Abbreviations

B2S = Built to Specifications

DOA = Description of Action;

VCMP = Virtual Construction Management Platform;

WP = Work Package.

QS = Quality checks

2 Introduction

A building should live up to the promises made to the investor. Structural damage, wastage of time, materials and money should be avoided. Moreover, the building should be environmentally friendly, and should not consume more energy than planned, and/or should generate as much energy as planned. However, it should also provide the necessary level of comfort and the required functionality. These are high demands, and to deliver such buildings is a complex process which all those working in construction have go through on a daily basis.

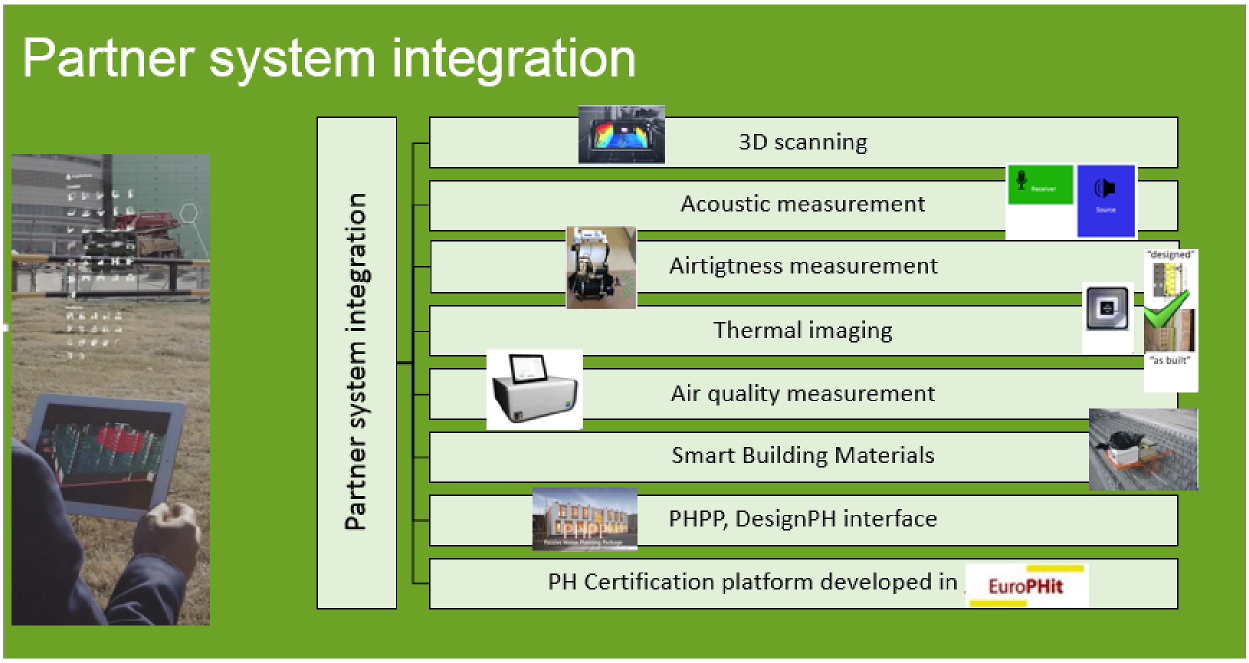
Generally speaking, the platform for which requirements are to be defined below is intended to help stakeholders involved in construction to ensure the quality of the building as promised to the investor during the design phase; in doing so, the emphasis should be on the inclusion of modern technology as far as possible in a reasonable way.

This is a big challenge and a very complex undertaking. The following sections describes the basis for the development of the catalogue of requirements. The purpose of the formulated requirements is that the platform should find widespread acceptance in the construction industry by accommodating the existing needs of the users and aligning itself with them on the one hand, and by addressing the boundary conditions which have changed due to the introduction of integrated construction processes, BIM and automated processes on the other hand. This flexibility of adaptation is a very important feature.

3 Methodology

Self-inspection technologies

The VCMP includes several self-inspection technologies which are essential for the VCMP requirements. Each of them contributes significantly to the reduction of the performance gap. These are 3D scanning, acoustic measurement, thermal imaging, air quality measurement, smart building materials, PHPP and Design PH interface and interlinkage to the Passive House Certification platform. BIM (Building Information Modelling) and the data format IFC (Industrial Foundation Classes) play an important role.



Partner system integration

Partner system integration

- 3D scanning
- Acoustic measurement
- Airtigtness measurement
- Thermal imaging
- Air quality measurement
- Smart Building Materials
- PHPP, DesignPH interface
- PH Certification platform developed in EuroPHit

Fig.: System integration

Construction processes

The process adopted in this project was to identify the important steps required to assure quality and to identify the requirements for the VCMP platform. In a first step the construction processes in the Netherlands, Italy, Spain, Germany, Ireland, UK and France were examined and the quality checks applied by the partners were compiled. The data was collected using questionnaires relating to the construction processes that are commonly applied in the individual countries. As far as it was possible, a common framework was worked out which is applicable beyond the national systems and which can be regarded as an overarching framework. With this framework, the national approaches as well as the different management approaches and the different technologies can be depicted using this outline. A particular effort was made to ensure that it is possible to integrate the newer integrative approaches which involve all participants at a very early stage of the construction process.

Each of the activities depicted in this outline, which we have designated as the '**Map of the construction process',** are linked, or can be linked, with quality checks and the involved actors.

Quality checks

Based on the information provided by the consortium members, the overview of currently applied quality checks necessary for the construction activities were collected during the task of depicting the construction process in its entirety (Annex 1). Apart from this, a connection was established to determine how quality assurance can take place in future.

The collected information relating to quality checks was evaluated and, as far as possible, similarities were identified and categories were created in order to identify systematic approaches for the VCMP. In a next step (task 5.1) the most important quality checks will be detailed into step-by-step approaches.

User needs

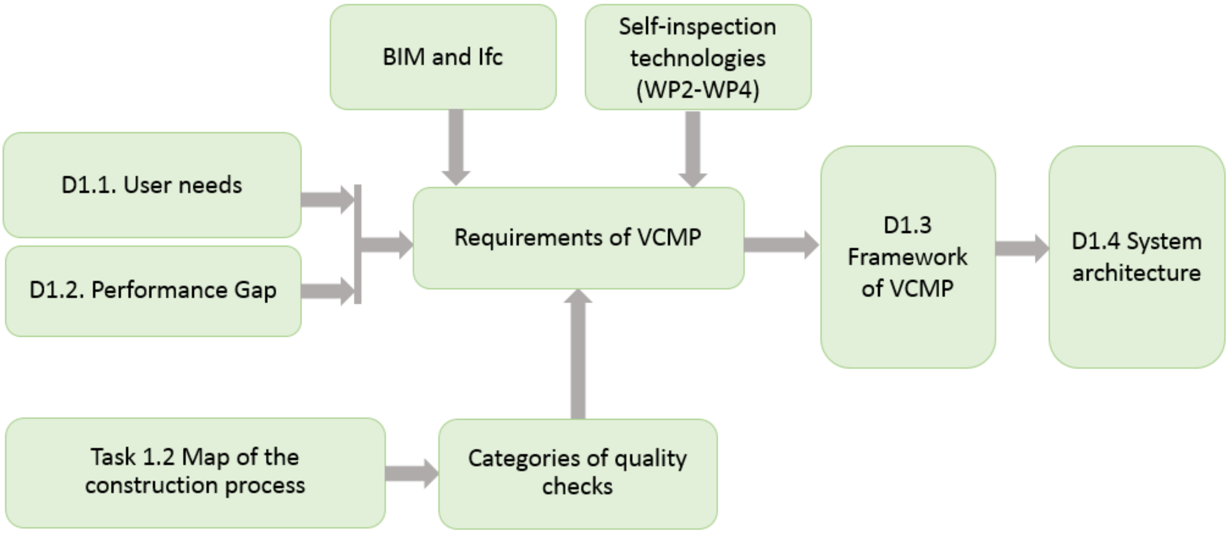
Workshops were held in Spain, France, Ireland, Italy and UK, which yielded a list of user needs which was provided in Deliverable D1.1 under 4.3. This list and the information which was provided in D1.2 about the 'Performance Gap' were analysed. Under consideration of the partner assessment and results of literature research, requirements for the VCMP were elaborated, which are described below.

Additionally it should also be mentioned that the 'user needs' mainly came from persons who are construction experts, although the practical experience with BIM differ from ‘no experience’ to ‘some experience’. It was also apparent that mostly traditional processes such as 'Design – Bid – Build' are currently predominant, therefore it is considered likely that a development and slight additions to the 'user needs' may take place during the course of the project. This should be considered for the development of the platform.

Integrated innovative construction processes

Internet research results were used for evaluating the integrated construction processes IDDS, IPD, IDP and Lean. Assessment of the processes took place based on discussions with experts. The information relating to 'Scrum' was collected in the IEE co-funded project PassREg on the one hand, and as a result of personal talks with the involved parties on the other hand. The conclusions for the VCMP were drawn based on these experiences, further talks with construction experts and the study of literature.

Workflow in WP1



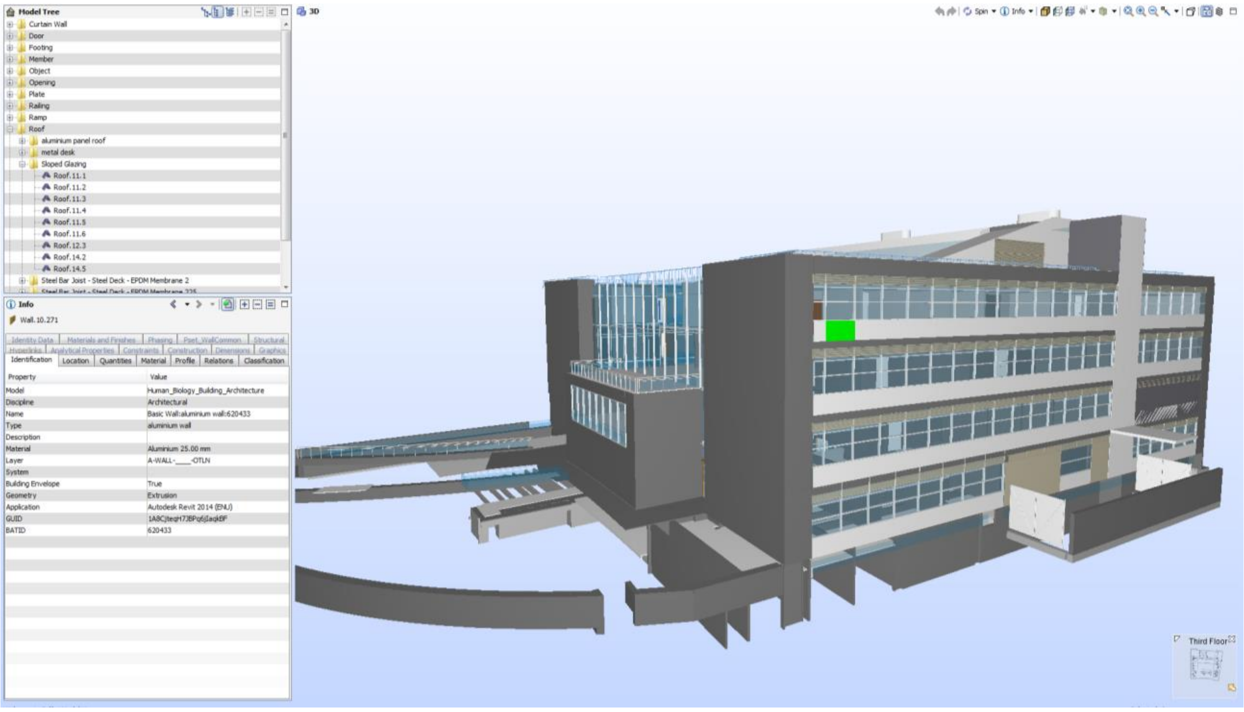
4 Framework of VCMP

4.1 VCMP supported by BIM

BIM is an important component of the VCMP. BIM is explained in detail he Deliverable D1.4, in this section only provides a very short introduction to BIM

BIM stands for 'Building Information Modelling'; sometimes also referred to as 'Building Information Management'. The term 'Building' can be seen as a verb. In simple terms BIM is about data. It is a container-term to mark the transformation from a paper/drawings driven industry to a data driven industry. BIM is a collective term to highlight the industry's movement from paper based operations to data based operations.

BIM equals data. It is a collection of virtual objects with properties and relations. Because a computer has semantic awareness of the objects, intelligent operations can be performed on the data. The richer and more semantic the dataset, the more intelligent the operations can be.



Property	Value
Model	Human_Biology_Building_Architecture
Discipline	Architectural
Name	Basic Wall:aluminium wall:620433
Type	aluminium wall
Description	
Material	Aluminium 25.00 mm
Layer	A-WALL-____-OTLN
System	
Building Envelope	True
Geometry	Extrusion
Application	Autodesk Revit 2014 (ENU)
GUID	1A8CjteqH7JBPq6jIaqkBF
BATID	620433

Figure: Impression of the Built2Spec BIM dataset

In specialized disciplines other tools are very popular. A construction engineer will probably work with Tekla, Scia or (on a lesser scale) Allplan. MEP modelling is done in MagiCAD or DSS (depending on the region in Europe). Tools like Solibri are very popular to check the quality of the data and to coordinate different discipline models. Most software tools express the same basic concept of BIM: a central model that is used to generate many different views (floor plans, sections, simulations, etc.).

At this moment a new wave of online BIM tools is being developed. Online BIM collaboration platforms are the new trend in BIM. The number of BIM tools and start-ups keeps growing daily. There are many misconceptions about BIM. Maybe the biggest misconception is that BIM is centralizing all data of a project into a single data repository.

Because most BIM software tools work with a central database that is being used for all features, this concept has been tried on a project scale. The recent rise of online BIM collaboration platforms is feeding this concept. However, many research projects and publications have proven that working with a central data repository is actually decreasing productivity of the project. Working efficiently with distributed data storages is more effective for the project than trying to centralize everything.

Two pictures are shown below, one shows a renovated house, the second one shows the BIM as section - one window is cut off.

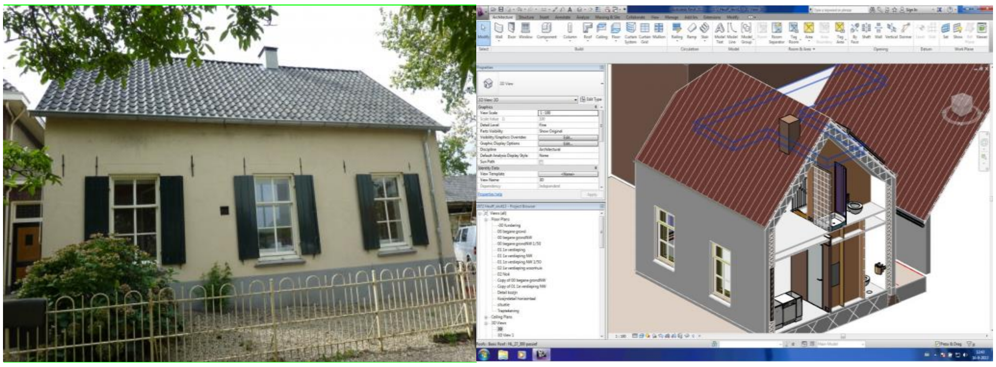


Fig: Comparison of a photo of a renovated house and the BIM[3]

Level of information

The picture above shows a very rough model suitable for overview purposes only. For the actual construction, the level of information in a BIM needs to be much higher at least. The term Level of Detailing (LOD) or Level of Development (LOD) is used to discuss what information needs to be in a BIM for a specific application. Many research has shown that the term LOD doesn't provide a solution to the problem. Information requirements depend on the need of information which the client, site worker, site supervisor, construction company, facility manager and inhabitant of the building have. E.g. the worker who is implementing a critical detail needs a very high level of resolution while the building user is not interested in such a high resolution. A standard wall does not need a very detailed resolution because the workers know how to build it.

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[3] Source of both pictures: http://passregsos.passiv.de/wiki/Passive_House_retrofit_of_a_monumental_bake_house

However, generic requirements can be found in different phases of a project. These generic requirements can be described in 'information levels'. The Dutch consortium member TNO has provided a workflow of a building process using BIM. This workflow below gives an impression of useful information levels proposed for the Netherlands:

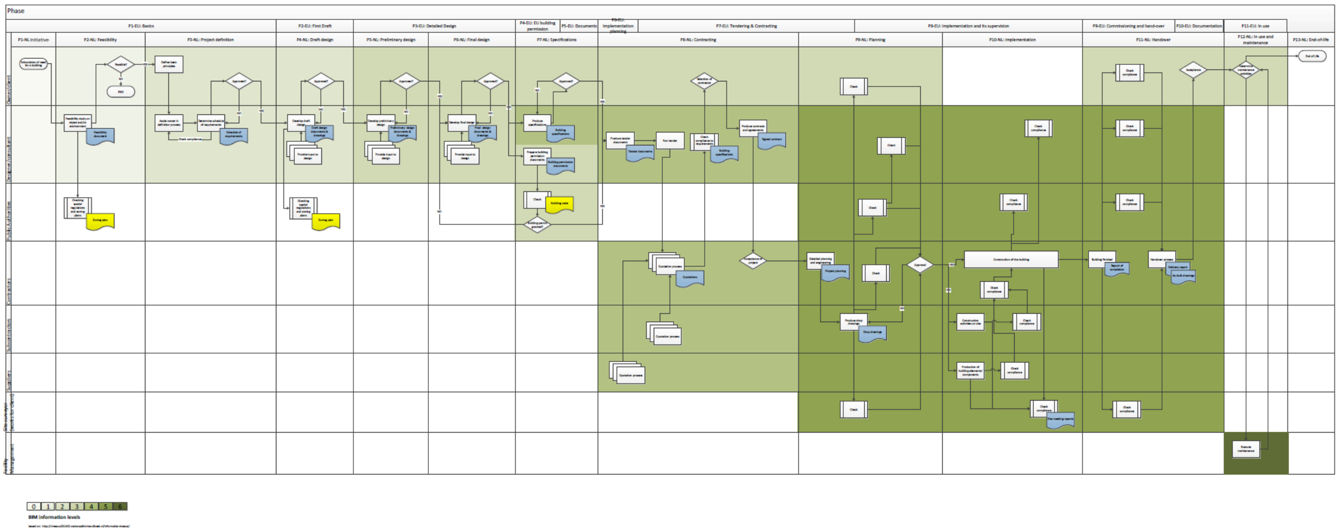

Fig: Workflow of a construction project using BIM

Seven Information levels are proposed: Information level 0 to information level 6[4]. Following this approach and in accordance with the mentioned source (footnote) the application of the BIM in the related project stage can be explained as follows:

BIM Information Levels:
Information Level 0: Basics1: demand specification (+ context), program requirements
Information Level 1: Basics2: model can be used for scenario variants and feasibility checks of first drafts with variants
Information Level 2: First design: model can be used for preliminary energy simulations, construction principles, floor plans
Information Level 3: Detailed design1: model can be used for building application and as a base for collaboration between parties
Information Level 4: Detailed design2: the model can be used for contract preparation, specifications, procurement
Information Level 5: The implementation: model can be used for site management, construction preparation, production and construction, product purchasing.
Information Level 6: For in-use: Model can be used for facility management and maintenance

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[4] https://github.com/BIM-Handboek-NL/shared-resources/blob/master/publications/20140403_BIM-InformationLevels-extended.pdf?raw=true

The typical BIM supported workflow as it is proposed in the Netherlands shows that the level of information depends on the purpose for which the data is used: high resolution only if it is required.

BIM is seen as an upcoming technology. Experts expect that the future construction industry will not be conceivable without BIM; however currently the extent is not yet clear.

VCMP will have a strong BIM part. It will use the BIM data to provide the right information at the right location and time and connect the location and time with the right quality checks. Therefore access to BIM is a basic requirement.

VCMP and the integration of air pulse testing via BIM

In addition to the various quality checks during a construction project which uses BIM, different innovative technologies which are part of the Built2Spec projects will be interlinked with the platform. Exemplary for the innovative technologies the interrelation between VCMP/BIM and the air pulse testing is introduced:

From the building airtightness' point of view, BIM can provide building information such as building location, type, parameters including internal volume and envelope area of building thermal envelope to the B2S VCMP, which is compatible with BIM, after the building detailed design is finalised.

Prior to an airtightness test, the tester is able to acquire the internal volume and envelope area of the test building from the B2S VCMP, which are input into the control box of PULSE unit. When the airtightness test is conducted at different key stages, the test results are displayed instantly on-site for quick decision making on whether the measures undertaken have achieved the desired purpose, or whether remedial work is required before moving on with construction.

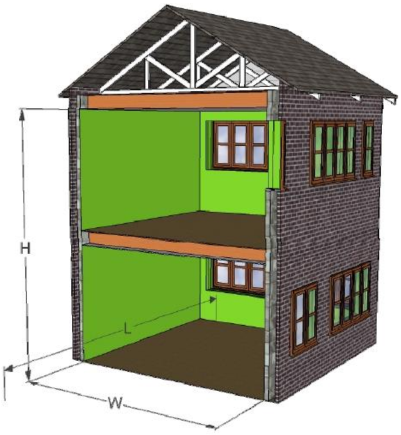
All test data including test ID (Test ID consists of building and test information, such as geotag info and test time), test result, geotag and construction progress (such as before and after the external wall insulation is installed) should be uploaded to VCMP automatically after each test is done for quality control and future reference purposes. Potentially the testing data can be used for analysis to correlate the leakage type and the test results. This can be facilitated by BIM and B2S VCMP.

The way that the internal volume and envelope area are calculated is as follows (complies with the previous UK standard--ATTMA TSL1 and ISO 9972 which superseded ATTMA):

An accurate evaluation of the envelope area and volume of the test building must be made prior to the test in order to obtain the airtightness results such as air permeability and air changes per hour on-site. However, the user also has the option of analysing the data at a later stage when the building volume and envelope area are available. It must be noted that the building volume and envelope area in this context are for the conditioned spaces in the test building.

The building envelope area and volume are normally calculated from accurately dimensioned drawings, which should be up-to-date and accurate. In the case of any extensions, these need to be included in the calculation but only if they are heated or cooled spaces. The dimensions for calculating the envelope area and volume should be measured along the inner surface of the wall or roof assembly.

For an envelope area, all walls (including basement/loft walls, if the basement/loft is subject to test), roof and the floor are considered as part of the building envelope. The space enclosed by them is the volume of the test building. This is the method of envelope measurement referred to in the Building Regulations. An example of a building with a regular shape is shown Figure: with dimensions.



Where: L = 7.40 m W = 4.40 m H = 5.30 m

Figure: A residential building with cold roof (ATTMA TSL1)

This building has a cold roof with the insulation installed at the horizontal ceiling level on the first floor. The calculation details for this building are listed in Table:1.

Table:1 Calculation for a residential building with a cold roof

A house with cold roof construction (i.e. the roof space is unconditioned)		
Area	Calculation	Results (m^2)
Floor area	L×W (7.40×4.40)	32.56
Roof area	L×W (7.40×4.40)	32.56
Wall area	2×H× (L+ W) 2×5.30×(7.40+4.40)	125.08
Envelope area (m^2)		190.20
Volume (m^3)	Floor area × H (this varies when building shape is irregular) 32.56×5.30	172.57

4.2 Self-inspection integrated in the VCMP

The different self-inspection partner technologies form core parts of the VCMP. They will be shortly introduced in the following sections.

4.2.1 Thermal inspection tools

The B2S thermal inspection tools aim at characterising the thermal performance of the envelope and ensuring the good quality of the implementation of its components, thanks to an approach combining on site measurements and thermal modelling.

Several levels of thermal inspection can actually be adopted, from the more standardised and replicable (standard protocol, non-quantitative thermal characterisation), to the more technically advanced and innovative (specific protocol, quantitative thermal analysis).

Several workflows and contexts of application have been conceived for integration into the VCMP:

- Quality check for thermal bridging of the external envelope
- Quality check for wall insulation installation on site (can include a qualitative thermal characterisation but quantitative as concerns the checked surface area parameters, or can include a more specific quantitative thermal approach)
- Checking thermal performance of structure using a suitable infrared camera and networked processing (includes direct comparison with dynamic thermal modelling)

Figure: Workflow of quality check for wall insulation installation on site

More details of these workflows are available in deliverable 1.1 (requirements for thermal quality checks).

4.2.2 Indoor air quality tools

Recently, indoor air quality (IAQ) has become an important parameter to check in order to satisfy the performances targets of the sustainable building concepts and approaches such as LEED, BREEAM, and HQE. Indeed, it has been proven that the IAQ could affect the occupants' health and this issue is also now addressed by new regulations.

The indoor air quality tool[5] will be an all-in-one analyzer which will combine the technology developed by the company "BLUE Industry" (Blue X-FLR8 IAQ Monitoring) with other technologies such as the one developed by the start-up CAIRPOL. The apparatus will be portable which means that it will weigh about 5kg and will occupy a volume about 10 liters. The Blue X-FLR8 IAQ Monitoring analyzer allows the measurement of harmful volatile organic compounds (pollutants) such as the formaldehyde and the toluene by using the infrared technology. This analyzer allows a real-time measurement and a simultaneous multi-gas analysis (up to 80 harmful gas pollutants are commonly found in Indoor Air). Besides, this apparatus presents a high selectivity (able to differentiate each species from the others) and a very low detection threshold (down to ppb level).However, as it is necessary to assess the concentration of fine particles and the ambiance parameters (temperature, relative humidity, etc.), this technology will be combined with technologies present on the market to obtain an all-in- one solution.

The analyzer can be used for several use cases such as the validation of some equipment/materials, the prevention of health damages, and the qualification of construction sites. The IAQ measurement will be planned according to the results of the survey completed by the different companies working on the site, where they will explain when and where they will introduce materials that could degrade the IAQ, or when and where they want to validate some equipment. The planning will be integrated in the platform and a message will be sent to the operative when an IAQ measurement has to be realized (all the measurement protocols will be available on the platform). If the values obtained correspond to the ones expected, the report is integrated to the platform and the work can go on. Otherwise, actions required have to be notified to who it may concern using the platform, and have to be taken until the desired values are obtained (actions will be listed into the platform and the measurement after each action will be uploaded to the platform). These actions could lead to the research of pollution emission sources that can be made with the same analyzer using the "source emission detection" mode. Once the measurements satisfy the requirements, the other construction steps can continue and the people working on the next step are notified by message.

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[5] ref also to D3.8 IAQ software interface, due date M30

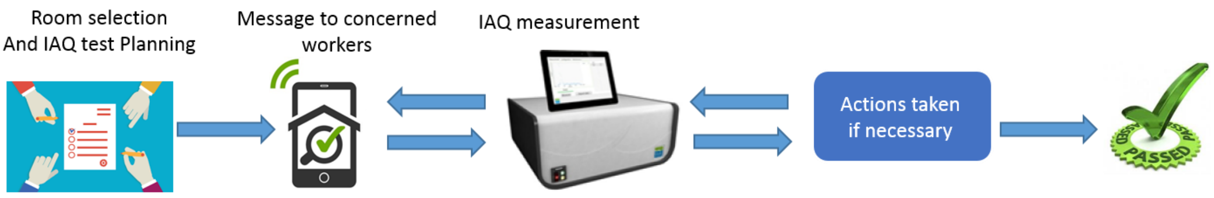

Figure: Workflow of IAQ measurement

4.2.3 Airtightness test tools

The B2S airtightness testing tool[6] is the PULSE technique, which is a standalone unit that, maintaining the building integrity, measures the building airtightness at low pressures by releasing compressed air into the test building over 1.5 seconds from a compressed air tank and creating an instant pressure rise. The pressure variations in the building and tank are monitored and used for establishing a correlation between building air leakage rate and pressure difference across the building envelope. In the Built2Spec project, this testing tool is employed to check the building airtightness at different key stages to assess the effectiveness of the measures taken during construction in improving the building airtightness. As one integrated technology on the B2S VCMP, PULSE achieves the quality checks based on two way communication with VCMP, including pre-testing and post-testing.

At the pre-testing stage, the VCMP provides updates on the building construction progress to the airtightness test operative so appropriate preparations can be made. When the building is ready for airtightness testing, a notification is generated on VCMP and sent to the operative. This is done by checking the list of requirements that need to be met in order to allow a valid test to happen, including:

- Is the wall construction finished?
- Is the roof/ ceiling (the one that is part of thermal envelope) finished?
- Is the floor finished?
- Is the external door(s) installed?
- Are the windows installed?

Once all the requirements above are ticked, the airtightness test to the building can be conducted in order to assess the effectiveness of installing other airtightness related materials or components such as insulation, air membrane and sheeting, etc. Therefore, in order to make these quality checks possible, it is highly recommended the procedures listed in the checklist above to be completed prior to conducting airtightness test. If the requirements in the checklist can't be met due to various reasons, only one or limited quality checks can done to the building

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[6] ref also to D3.2 airtightness integration software module, due date M24

during construction, Endeavour must be made to avoid this happening in order to eliminate the reprocess to the building work after the construction is at or close to finishing stage.

At the pre-testing stage, the envelope area and internal volume of the test building also need to be calculated and provided to the airtightness testing tool once the detailed design of the building is finalised. These building parameters are then stored on VCMP. When the airtightness of the building is tested, the parameters are available for use.

At the post-testing stage, each conducted test is tagged with time, building ID and construction progress (for instance, before installing air membrane, after installing air membrane).

The test results, presented in four parameters, including flow rate, air permeability, ACH (air change per hour) and ELA (effective leakage area), are compared with the pre-defined value of the building airtightness. Decisions will be made on whether the measures taken have achieved the desired purpose, and whether remedial work is required before moving forward. The test results of each test are uploaded to a cloud database which can be viewed from VCMP. To summarise, the information that needs to be exchanged between the VCMP and PULSE include:

Pre-testing: Building ID (including building location, type, envelope area and internal volume), construction progress associated with the checklist.

Post-testing: Testing results (test ID, air leakage rate, air permeability, air change per hour and effective leakage area, potentially the location of leakage pathways).

It is essential that VCMP incorporates the feature of being able to communicate with the airtightness testing device wirelessly. A diagram is shown in the Figure: .

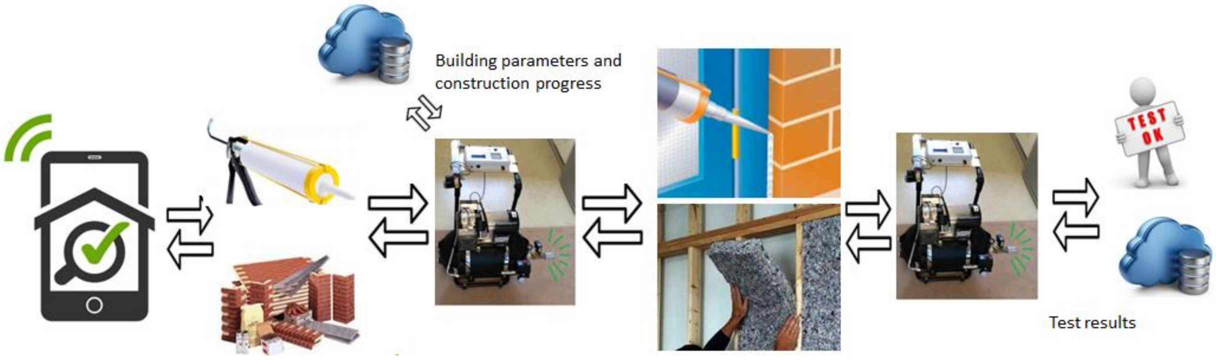


Figure: Workflow of airtightness test within B2S VCMP

4.2.4 Acoustic tools

Nowadays, most European countries check the acoustic quality of the building according to the performance. Sound insulation regulations and guidance also involve a prescriptive approach only in a few countries, while construction technical drawings are provided in others. Moreover, the acoustic performance tests must be realised by authorised acoustic consultants and are expensive measurements.

With the Built2Spec portable acoustic measurement unit, quick tests can be carried out complementarily to traditional tests to gather information in a better and faster way. The acoustic measurement consists of a mobile device and a novel omnidirectional parametric loudspeaker.

The room selection and the measurement procedure will be performed following the ISO 16283-1 guidelines.

The algorithm created for this application will be presented in deliverable D.13 (M24).

Figure: Workflow acoustic tool

4.2.5 3D imagery tool

To facilitate the process of collecting and analysing data, researchers have focused on devising methods that can semi-automatically or automatically assess on-going operations. A line of work is particularly focused on developing Computer Vision techniques that can leverage still images, time-lapse photos and video streams for documenting the work in progress. A possible workflow can be seen in the next Figure.

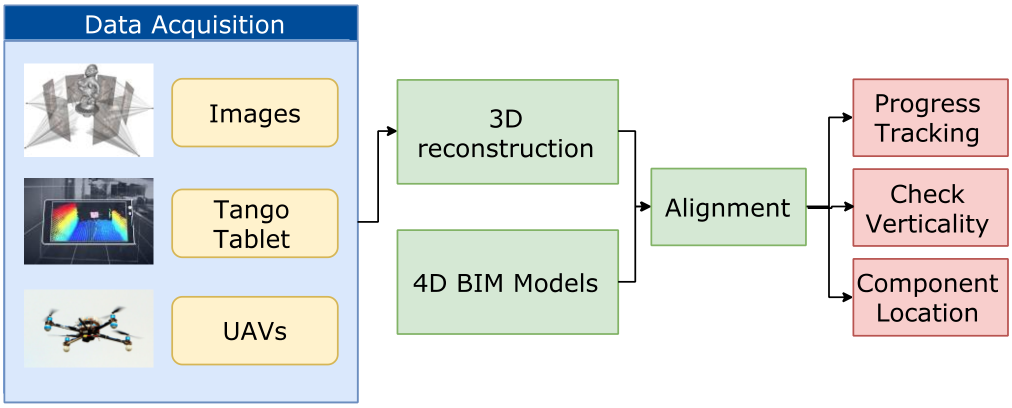


Figure: 3D Scanning workflow

4.2.6 Smart material

In order to perform the required quality checks, Built2Spec Project uses smart materials (smart construction elements). Specifically for task 4.2 the instrumentation used will be:

i. VW strain gauges in the concrete floor to monitor the strain of the concrete floor structure.
ii. IP68 rated thermistors embedded in the precast concrete slabs in order to monitor the temperature profile through the element.

These smart materials should allow continuous self-inspection and quality checks of building structural elements during the manufacturing, construction and commissioning stages of the product life cycle of certain building elements/systems. Not only this, but also this system will be able to analyse the building performance during its operation. Besides, the obtained data can be compared to initial calculated results and laboratory tests to deeper analyze potential sources of divergence in its performance. Figure 1 shows a typical workflow related to a Smart material.

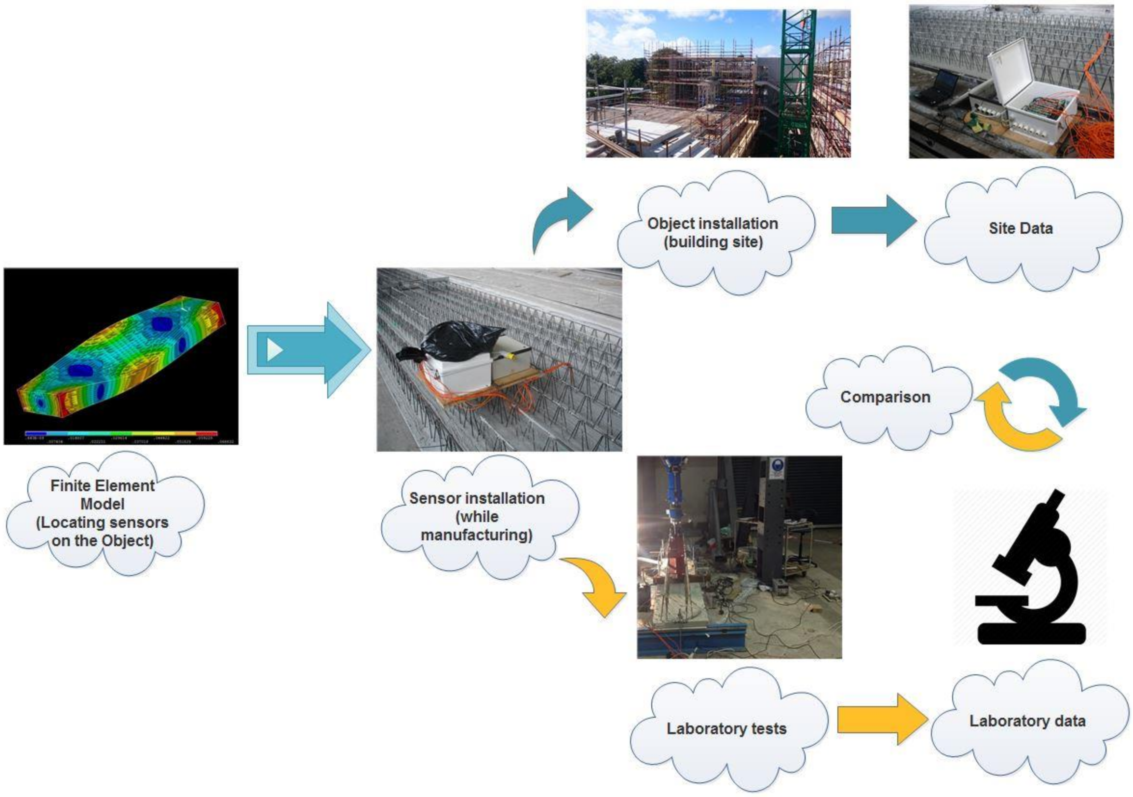


Figure: Smart Material workflow (Example)

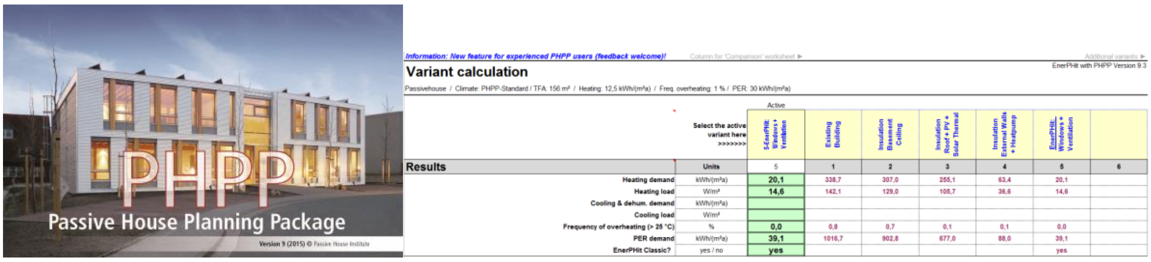
4.2.7 PHPP and DesignPH integration

The Passive House Planning Package (PHPP) is an energy balance tool which architects and energy planning experts can use to design all kind of energy efficient buildings, Passive Houses (Classic, Premium, Plus, Nearly Zero Energy Buildings, other energy plus buildings and all kind of renovation.

Over many years, the Passive House Planning Package (PHPP) has proved extremely successful and accurate for planning new Passive House buildings as well as retrofits according to the EnerPHit Standard. In the early design phase, it is recommended that the planning tool designPH is used which functions as a 3D data input interface for the PHPP and is available as a plugin for the design software SketchUp.

The specified energy consumption matches exceptionally well to the planned demand, both in the case of Passive House new builds and in existing buildings which have been retrofitted to the EnerPHit Standard for building refurbishments. The comfort level in these buildings also meets or exceeds expectations and in most cases the construction project can be implemented cost-effectively. Major differences in the actual energy consumption and the planned energy efficiency target, known as the performance gap, do not arise with

Passive House buildings and EnerPHit modernisations; this has been proven over the years in numerous monitored projects.



Information: New feature for experienced PHPP users (feedback welcome)!   Column for 'Comparison' worksheet ►   Additional variants ►

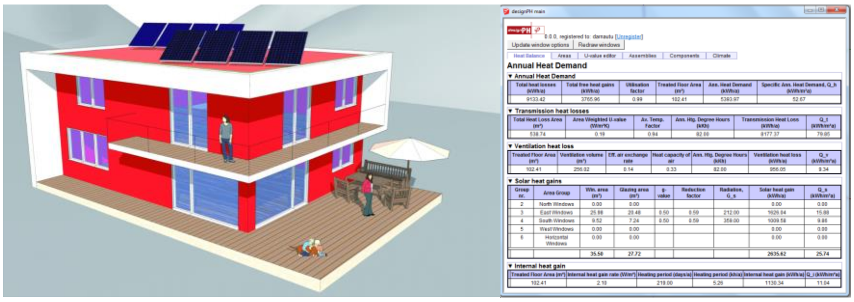
Variant calculation   EnerPHit with PHPP Version 9.3

Passivehouse / Climate: PHPP-Standard / TFA: 156 m² / Heating: 12,5 kWh/(m²a) / Freq. overheating: 1 % / PER: 30 kWh/(m²a)

		Active						
Select the active variant here >>>>>>>		5-EnerPHit: Windows + Ventilation	Existing Building	Insulation Basement Ceiling	Insulation Roof + PV + Solar Thermal	Insulation External Walls + Heatpump	EnerPHit: Windows + Ventilation	
Results	**Units**	5	1	2	3	4	5	6
Heating demand	kWh/(m²a)	20,1	338,7	307,0	255,1	63,4	20,1	
Heating load	W/m²	14,6	142,1	129,0	105,7	36,6	14,6	
Cooling & dehum. demand	kWh/(m²a)							
Cooling load	W/m²							
Frequency of overheating (> 25 °C)	%	0,0	0,8	0,7	0,1	0,1	0,0	
PER demand	kWh/(m²a)	39,1	1016,7	902,8	677,0	88,0	39,1	
EnerPHit Classic?	yes / no	yes					yes	

Figure: PHPP Data sheet

Interlinkage with BIM and quality checks of the VCMP will provide quick and accurate energy performance assessment of all design stages on the one hand and quality requirements will be derived even if changes occur during the design and construction process on the other hand.



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Annual Heat Demand

▼ Annual Heat Demand

Total heat losses (kWh/a)	Total free heat gains (kWh/a)	Utilisation factor	Treated Floor Area (m²)	Ann. Heat Demand (kWh/a)	Specific Ann. Heat Demand, Q_h (kWh/m²a)
9133.42	3765.96	0.99	102.41	5393.97	52.67

▼ Transmission heat losses

Total Heat Loss Area (m²)	Area Weighted U-value (W/m²K)	Av. Temp. Factor	Ann. Htg. Degree Hours (kKh)	Transmission Heat Loss (kWh/a)	Q_t (kWh/m²a)
538.74	0.19	0.94	82.00	8177.37	79.85

▼ Ventilation heat loss

Treated Floor Area (m²)	Ventilation volume (m³)	Eff. air exchange rate	Heat capacity of air	Ann. Htg. Degree Hours (kKh)	Ventilation heat loss (kWh/a)	Q_v (kWh/m²a)
102.41	256.02	0.14	0.33	82.00	956.05	9.34

▼ Solar heat gains

Group nr.	Area Group	Win. area (m²)	Glazing area (m²)	g-value	Reduction factor	Radiation, G_s	Solar heat gain (kWh/a)	Q_s (kWh/m²a)
2	North Windows	0.00	0.00				0.00	0.00
3	East Windows	25.98	20.48	0.50	0.59	212.00	1626.04	15.88
4	South Windows	9.52	7.24	0.50	0.59	359.00	1009.58	9.86
5	West Windows	0.00	0.00				0.00	0.00
6	Horizontal Windows	0.00	0.00				0.00	0.00
		35.50	27.72				2635.62	25.74

▼ Internal heat gain

Treated Floor Area (m²)	Internal heat gain rate (W/m²)	Heating period (days/a)	Heating period (kh/a)	Internal heat gain (kWh/a)	Q_i (kWh/m²a)
102.41	2.10	219.00	5.26	1130.34	11.04

Figure: DesignPH

In addition the originally calculated energy performance the as-built data from the as-built BIM will provide the investor and the future user a realistic idea of the expected future energy performance and a basis for plausibility checks during the life-time of the building.

4.2.8 Passive House Certification platform

While the quality checks of the VCMP will deal with the details of the construction process, the Passive House certification platform which was developed in the context of the IEE co-funded project EuroPHit[7] will provide support and guidance to architects and engineers during the certification process.

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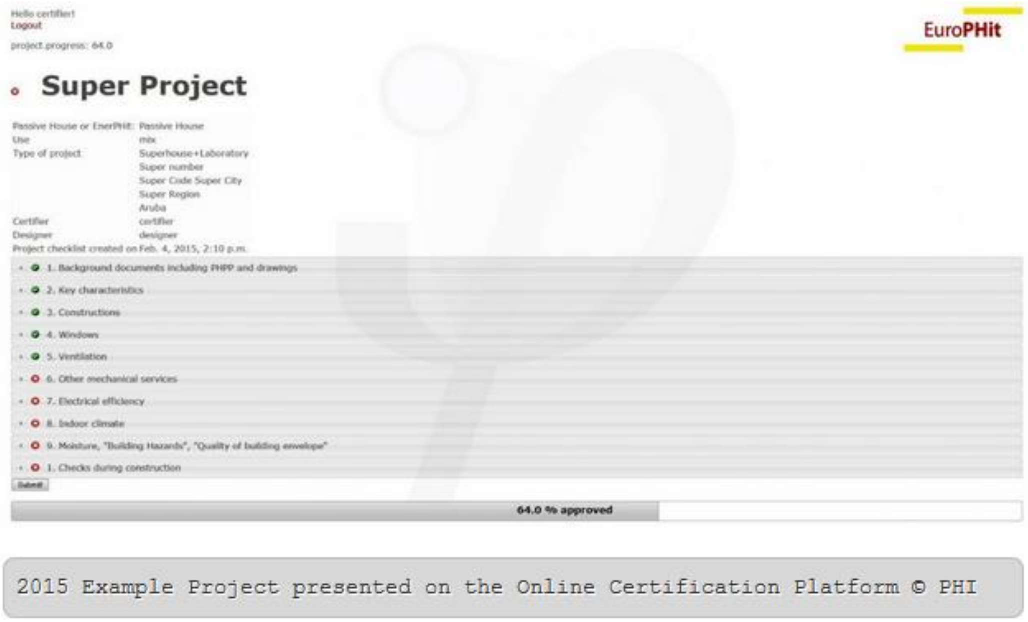
[7] http://www.europhit.eu/certification-platform



Hello certifier!
Logout

project.progress: 64.0

Super Project

Passive House or EnerPHit: Passive House
Use: mix
Type of project: Superhouse+Laboratory
Super number
Super Code Super City
Super Region
Aruba
Certifier: certifier
Designer: designer
Project checklist created on Feb. 4, 2015, 2:10 p.m.

- ● 1. Background documents including PHPP and drawings
- ● 2. Key characteristics
- ● 3. Constructions
- ● 4. Windows
- ● 5. Ventilation
- ○ 6. Other mechanical services
- ○ 7. Electrical efficiency
- ○ 8. Indoor climate
- ○ 9. Moisture, "Building Hazards", "Quality of building envelope"
- ○ 1. Checks during construction

64.0 % approved

2015 Example Project presented on the Online Certification Platform © PHI

Figure: Example project in the certification platform

This platform is a structured guideline following an interactive workflow which is annotated with comments, reminders and check boxes. It is designed to increase quality assurance and speed up the verification process. It serves as the backbone of the entire certification process. In Built2spec this platform will be interlinked with the VCMP.

4.3 Quality checks in the construction process

Beside the self-inspection technologies a set of automated quality checks will be integrated in the VCMP. In order to identify the relevant construction process steps the entire construction process was investigated. In the following the most important aspects are described:

4.3.1 Phases of the construction process

Each country has its national traditions for realising buildings and for organising the process of building delivery. Nevertheless, during the evaluation of the answers in the questionnaire, the following common phases of the construction process could be identified which are independent of the nationality. The specific activities described under the national frameworks like CABE in UK, ‘loi MOP’ in France or HOAI in Germany can be included in this structure. It is important to mention that these phases are not necessarily in chronological sequence. What matters most is the kind of contract with the implementing companies.

The following phases were identified:

1. Basics
2. First draft

3. Detailed design
4. Building permission documents
5. Implementation planning
6. Tendering and contracting
7. Implementation and its supervision
8. Commissioning and Hand-over
9. Documentation
10. In-use

Finally the phases were clustered under

A. Preconstruction
B. Implementation
C. In-use

These clusters will also partition the VCMP because the involved parties and the type of quality checks differ substantially. Stages 1-6 can be clustered under A. ‘Preconstruction’, stages 7-8 under B. ‘Implementation’. However, overlapping will occur between these phases. Currently this is seen only as a question of access to and interlinkages between parts of the new VCMP.

4.3.2 Selected user groups

In addition to the identified phases in the construction process, the following stakeholders in the construction process could be identified when evaluating the answers of the questionnaire and drawing the ‘Map of the construction process’:

- Project initiation: owner and investor, project management/control
- Project implementation: designer, architect, structural engineer, technology planners, safety officer, worksite supervisor, expert for energy and energetic quality assurance, expert for certification, construction companies, site worker, building physicist, material and component supplier
- Other project related groups: facility management, public offices, financing institutions, insurance companies, building user, general public

In order to avoid too much complexity, we have reduced the original list to the following main groups:

1) Owner and investor,
2) Designer, architect
3) Technology planners (HVAC engineer, environmental engineer, structural engineer, soil experts, acoustic engineer, building physicists, et al.)
4) Worksite supervisor (including site workers)
5) Experts for quality assurance: 5a: energetic, 5b other certificates
6) Construction companies (and the specialised insurance companies)
7) Material and component supplier
8) Facility management
9) Public offices
10) Building user

The above 10 main groups are clustered in 3 categories which are also related to the stages of the construction process:

Category A/Stage A: Involved in the design process (from basic evaluation until building permission) which relates to BIM Information Level 1-4
Category B/Stage B: Involved in the construction implementation process (implementation design until documentation) which relates to BIM Information Level 5
Category C/Stage C: Involved in the activities during when the building is in use which related to BIM Information Level 6

The applied BIM Information Levels are explained in Section 4.1

Analysing and comparing the different workflows in the different countries, it was found that there are deep similarities between the different country specific approaches involved in Built2spec

Differences occur independent from the nationality when different kind of contracts are made: e.g. design, build, design + build, traditional tenders, etc. Depending on the kind of contract, particularly the contracted construction company and some of the other trades are already involved in the stage A (pre-construction) and some of them are involved in stage C (in-use). When an integrated approach is applied the input from the design team and the different technology engineers is also available in the stages B (construction) and C (in-use), e.g. availability of the engineers in stage C (in-use) is one of the core elements of the so-called 'soft landings' approach.

4.3.3 Quality Checks

Quality checks are a major part of the VCMP. As mentioned above, in order to find the appropriate approach for the new VCMP a 'Map of the construction process' was developed which includes the related quality checks during the design, implementation and in-use stage on an overview level. From this, the list of quality checks is derived which is included as Annex 1 in this document. It takes the fact into account that a large variety of building technologies are available. In addition to the different building technologies the HVAC equipment varies to a great extent and requires specific quality checks.

During the evaluation of information provided by the partners in the questionnaire, it became clear that most probably it will be possible to develop a core of the VCMP which is common for all the partner countries. The national specifics will be added as extras, and the basic elements can also be adapted nationally (ref. matrix of quality checks). Although there is a common core in the VCMP, only the nationalised tools will be visible to the user (ref. VCMP requirements).

Prioritising quality checks in the VCMP to assess user needs

In order to explore the priorities of the partners they were asked to indicate their assessment (red = a must for VCMP, orange = very meaningful, green = good addition). Compiling the answers of the partners it is difficult to have a single result, only tendencies can be noted. Assessment from partners in Italy, Spain, France, UK, Ireland and Germany were available.

In the preconstruction stage the number of 'musts' clearly increases when the design proceeds. At the end of the preconstruction stage general checks related to the question if the building remains permanently damage free (no potential risk for condensation, cracks, water, noise, harmful substances, etc.) and if the performance framework and the planning requirements are met were marked as 'musts' from most of the partners.

Some partners also assess checks as musts at the end of the early phases of the preconstruction stage, particularly in in relation to energy balance calculation, renewables and identification of critical details with elaboration of technical solutions and meeting of the framework conditions in general. Time management was also noted as being important. The assessment of the quality checks for the building permission documents varied from being unimportant to 'must'. In the detailed design stage, depending on the area of activities, most partners assessed quality checks in the VCMP as a 'must' or at least 'very meaningful'. There was a tendency for greater interest in topics relating to thermal envelopes rather than building services, natural ventilation and integration of renewables. But this could also be influenced through the area of activity of the asked partners. There were also several ‘musts’ for quality checks in the ‘tendering and contracting’ stage.

When looking at the implementation stage, only orange and red cells can be seen with just a few exceptions. Partners demonstrate a clear need for integrating the implementation quality checks as much as possible into the VCMP, with the tendency to assess as ‘musts’ the energy efficiency and acoustics-related topics in addition to the material properties, geometry and position checks, and other topics as ‘very meaningful’. Correct commissioning and hand-over and in-use quality checks also have the highest priority for inclusion in the VCMP. Documentation focuses on quality checks related to availability of drawings as-built, user manuals and to the commissioning of the building control , and documenting the reporting is assessed from ‘very meaningful’ to a ‘must’.

Character of quality checks

When analysing the quality checks during the whole process, it was found that the character of the quality checks changes fundamentally from the pre-construction to the implementation and in-use stages.

Predominant in the pre-construction stage are questions such as: has the information been collected and made available and is the planning complete, consistent, technically correct and technically feasible? Have the requirements of the investor/users been met and have the norms and regulations been met with all their various aspects? Have the requirements of the chosen certification scheme been met? The planning process itself through the different stages also has certain requirements (e.g. involvement of experts). Some quality checks can be answered with a clear yes/no, e.g. consistency check, other answers are not that clear, e.g. technical feasibility implies the next questions: Is the implementation feasible within a certain time frame and within the budget frame? Additionally other question are difficult to answer : e.g. questions related to aesthetic requirements?

*Typical character of quality checks in the **pre-construction** stage:*

Are the information collected / provided:

- *Complete?*
- *Consistent?*
- *Technically correct?*
- *Technically feasible (at all and related to the given cost and time frame)?*

Are the requirements of the owner/users, norms & regulations, certification schemes and of the chosen design process met?

In the implementation stage, the structure and character of the quality checks is fundamentally different from the previous stage. Quality checks in the implementation stage check the correct geometry of items (length, width, height, check of accuracy of the surface), the correct position (distance between two items) and the prerequisite for execution of work/installation and the correct installation and application, the material properties and other component characteristics (material acceptance) in comparison to the specifications, the bill of quantities and the order, the protection during construction time.

Typically quality checks are performed several times at the same location e.g. at the location of a window (A) at intermediate stages: (a) only the opening in the wall without installed window, (b) the safety of workers, (c) the installed window, (d) after taping, (e) after plastering, and (B) in the final stage (f) the final clean and damage-free surface, and in case the pane was scratched (g) the exchanged pane. In addition, (h) unforeseen quality checks may sometimes take place.

There are also quality checks for the typical temporary elements of the construction site: formwork, scaffolding, safety of workers, temporary pit systems, cranes and their maintenance etc.

During implementation, there are also some tests which have an overarching character (e.g. airtightness test, testing of the commissioning of the building systems, testing for gas safety or waterproofing etc. and final acceptance and the appropriate involvement of the future users).

Typical character of quality checks during the ***implementation*** *stage:*

- *material properties and other component characteristics (material acceptance, comparison with specification, bill of quantities and orders)*
- *geometry*
- *position (distance to other items)*
- *prerequisite for installation/application*
- *installation/correct application*
- *protection during construction*
- *final check for final acceptance (appearance, geometry, position and function, absence of damages)*

Also typical is that the same item is checked several times, however related to different aspects

Also temporary elements need quality checks (formwork, scaffolding, etc.).

Some quality checks have an overarching character (e.g. airtightness)

In the <u>in-use</u> stage, the quality checks again differ fundamentally from the previous stage, the involved persons are also almost completely different (e.g. facility managers and building users and in the first years also the building service experts). The quality checks can be grouped as follows:

<u>As-built documentation</u>

Checks whether the as-built documents are complete, comprehensive and available. These include drawings, technical data-sheets, operation licences, user guidelines, building control documents, final acceptance, also all documents relating to building permits, structural and energy design, expert reports, contact data etc.

Regular checks to see whether the building and the components remain free of damage and free from malfunctioning, check the follow-up of the snagging list (if required).

<u>Monitoring</u>

Check if the building services function as desired. Check the building-services set up, do checks take place on a regular basis, and is the follow-up executed correctly. Is energy consumption data collected and evaluated? Is a plausibility check of the energy performance carried out and documented? Is the user feedback considered?

Maintenance

Is a maintenance plan available interlinked with the time schedule? Does the maintenance take place correctly? Are the details of the items which must be replaced and maintained available? Are the contact data and the instructions available?

Typically the quality checks during the ***in-use*** *stage are related to:*

- *As-built documentation*
- *Building damage and construction deficiencies*
- *Evaluation of monitoring data of energy and water consumption*
- *Maintenance*

Selection of details

At present, it has not yet been decided which single quality check will finally be integrated in the general catalogue of the VCMP, this will take place in the coming months. As described above, there will be a common basis and the provision that each user can adapt the templates according to his needs.

4.4 VCMP requirements[8]

4.4.1 VCMP based on the existing Refurbify platform

The new VCMP uses the existing Refurbify platform as basis. Refurbify is a cloud-based management platform for construction site task management and a suite of products that uses mobile technology already to connect and streamline the complex construction supply chain. It supports the process that every critical construction activity is accurately captured, on-site, in real time using mobile technology and fed back into the overall construction plans generating an accurate audit trail[9]. Refurbify's main features are the production of on-site data capture and production of quotations using a cloud based

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[8] The wording 'Recruitments' is used in the DoA. It has obviously been used by mistake instead of 'requirements'. In the text we have substituted 'recruitments' with 'requirements'.

[9] Source: http://www.refurbify.co.uk/products/refurbify/

solution, the workforce management by assigning tasks to specific user and groups and progress monitoring for all different users (clients, site manager, builders) for a specific project and overview management about the progress of all assigned jobs and projects. This includes also a reporting section. Refurbify enables the user to manage all the documents required for each project with permission levels included ensuring that all documents and drawings are up-to date.

The following is a short summary of the functionalities already built into Refurbify and which can be used as basis in the VCMP.

Refurbify includes the following modules, apps and features:

Mobile Survey App

- Mobile Work Tracking App
- Evidence of Use App
- Prepayment Module
- Project Management / Scheduling
- Dashboard:
- Residents' View
- Invoice Management: Quotes and Invoicing
- Users' Roles and Responsibilities
- Quality Checks / Compliance
- Online preview

Reports

- Overall Project RAG Report
- Employee Performance Report
- Project Progress Report
- Project Status Report
- Project Performance Report
- Job Progress Report
- Job Status Report
- Job Performance Report
- Job List Report

Survey Administration

- Survey Template Editor
- Skill validation and Survey assignment
- Survey Application
- Document Administration
- Folder and Placeholders
- Folder and Placeholder Templates
- Document permission

4.4.2 General requirements of VCMP

As it was mentioned in the introduction, the delivery of high quality buildings which meet the requirements of the investors and the rules and regulations, in a reasonable time and for a reasonable budget, is a very complex undertaking. The VCMP will support this process and put the stakeholders in a position to deliver buildings with a smaller, or preferably no, performance gap.

Flexibility

The quality checks are almost numberless, the components used in the building are becoming technically advanced, the process is complex and is also evolving, particularly when BIM comes into play as it is currently.

The VCMP already integrates BIM, nevertheless it can be formulated as a general and essential requirement for this platform that it should be **flexible and adaptable** to the different construction technologies throughout Europe and open to future developments.

Entry area

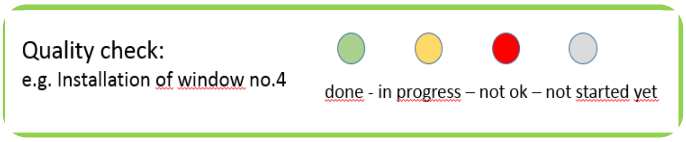
It is obvious that like any other programme, the VCMP will also have an **entry area** where a password is requested. The ‘role’ will decide which area the user can access. The role of the user will be pre-defined by the system owner. This area will also deal with the display of the user's projects and the creation of new projects. Information about the status of the project and the passed and upcoming quality checks (or a window showing an **overview of the due quality checks**) will also be included in this part.

Ease of use

One major and basic requirement is related to ease of use: it must be **easy** to identify the objects which needs to be quality checked in the design stage, which needs to be installed and quality checked in the implementation stage and which needs to be maintained with quality checks in the in-use stage. This aspect needs to be solved in the VCMP.

The virtual model is divided into objects which are linked to geometry (length, width, height, volume), properties (including thermal properties, or acoustic or fire protection, vapour transmittance, etc.). Some elements are small, some are larger. The elements are linked with material properties and time and costs. When talking about quality checks or installation guidelines, and also about specifications, smaller or larger units will be formed with the elements. Some objects will be interlinked with functions (e.g. one window can be tilted, another cannot), others are interlinked with commissioning or in-use requirements, the related installation guidelines and the related quality checks at several stages (1, 2, 3 temporary stages and the final stage).
The user can identify the object which the user wants to look at for the upcoming activity. The specific objects are linked to several quality checks of VCMP. Overlapping will occur. Intuitive handling needs to be developed for the selection of objects and the VCMP in general in order to keep the system attractive and ‘easy to use’.

Indicator system


Quality check:
e.g. Installation of window no.4
done - in progress – not ok – not started yet

We propose that the whole work flow should be accompanied by an indicator system which helps the user to keep an overview of necessary, running and executed quality checks (e.g. a green light system with green = done, orange = in progress and red = not fulfilled and grey= not yet started or similar). Such a green light system has the prerequisite of reducing the questions of passing the quality checks to questions which can be simply answered by yes/no.

It is conceivable that this indicator system is designed as an expert system with recommendations for the next step or solutions. At the end of a stage, all quality checks (predefined by the project leader) must show green lights. The indicator system could also include a warning if documents and drawings are not consistent with each other (BIM).

The quality checks should not be one fixed block of quality checks at the end of each sub-stage (1=basics, 2=first design, 3= detailed design, 4= building permission, 5= implementation design, 6=tendering contracting), instead it should be possible to initiate single quality checks or groups of quality checks whenever needed.

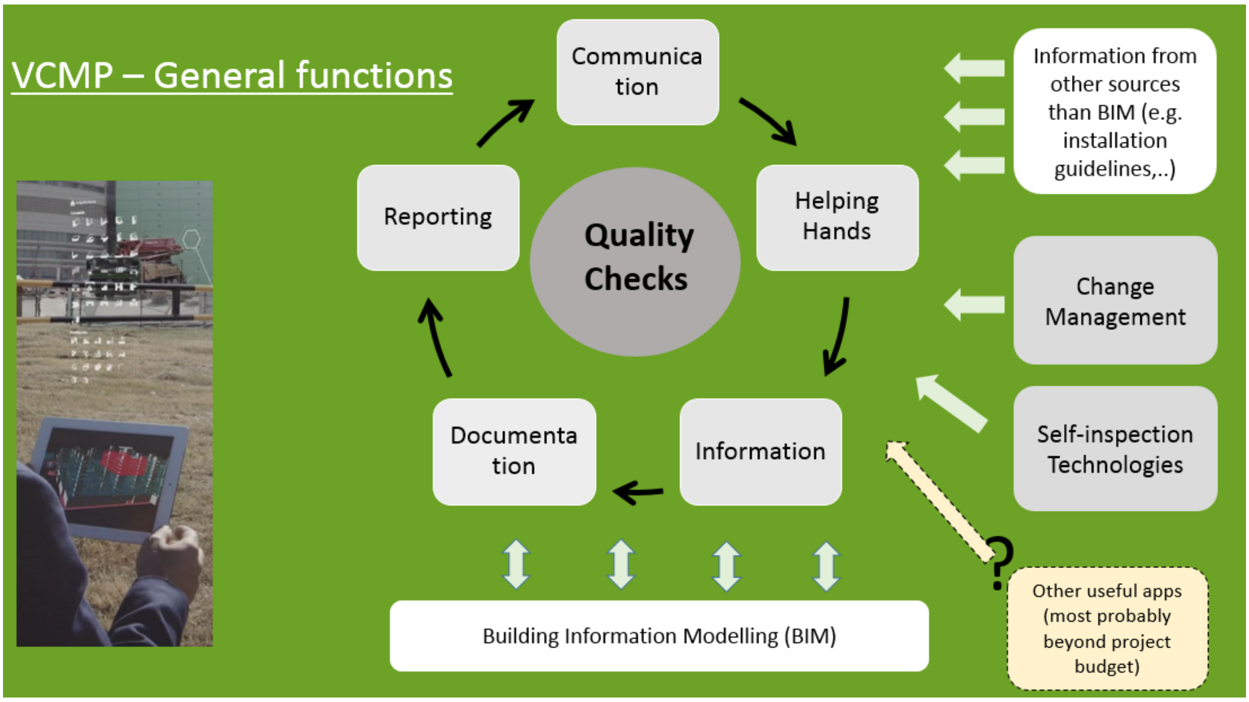
4.4.3 BIM as important part

The VCMP integrates BIM (Building Information Modelling). The involved parties are linked to each other via BIM and inconsistencies between drawings can be detected early. The workers will benefit because the drawings match with each other and the facility manager will receive accurate as-built documents. More details about BIM are mentioned in the section 4.1 and the Deliverable D1.4.

Access to the BIM is very important and is a leading part of the VCMP. Interlinked to the BIM, the user can find project-specific information and drawings which he has access to. In order to keep everything simple, it is proposed that some information may be in the foreground according to the construction progress (future – current – past function), others will only be visible for specific experts. Also the level of detailing of the provided information will vary according to the role of the user (less for insurance companies, higher in part for workers depending on the specific job to be done)

4.4.4 General program parts/functions

During the content-related analysis of the user needs described in Deliverable D1.1 and the quality related activities during the construction process described in the ‘map of the construction process’, we discovered that the processes relating to quality checks possess similar elements (Annex 2) Apart from the actual quality check, one always needs the following: **information** (drawings, descriptions etc.). Results (also interim results) must always be **documented** and be **reported** and **communicated**. Besides these requirements, also a **'helping hands'** function is very meaningful which allows access to further information and provides guidelines (e.g. for installation). Other requirements of the VCMP will be presented further below, however, the five mentioned previously are **very important** for the framework setting.



Information

This function can provide access to project specific information. These are:

- drawings via BIM an overview orientation included;
- other technical documents;
- expert reports;
- specifications contracted/updated;
- bill of quantities;
- energy and structural calculation;
- building permission;
- licenses;
- contracts;
- installation manuals and installation guidelines, videos/photos showing e.g. installation;
- quality check guidelines, videos/photos showing the quality check;
- etc.

Documentation:

This part of the VCMP can manage the documentation of the whole process which includes the steps from design to the building how it is built and how it performs in reality. It links all data with the respective unit in the virtual model (location, time, but possibly also with costs and other properties)

Documentation during the building process include:

- pictures/videos, notes with signatures and other evidence of execution (e.g. GPS report of excavation machines, manual input e.g. scan of documents from other sources.
- documents relating to orders and received material and components and their acceptance (task 5.4)
- documentation of the evidence of progress (time, date) interlinked with the bill of quantities, specification and possibly an invoicing app (= quantification and documentation of progress) (photos, notes, reports etc.)
- notes/communication about decisions
    - Material selections of the owner/investor
    - Material/component selection of the constructor
    - Other decisions
- documentation of communication (written, verbal)
- notes (e.g. meter reading (electricity, water))
- etc.

Documentation of commissioning and hand-over process include the:

- building control commissioning
- building control adaptation
- documentation of hand-over process and final acceptance
- documentation of snagging activities
- documentation of related communication (written, verbal)

As-built documentation

This part facilitates that finally the comprehensive as-built information are available. Data from quality checks and change management provide the basis to update the BIM to the as-built level of information and stores the related information. It documents the

- implemented components
- as-built drawings and the as-built BIM
- as-built specifications
- as-built energy balance calculation
- as-built bill of quantities
- reports for public authorities etc.
- reports for certificates

In-use documentation

This part takes care for all data of the in-use stage and documents the

- maintenance that has taken place
- monitoring data
- plausibility checks of energy consumption
- building control adaptation

Reporting (task 6.5 of the GA)

The reporting section is closely related to documentation and communication. The 'template designer' app creates templates as standard templates or based on compliance or regulatory requirements. The templates will be filled-in with the correct data in order to create documents

- for official, national specific reporting
- required for certificates
- for reporting to clients
- for internal reporting (overview of quality checks, results of quality checks, reporting on changes, etc.)

Communication feature

A communication can be linked with the **documentation tool** in order to store the content of the communication at the right location (e.g. if we are talking about windows: the documentation of the communication should be stored interlinked to the windows). In the case where several topics are being discussed, it should be possible to give several tags). The communication feature should include:

- a documentable chat function
- an email system
- the former correspondence
- the contact lists
- the access to notes and the possibility to write internal notes and notes which will be shared to external parties
- web access
- a tool for sharing and storing web research results
- an order system (e.g. material order)
- the possibility to send/receive photos and videos

'Helping hands'

This section can provide access to the web, but can also have the function for customising.

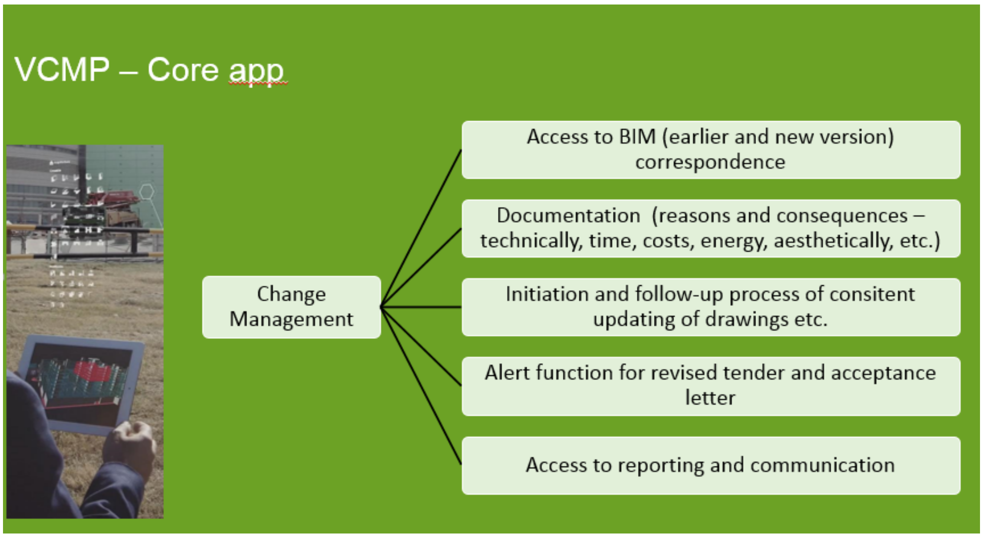
It can include information that is frequently used by the user, but not particular project-specific information. The helping hands function can provide:

- access to general information on specific details
- access generally to norms
- selection of out of a general library of installation guidelines
- selection of out of a general library of quality check guidelines
- photos and videos about correct installation and e.g. airtight implementation of specific details
- a search function (with memory function)

It also provides user specific information. This includes:

- frequently used information which is not project-specific
- a collection of helpful information (user-specific collection of frequently used additional information)
- frequently used norms (user specific)
- specific useful norms (more general than the information provided in the information tool)

4.4.5 Change management



VCMP – Core app

Change Management

- Access to BIM (earlier and new version) correspondence
- Documentation (reasons and consequences – technically, time, costs, energy, aesthetically, etc.)
- Initiation and follow-up process of consitent updating of drawings etc.
- Alert function for revised tender and acceptance letter
- Access to reporting and communication

A **core app** could be the ‘change management’ because the changes during the construction process causes a major impact on the performance gap (e.g. if material properties are changed out of budget reasons). This ‘Change management’ programme part of the VCMP could allow access to the

- earlier version of details as originally planned and
- new details (material property, length, width, height, position, new component)

It documents the reason for the change and its consequences:

- technically
- time
- costs
- aesthetically
- energetically
- on the targeted certificate

This parts could support and ensure the process of updating all related documents:

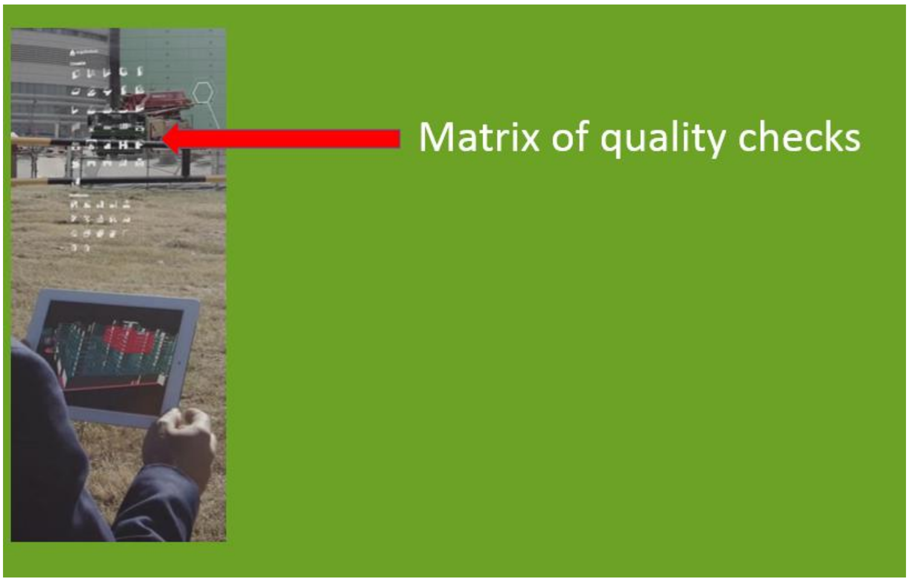
- drawings in IFC of all involved contractors/subcontractors

- energy calculation
- comparison with certificate requirements
- specification
- bill of quantities
- time schedule
- cost management

It is proposed that it alerts that a revised tender needs to be produced and the contracts need to be updated.

It could also document who has taken this decision with date and time, and to which component in the BIM it is related to. With the help of the reporting and the communication tool the involved people are informed and a related acceptance template for the client and the public authorities (if required) can be produced and sent. It could also provide an alert function if the acceptance letter is not yet available.

4.4.6 ‘Matrix of quality checks’



Matrix of quality checks

This part of the VCMP, called the ‘matrix[10] of quality checks’, is the key purpose of the creation of the VCMP and brings the platform to life. It can be organised as follows:

There are different categories of quality checks. Some have already been identified, others may be added. However, the total number of categories should not be too high in order to ensure clarity for the developer as well as for the users. The categories which are already predefined in Ifc should be used to the extent possible.

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[10] Matrix as a scheme for visualisation not in the mathematical sense

Some quality checks will take place through automatic data acquisition ((3D laser scans + automatic compliance check, etc.), while others could be supported and/or supplemented by expert systems and other applications (internal and external). Some quality checks (QS) will take place using checklists, others can be reduced to a simple YES/NO answer. Some quality checks are more suited for standardisation, some are less suited.

The matrix is created as follows:

Index 1: Object (according to Ifc)

Index 2: Category

Index 3: Layer (each layer contains quality checks (which are adapted to national regulations or specific certification schemes)

Basic Layer 01:

Unit/products/object (according to IFC) which is checked	Cat.1	Cat. 2 e.g. geometry	Cat. 3 e.g. position	Cat...	Cat…	Cat.n
Objects1		QS1/2/1				
Object 2			Q2/3/1			
Object 3 e.g. window opening no.7 in first floor		QS 3/2/1 Measurement Of length and width (full thickness of the wall) and height	Q3/3/1 Measurement Distance from shear wall (left, right), distance of the floor and ceiling			
Object 4						
Object 5						
Object ...						
Object n						

We will follow the IfcObjects, IfcProperty, IfcProduct and IFcRelationship definitions to the extent possible. Each of the objects/products will be identified by a GLUID (Globally unique identifier).

IFC has already predefined most of the categories (e.g. 'Body' which indicates the 3D shape or 'Profile' indicates a side profile for opening elements (e.g. door, window) for which material constituents are bounded[11]. We will use them to the extent possible. The following categories are assessed as meaningful (this list may be extended or reduced):

Checks of

- prerequisite to start the job (quality of previous job, outside temperature)
- completeness
- technical correctness
- compliance with
    - norms
    - specifications
    - other documents
- geometry
- position
- material and component property
- correct installation
- function
- protection against damages
- absence or deficiencies in the construction
- safety
- etc.
- standard template which is usable for quality checks not matching above

Time, costs and additional information

Because the kind of quality checks differ according to the point in time during the construction process, the introduction of a 4th dimension is meaningful. The already existing predefinitions in Ifc will be used (e.g. Ifc processes) wherever possible. It is proposed that the VCMP will employ at least the 10 general stages for the whole process as defined earlier. For the implementation stage a higher degree of detailing will be meaningful.

4.4.7 3-step set-up for the user

The idea is to develop for the above mentioned categories a pool or catalogue of quality checks as a general pool, from which the user can select those which are important for him and which he can adapt according to his needs. The quality checks will then need a project-specific adjustment for the respective projects. We therefore assume a 3-step set-up:

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[11] Source of the information on IFC: https://en.wikipedia.org/wiki/Industry_Foundation_Classes (28, January 2016)

- general pool
- user-specific
- project-specific

4.4.8 Passive House certification, BREEAM etc.

Certification quality checks as separate layers in the matrix

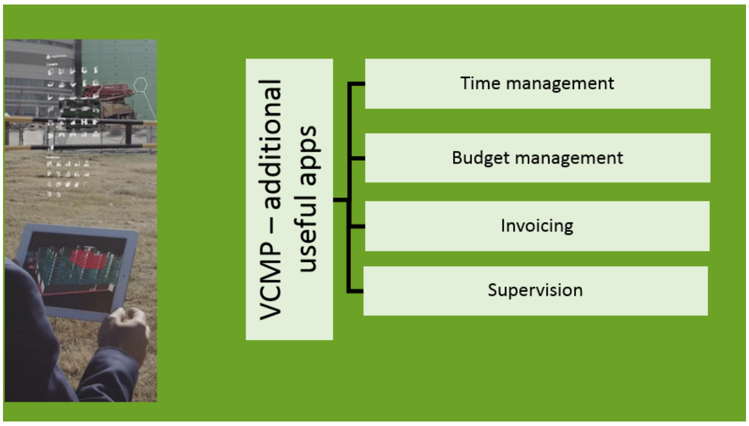
Quality checks for certification are technically similar to usual quality checks, only specific details differ. Therefore the differing quality checks in questions for certification (Passive House, BREEAM, et al.) are selected from the pool in the basic layer 1 and adapted to the respective requirements for the certificate. Regardless of whether an investor is building a Passive House or a house which is to be certified in accordance with BREEAM, or other certificates the execution of the steel reinforcement will remain the same. However details of thermal bridges might differ when a building is certified after Passive House standard or after BREEAM, e.al
These adapted quality checks e.g. of Passive House standard are in layer 02, e.g. BREEAM in layer 03. etc.

4.4.9 National adaptations (norms/ language)

National adaptations (norms and language) as a separate layer in the matrix

The construction industry still depends greatly on the national adaptations of the platform. Finally, the building needs to meet the national norms and regulation. In addition the national language is also very important for daily use of the platform in a construction project. Therefore the national adaptations will be superimposed on the respective layers so that the user in Spain will find only the Spanish regulations and only in the Spanish language or if applicable the quality checks for certification in Spanish language in the case they are stricter than the Spanish regulations,
e.g. the Spanish quality checks are in layer 11, the Spanish Passive House specific quality checks in layer 12 etc.
e.g. the Irish ones in layer 21…
….

4.4.10 Additional useful apps



We are aware that the budget is limited, however we propose the following very useful apps, either to develop now or later on.

Time management -

This app could include:

- Planned progress + update + warning relating to activities on the critical path
- Comparison actual progress vs planned progress
- Maintenance plan of construction machinery interlinked with in-use app
- Time schedule for specific trades

It should be:

- Interlinked with documentation app
- Interlinked with invoicing app
- Interlinked with cost management app

Budget management

This app could include the planned costs vs. actual costs with trend analysis.

- Overall costs
- Costs trade related
- Costs construction step related (e.g. floor-wise, trade-wise, etc.)

It should be:

- Interlinked with time management
- Interlinked with documentation

Invoicing

This app could provide invoice documents according to the progress of work:

It should have:

- Access to proof of work progress documentation
  - Bill of quantities
  - Specifications
  - Contract (contractual payment schedule
- Access to as built documentation

It should be:

- Interlinked with time management
- Interlinked with cost management
- Interlinked with change management

Supervision

This app could include:

- Capacity checks: are workers present at the site (e.g. only one or the planned five workers?)
- Time data entry for pay slips and controlling (interface with systems already available on the market) (interlinked with documentation tool)
- Material and components data entry (quantity and property) for checking with the orders and the specification and for the administration (interface with systems already available on the market)

It should be:

- Interlinked with documentation tool
- Interlinked with bar code scanner
- Interlinked with document scanner
- Interlinked with a camera.

4.4.11 The Requirements of the VCMP related to the project stages

The following requirements of the VCMP related to the project stages are proposed:

Predefinition of quality checks

Because there are a large number of construction technologies, each building is different and each project has its own specific critical points the VCMP needs a certain flexibility. In order to ensure the necessary flexibility of the VCMP, it is proposed that the VCMP asks the project leader for identification of the upcoming quality checks. The project leader will not be able to or want to account for these totally in advance, therefore it is advisable that it should be possible to repeat this identification step at any time, even spontaneously on site.

For preparation of the upcoming quality checks, the project leader can upload relevant detailed information or guidelines for the corresponding point. This function, modified slightly, can be used also for downloading installation instructions by workers, for example.

The machine should ask the user to identify the location in BIM and the kind of quality checks in advance (selection out of a pool of building specific quality checks (from a general pool or user defined pool. or identified as specific singular quality check which is unique). For the latter case a template for such a unique quality check is foreseen. The quality checks are interlinked with the BIM, the specifications and the bill of quantities, the time schedule, specific norms, drawings, details, sample photos, installation guidelines, and quality check guidelines. The machine should ask the users for identification of critical details and the point in time when, at which stage and which specific quality checks are required at which stage and to whom the results shall be forwarded. The recipient could also be an ‘invoicing app’ or a ‘time management app’

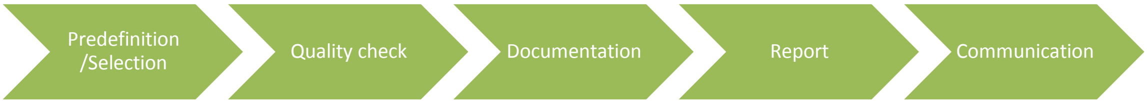


Fig.: Typical Flow

Machine self-aligning at construction site

When the site supervisor visits the construction site, the VCMP should orient itself to the place in the building where the user is standing (self-alignment / calibration) be means of a camera/GPS/ RFID. Conversely, information should also become available by clicking on or touching the specific location in the BIM model. This function can also be used for documentation purposes or in connection with a 3D scanner or the camera for data collection purposes. If this self-aligning function is used for quality checks, the level of accuracy that is possible could be a limiting factor. Some quality checks need extremely high accuracy, while other quality checks need less.

Requirements of VCMP for the pre-construction stage.

For the Pre-construction stage, BIM will be used to the maximum extent possible to check the **consistency** of the drawings and documents from expert systems and compare the design with specific requirements. In addition, other systems should be integrated to the greatest extent possible (e.g. drones for survey of existing buildings), visualisation tools for investor requirements, energy balance calculation, cross calculations, thermal bridge overview assessment tool, component databases (general, user specific, project specific), access to information databases, visualisation tools for critical details, etc.).

Separate blocks of quality checks on details of energy efficiency engineering and critical details in general should also be foreseen (linked with BIM). A higher level of detailing is potentially required for these checks.

Other quality checks will take place in the design stage which ask for checks along other requirements and which are not covered and not coverable by the VCMP evaluation.

If the project targets a specific certificate, a set of checks relating to the requirements of this certificate is needed.

Quality checks are required at the end of each stage in order to ensure that the design still meet all requirements. This final check is particularly important when the design is handed over to the construction company for implementation.

VCMP requirements for the preconstruction stage:

Indicator systems (e.g. green light system) for keeping an overview of necessary, running and executed quality checks to be carried out in predefined stages. It evaluates the

- *status of BIM consistency checks*
- *results of interlinked tools*
- *single quality checks which cannot be covered by automatic and expert systems (yes/no)*
- *status indicator of change management*

(It is potentially associated with time and cost management)

Quality checks which cannot be covered by automatic and expert systems need to be condensed to YES/NO for the indicator system

Additional conceivable sub apps for the pre-construction stage are:

- an electronic tool for simple assessment if a detailed thermal bridge calculation is required
- visualisation of user requirements interlinked with the BIM.

Traditional vs. innovative integrative construction process

For elaboration of the requirements for the VCMP, importance was placed on ensuring that the platform which is supported by BIM can be used for traditional as well as for innovative construction processes. The links for this are detailed quality checks of the documents, which are handed to the construction company by the planning team for a formal hand-over in a traditional approach. However the formal hand-over does also appear in an integrative approach, but in a modified way.

Examination of the documents prior to implementation

Even if the platform is BIM supported and clashes and contradictions are revealed early on in the design process due to BIM, the actual implementation must be adapted and full, congruent documents must be available at the start of construction work. Each contradiction and uncertainty leads to effort for clarification, delays and costs. Furthermore, in the frenzy of construction activity, all integrative construction processes as well as the traditional approach entail the risk of 'we'll worry about that later', meaning that the necessary elaboration of critical details in advance, i.e. the complete development of a virtual model with the depth of detail necessary for implementation (as rough as possible, at specific points as detailed as necessary) is in danger not to take place with the requisite quality. LEAN/Scrum requires that the tasks at hand are fully understood and the obstacles in the way of implementation are eliminated before the start of a job. Quality testing at the outset of the construction work can be regarded as an important requirement of the VCMP as per feedback from the construction company involved in the project.

Requirements of VCMP for the implementation stage

Hand-over to construction company quality check

In the beginning and hand in hand with the predefinition of quality checks, there should be congruency checks of all documents (drawings, energy planning, expert reports (soil, acoustics, fire protection, structural engineering, HVAC), time and budget planning, and specifications. These congruency checks are a typical part when working with BIM. The related reports will be produced by the VCMP in order to document the required quality at this stage.

Adaptation of details to the actual implementation

For the next step the VCMP needs an area in which the adaptations relating to the actual production and implementation are checked.

VCMP requirements for the implementation stage:

Hand-over area from design team to construction company

Adaptation to the actual production/implementation process

Integration of different typical self-inspection technology
Checks of geometry, material properties, position, installation, commissioning and function
+
Additional supporting tools if self-inspection is technically not yet feasible or not meaningful

Change management app to ensure incorporation of the changes in the entire process

Hand-over area from the construction company to the user

Implementation quality checks

With the BIM model available and using the camera or RFID/GPS or manually the user identifies the location of a specific quality check (wall/ceiling/floor/openings for windows, doors, pipes, cables, fire shutters, etc.) Normally the quality checks are predefined in advance, also the quality checks at intermediate stages, e.g. wall before plastering or temporary protection against damage during construction. However additional spontaneous quality checks are usually occurring and should also be possible.

The VCMP is intended to have a set of typical quality checks, which can be adapted to the project needs by the user and it will be flexible enough for supplementation with additional checks, including the relevant reports. In addition it will be possible to generate reports on manual quality checks which were not foreseen in the system.

It is proposed that the VCMP
- scans surfaces
- measures length, width, height, distances between elements (= correct geometry),
- calculates average values (for erasing/identifying spikes)
- measures accuracy of surfaces, (surface scanning with a 3D scanner or a drone)
- checks position/correct fixing (partly manually checked)
- scans bar codes (otherwise manual checks) if the material properties match with the specifications)
- shows videos and pictures about correct installation and appropriate quality checks (interlinked with a help function and the info tool), correct commissioning and function
- provides general, user and project specific checklists (for the case where self-inspection is not yet feasible or is not meaningful) and guidelines for quality checks and
- produces reports on the executed quality checks.

The created reports on the quality checks, videos, photos can be taken as proof and documentation of implementation. They may also be linked with the bill of quantities, time management, and may act as supporting documents for an invoicing tool.

Requirement of VCMP for the in-use stage

In the in-use stage, access to as-built documentation, maintenance and monitoring are the core requirements. These are in detail:

As-built documentation (is provided by BIM and linked programmes) includes:
- as-built drawings, as-built energy calculation, as built specifications
- technical manuals
- building permit and related documents
- final acceptance documents
- geodetic measurements

The sub app ‘maintenance’ could include:
- a maintenance plan interlinked with time management and documentation
- warnings when maintenance is due
- contact data of involved companies

The sub app ‘monitoring’ could include:
- monitoring plans
- a data collection app (interlinked with data logging systems)
- plausibility checks with warnings if systems are not running as desired
- the documentation of adaptation of building control
- the provision of access of users to simplified data collection and simplified plausibility check for the specific area of the users
- involvement of users incl. feedback to check if the systems are running as planned and to collect information if the kind of usage has changed and subsequently the energy consumption

VCMP requirements for the in-use stage:

In the in-use stage there are three topics which are proposed that the VCMP deals with

Access to the comprehensive as-built documentation

Monitoring the performance of the building and execute automatic plausibility checks

Support the maintenance process

4.5 Integrated Project Management (IDDS, IDP, IPD, Lean)

Different advanced construction management methods are briefly explained below:

Integrated Design and Delivery Solutions (IDDS)

> Integrated Design and Delivery Solutions use collaborative work processes and enhanced skills, with integrated data, information, and knowledge management to minimize structural and process inefficiencies and to enhance the value delivered during design, build, and operation, and across projects.

Source: http://www.nist.gov/el/upload/IDDS_White_Paper-1owen2.pdf

This definition makes it clear that collaborative processes across all project phases are key elements of IDDS (Integrated Design and Delivery Solutions). Bringing together all information and knowledgeable persons including the occupants, ideally contractually tied to the same overall project goal. Integrating the team in the construction project at a very early stage avoids unnecessary reviews of the design and saves time and costs. Typically the IDDS covers the entire lifecycle from the preliminary design (conception) through the design, implementation, operation and recycling, and is computer aided. Building information modelling (BIM) based on the Industrial Foundation Classes (IFC) is an ideal tool for supporting the integrated processes (ref. IDDS_White_Paper-1owen2.pdf). The interlinkage with BIM reduces design errors (collision check), visualises functional requirements and can provide location-related information about design details or implementation expertise (knowledge management) and provides also documentation possibilities (e.g. as-built documentation). It facilitates improved communication between the involved stakeholders. With BIM and related programmes, IT tools are available which have the potential to close the gap in good communication.

LEAN construction

Lean construction[12] was developed from lean production in the Japanese automobile industry, which was particularly developed by Toyota. However the conditions in the building construction industry are greatly different from the automobile construction industry, which is mass production at a fixed and defined location. Building projects are almost always pilot projects which are unique and have not been realised previously. Exact repetition is possible only in very rare cases. The construction site is unique for each project. This is another big difference to the mass production of automobiles. However principal approaches can be transferred if these are adapted (Gehbauer, 2011, Lean management in the construction industry). Core values of the lean

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[12] Source: Wikipedia: Lean construction, 17, July 2015

process are client orientation, reliability, responsibility, transparence, trust, cooperation, skills, striving for 0 errors, smaller work packages, etc. Typical for the lean process is 'Just in time' and the continuous improvement process (CIP) (= in Japanese language KAIZEN).

Because construction does not take part in a production line and the Toyota principles cannot be transferred 1:1, the Last Planner System was developed[13] (e.g. involving the facility managers already in the design) Source: (Gehbauer, 2011, Lean management in the construction industry in German language)

Lean construction is a "way to design production systems to minimise waste of materials, time, and effort in order to generate the maximum possible amount of value," (Koskela et al. 2002[1]). Designing a production system to achieve the stated ends is only possible through the collaboration of all project participants (owner, A/E, contractors, facility managers, end users) at an early stage of the project. This goes beyond the contractual arrangement of design/build or constructability reviews where contractors, and sometimes facility managers, merely react to designs instead of informing and influencing the design (Abdelhamid et al. 2008).

Source: Wikipedia: Lean construction, 17, July 2015

Integrated Project Delivery (IPD)

The information below is taken from the IPD_guide_2007.pdf of the AIA national/AIA California Council, the American Institute of Architects:

Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practice into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste and maximize efficiency through all phases of design, fabrication, and construction.

Integrated Project Delivery promotes a change in the culture of the construction business. Further citing the IPD guide of the American Institute of Architects:

Technological evolution coupled with owners' on-going demand for more effective processes that result in better, faster, less costly and less adversarial construction projects are driving significant and rapid change in the construction industry. Envision a new world where…

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[13] The Last Planner System consists of 5 stages which are related to each other and which are effective in their entirety: Stage 1 Overall schedule, Stage 2: Scheduling of details like windows to a specific group of activities, Stage 3 Preview planning to identify and clarifying barriers, Stage 4 Detailed planning (production planning), Stage 5: evaluation, learning and improvement

(Source: Gehbauer_2011_Lean management in the construction industry, basics)

… facility managers, end users, contractors and suppliers are all involved at the start of the design process

… processes are outcome-driven and decision are not made solely on a first-cost basis

… all communications throughout the process are clear, concise, open, transparent, and trusting

… designers fully understand the ramifications of their decisions at the time the decisions are made

… risk and reward are value-based and appropriately balanced among all team members over the life of a project

.. the industry delivers a higher quality and sustainable built environment.

IPD seeks to break down the traditional separate silos of responsibility of the participants. It focuses on achieving shared goals, not to say that IPD participants do not have separate work scopes for which they are primarily responsible. But there are overarching shared goals of the project.

IPD integrates BIM as one of the most powerful tools supporting IPD. BIM provides a platform for collaboration throughout the project's design and construction. The owner may use BIM to manage the facility well beyond completion of construction (section 4.1.4, page 10 of the guide mentioned above). On page 20: …integrated project delivery and BIM are different concepts…..the full potential benefits of both IPD and BIM are achieved only when they are used together. Thus, the IPD phase descriptions included here (auth.: in the guide) assume the use of BIM.

Integrated Design Process (IDP)

The following information is taken from the Integrated Design GuideENG.pdf by Alex Zimmerman, A.Sc.T. It originated in Canada in the early 1990s. It describes a more holistic approach to building design which is

- *Inclusive* – it involves everyone, from the owner to the operator early on in the design stage.
- *Collaborative* – the architect is not simply the form-giver, but leader of a broader team of collaborators earlier in the process (author: than in the traditional approach)
- *Holistic* – it is based on the thinking that the whole is greater than the sum of its parts, even more economical.
- *Whole-building budget setting* – money is spent where it is most beneficial when a holistic solution is found.
- *Iterative* – it allows for new information in order to inform or refine previous decisions
- *Non-traditional* – expertise exists in the team as needed, or is brought in at non-traditional time to contribute to the process

The IDP process seeks to reduce site impact, reduce off-site impacts, such as storm water runoff, greenhouse gases or other emissions, reduce energy and water consumption, improve indoor environmental quality and thermal comfort, contribute to human health, increase construction waste redirection and recycling, re-use materials and recycled content, improve durability, longevity and maintainability.

A facilitator, mostly the design architect, allows the team participants to do what they do best – in this case, a green design. The aim is to invite all specialists and also representative of user groups and the facility managers to contribute to the improvement of the design at a very early stage.

The IDP process is divided into the following steps:

- Predesign 1 – Staging the project,
- Predesign 2 – Management and mapping of the goals.
- Design process – System optimisation,
- Construction and operation – realising the objectives

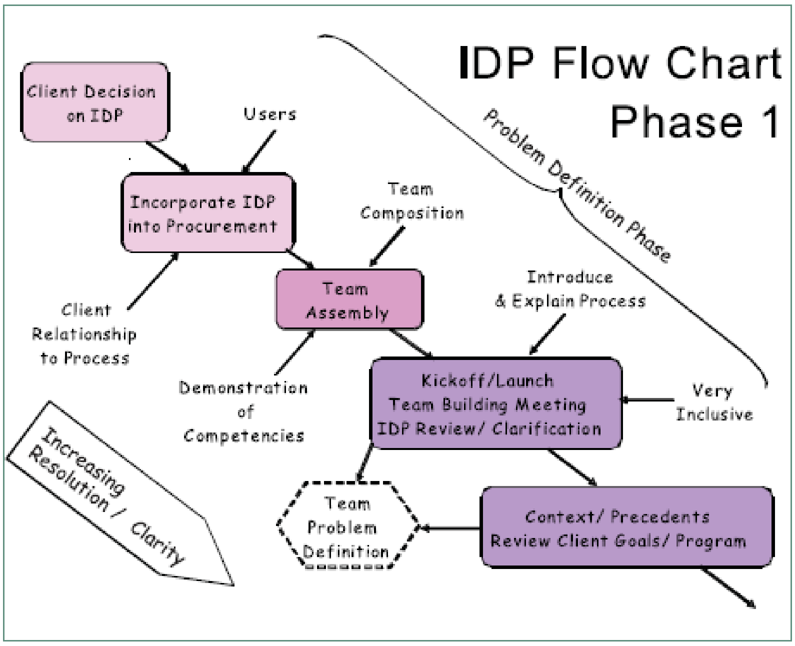

Figure 7 – Toronto IDP Workshop Approach – Phase I

Conclusions

The practical involvement of the team is very similar in all 4 approaches. Only the IPD clearly requires shared responsibility of the team. BIM is mentioned in IDDS as an integral part and in IPD as a powerful tool for the IPD process.

The elements of a continuous improvement process, collaboration, and trust in each other actually come from LEAN construction, but are integrated as basic elements into all approaches. They can be assessed as typical and common for the described advanced construction management tools, differing from the traditional process.

Real development can be found in the IPD and IDDS (however a more detailed guideline for the IDDS was not available). The entire project team works towards a single goal and is responsible, also in the contractual sense, for reaching the goal. Keeping BIM in view, there is the chance of an evolution, if not to say revolution, of the entire construction industry's approach towards quality and saving resources.

In reality, experienced site supervisors frequently claim that they are already working according to LEAN or IDP principles. Indeed, the early cooperation and integration of experts in the conception and design process has progressed over the last few decades. However, systematic feedback on the reason for mistakes is not collected and the clear rule that an upcoming task must be understood 100 % by all involved parties before the implementation work starts is not followed rigorously. A change at this point would be a major step forward in reducing the performance gap.

Experience in practice

During the IEE co-funded project PassREg, the Dutch group 'DNA in de bouw[14]' experimented with a new approach for organising construction work. They followed the so-called 'scrum team' approach called 'Agile working' which actually comes from IT developments. If one looks more closely, we find that it is based on the LEAN and Last Planner system (each of the work units = 'sprints' is small, and the work to be done needs to be fully understood before starting work, so-called 'stand-up meetings' lasting 15-minutes take place regularly, the client's wishes have the highest priority), but it also integrates the most important element from the other approaches mentioned above (IDP: all the experts are involved at a very early stage, IDDS: BIM is an integral part, with IPD the teams are contractually tied to the project goals[15]).

For more details, reference is made to the article on scrum teams[16] in the Solution open Source[17] which was created within the PassReg[18] project.

Working in 'scrum teams' requires trust in each other and working together. DNA states that this is the crux of the transition from the current contracting culture and such a change in the traditional company culture cannot be achieved in a single day (citation from SOS article on scrum teams (see footnote).

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[14] DNA in de bouw = De nieuwe aanpak in de bouw (Dutch) = The new approach (Engl.)

[15] DNA started with 'no contracts', but in the meantime a certain method of contracting has been introduced.

[16] http://passregsos.passiv.de/wiki/Scrum_team

[17] http://passregsos.passiv.de/wiki/PassREg-Solutions_Open_Source

[18] http://www.passreg.eu/

Influence of IPD, IDP, IDDS and LEAN on workflow of VCMP

The integrated project management approach is characterised by its consistent inclusion of the experts involved in the construction project at a very early stage. The approaches differ slightly from each other with respect to this integration. The newer approaches (IPD and IDDS) already have BIM in view. As a consequence for the workflow, the VCMP will have quality checks in the general pool which aim at the early integration of technological experts and future building users and the availability of technical expertise even if the building is already in use. Good communication will also be facilitated by the VCMP and moreover communication itself might also be covered by quality checks. However the VCMP cannot and does not want to dictate a specific kind of contract between the investor, the designers and experts and the construction company. It will be flexible enough to be used for all kinds of contracts.

4.6 Energy Efficiency Quality Checks

One overall goal of the Built2spec project is the reduction of the performance gap by 50 %. The following section provides an overview of most important energy efficiency quality checks and will be detailed during further development.

BASICS

Information regarding the boundary conditions for a project are obtained in the BASICS phase and the planning objectives are specified during this phase. The energy-relevant legal requirements for the building are compared with the energy-relevant requirements of the desired certificates. This activity directs the project towards the energy-relevant objectives at an early stage.

Quality checks relating to energy efficiency includes the following questions:
Which energy standard is the legal requirement?
Which energy standard is desirable? Has sufficient information been collected?
What kind of renewables are the most suitable for that location?

FIRST DRAFT

In the FIRST DRAFT phase, the requirements relating to use, design and energy efficiency decided in the previous phase are transferred into a draft. The space allocation programme is implemented and the architectural design, building construction and structure, and the rough concept for the building services are selected. The insulating envelope and the building services are defined with regard to the energy-relevant requirements. Not only energy-efficient construction aspects are considered but also the economic, ecological and buildability aspects are taken into account. In the process, an energy balance is created and the results are checked and compared with the selected requirements. This can be an iterative design process with several repetitions.

Quality checks relating to energy efficiency include the following questions:

- Have the energy-relevant boundary conditions been fulfilled?
- Has the concept for the insulation of the building envelope been developed and checked?
- Is a rough concept for the building services available?
- Has the heating demand limit been complied with?
- Has the cooling demand limit been complied with?
- Does the rough concept for the generation and use of renewables meet the requirements?
- Have the certification objectives been met?
- Has information about the impact of decisions on energetic performance been shared within the team including the investor?

DETAILED DESIGN

The façade with walls and window elements, the roof with its assemblies and the foundations as a thermal insulating envelope area are developed further. The wall build-ups are elaborated on a basic level of detailing; the absence of thermal bridges and airtightness and wind-proofing are checked. A concept for night-time ventilation in summer is also developed.

The building services system elements for heating, cooling, hot water, ventilation and lighting are specified and dimensioned. Any irregularities will become apparent in this phase and will be eliminated. The energy-relevant overall balancing of the building by the PHPP supports the work and checks the outcome. At the end of the detailed design, it is checked whether the energy-relevant and other boundary conditions of the first draft are still complied with.

Quality checks relating to energy efficiency include the following questions:

- Have the main boundary conditions of the preliminary draft been adhered to?
- Has the impact of the structural design on the insulation layer, the airtightness layer and the energy balance calculation been considered?
- Have the insulating envelope and the airtight layer been completed and correctly designed?
- Have the essential connections and joints been elaborated correctly with regard to thermal bridges and airtightness?
- Have technical solutions been worked out for all details relating to energy consumption, airtightness, vapour and humidity transport? Has the buildability been checked?
- Is the solar protection and night ventilation concept adequate for avoiding overheating?
- Have the technical components for heating, cooling, ventilation, domestic hot water and renewable energy been checked with regard to energy efficiency, availability on the market for a reasonable price, incorporation in the design, noise protection and other aspects of pollution? Have all electric appliances been considered in the energy calculation?
- Are the drawings and the energy balance calculation consistent?

- Is the data that has been entered into the energy balancing tool correct, plausible and realistic? Are the data and the outcomes complete, plausible and free of errors?
- Have the requirements of the energy certificate still been met?
- Have all parties involved in the next stage been integrated adequately in the process so far and have the details been communicated?

IMPLEMENTATION DESIGN

The degree of detail of the different building components (foundations, roof, wall and window elements) is increased, particular emphasis is put on the detailing of the insulation, airtight and wind-proof layers. Detailing of the façade elements and the windows will lead to the definition of the openings for natural ventilation of the building and to details of the thermal insulation, window connections, façade anchors and other thermal bridges etc.

All elements of the construction and building services will be specified exactly and the energy balance will be updated accordingly.

Quality checks relating to energy efficiency include the following questions:

- Have the conditions of the detailed design been maintained during further development and are the technical requirements of energy-related characteristics and moisture transport still being adhered to?
- Is the construction free of the risk of condensation in the long term?
- Does the entire design as well as the U values of the selected materials and the joints match with the energy balance calculation? Are the inputs for U and psi values correctly calculated and entered?
- Have the critical details been noted? Have technical and easily buildable solutions been elaborated for all critical details?
- Have the principles of thermal bridge free construction been complied with? (Junctions, penetrations, change of materials or components, built-in units). Has buildability been checked?
- Is a concept for airtightness available with solutions for the critical details including windows, exterior doors, their junctions and all penetrations?
- Is the value for the airtightness of the building predefined? Does it match with the energy balance calculation?
- Does the final detailed building services concept meet the requirements of the investor and the future user? Are the assumptions for the energy balance calculation accurate? Have energy efficient solutions been chosen?
- Is overheating prevented sufficiently? Are the renewables correctly incorporated in the energy balance calculation? Is the energy balance calculation updated?
- Do the results still meet the energy-relevant requirements?
- Were the construction teams sufficiently involved in the design process?
- Have critical details relating to energy performance been adequately communicated to the procurement team and the construction teams?

BUILDING APPLICATION

A complete energy balance calculation which is consistent with the other documents must be provided for the building application. The results of the energy balance must comply with the legal requirements.

Quality checks relating to energy efficiency include the following questions:

- Are the documents complete in accordance with the requirements?
- Are the drawings, description and the energy balance consistent with one another?
- Have the legal requirements for the energy consumption been complied with?

SPECIFICATIONS, TENDERING AND CONTRACTING

In the specifications, the elements of the planning are described in detail so that the contracting companies can submit an unequivocal quote which can be compared with other bidders. When preparing the specification of services, it should be ensured that all parameters that are essential for implementation have been fully stated and that all documents are consistent. The tendering companies will check the current planning and can provide alternative solutions. They may elaborate production plans which will adapt the planning documents to the upcoming construction process. Amendments will be cross-checked in the energy balance calculation.

Quality checks relating to energy efficiency include the following questions:

- Are all documents updated and consistent? Do the specifications match with the design and the energy balance calculation? Do the specifications contain up-to-date requirements and complete and correct trade specifications?
- Are all details relating to energy efficient construction and airtightness technically correct described and incorporated in the specifications?
- Is the procurement team sufficiently informed about the critical criteria relating to energy performance?
- Has the responsibility for energy performance been contracted adequately?
- Is the soft-landings approach (or similar) included in the contracts?

IMPLEMENTATION AND ITS SUPERVISION

In the quality checks during construction, it will be checked whether the specifications in the planning, the technical rules, manufacturers' specifications and the latest technological standards have been complied with. With reference to energy efficiency, this applies to the thermally insulating and airtight envelope area enclosing the building and the energy related aspects of the building services components. Particular attention will be given to ensuring that the materials and components possess the required properties and that they are installed in accordance with the requirements, that planned residual thermal bridges are implemented according to the requirements and that no additional unplanned thermal bridges are produced and additional energy consumption is not caused by any changes. The drawings and energy balance calculation are updated according to the actual implementation.

Quality checks relating to energy efficiency include the following questions:

- Are all documents, drawings, specifications, energy balance calculation etc. consistent and updated and adequately detailed? Are the details technically correct and buildable?
- Is all information including installation guidelines available on site? Have the critical details been adequately communicated?
- Is the construction team sufficiently trained with regard to energy efficient and airtight construction?
- A variety of applied quality checks ensure that the geometry, material properties, position, installation, commissioning and function of building components, the insulation and the airtight materials are in accordance with the design, the energy balance calculation and the specifications. The applied quality checks ensure that no additional thermal bridges are produced. The final question is if all quality checks related to the above mentioned aspects been passed?
- Has the targeted airtightness value been achieved?
- Is the design team available for questions if issues arise?
- Are changes with an impact on energy performance carefully carried out and assessed?
- Are all design documents and the energy balance calculation updated with the as-built information?

COMMISSIONING AND HAND-OVER

A small part of the checks relates to operation of the mechanical elements of windows and doors. The majority of checks relate to building services elements of the heating, cooling, hot water, ventilation and lighting systems which consume a lot of energy. Attention will be given to ensuring that adjustment of the components takes place with care and in accordance with the planning specifications. The same applies for elements that produce energy.

Quality checks relating to energy efficiency include the following questions:

- Are all as-built drawings and information (user manuals, building control set-up) and energy balance calculation available?
- Has commissioning been carried out with care and under consideration of the users' needs?
- Have the client and users been adequately informed about how to operate the building?
- Has a process of second commissioning or soft-landing or similar been put in place?
- Has an adequate metering strategy been put in place?

IN-USE

Besides maintenance of the system on a regular basis and checking whether the systems function without problems and in accordance with the planning specifications, the energy consumption values for heat and cold, electricity, water are regularly checked for plausibility during operation and compared with the calculations. This necessitates structured data collection.

Quality checks relating to energy efficiency include the following questions:

- Are the metered energy consumptions of the components plausible and within the expected range?
- Are the building users sufficiently trained about the use of the building?
- Is it ensured that the building control adaptations are correctly recorded?
- Is it regularly checked whether the building systems are running according to the user needs?
- Has a system for feedback to the design team and the engineers been installed?

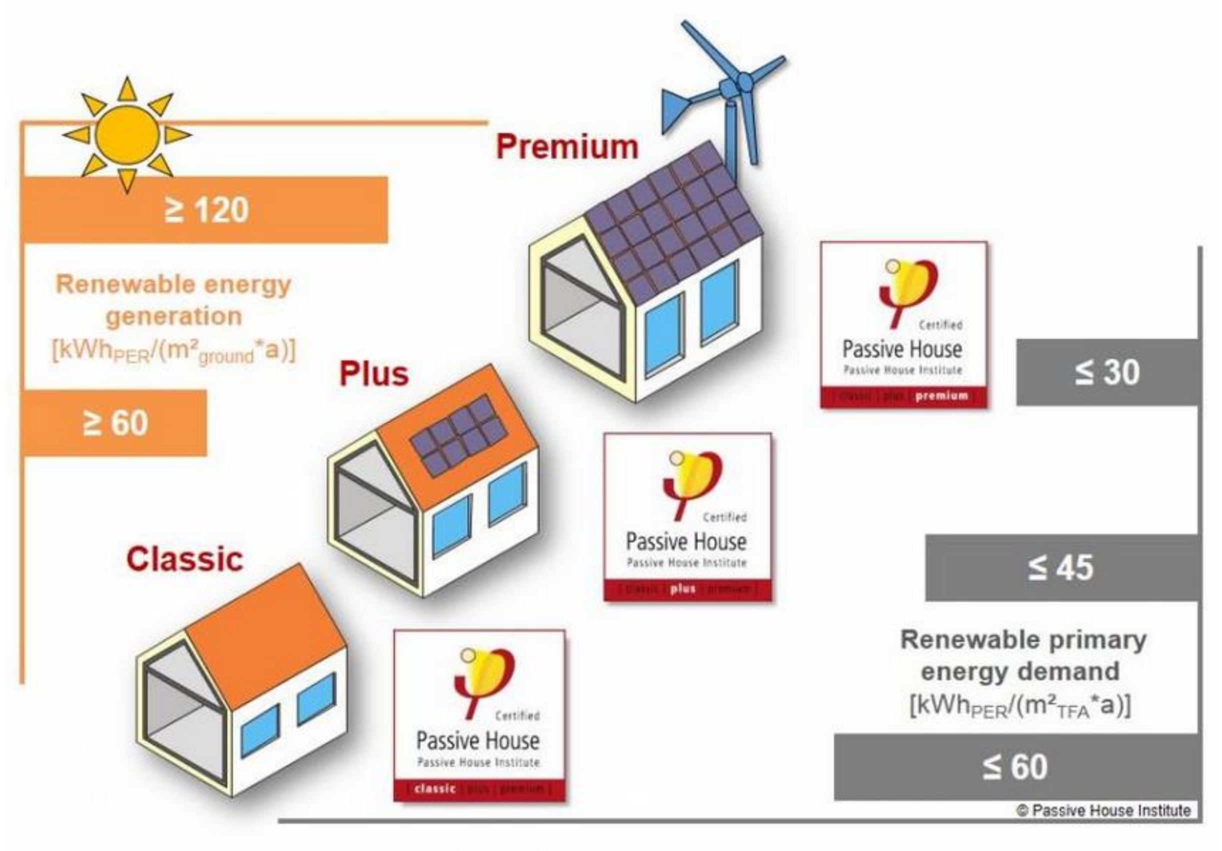
4.7 Certification schemes integrated in the VCMP

4.7.1 Passive House Certification

Quality assurance for Passive Houses is essential to achieve the desired thermal performance of the building and to avoid a performance gap subsequently. Quality assurance for a certified Passive House follows a 3 step approach.

The "first step" takes place during the planning phase. The designer involves the certifier and submits the planning documents and the PHPP calculation (PHPP = Passive House Planning Package) so that Passive House suitability can be checked. During the construction work, the site supervisor conducts the required site inspections and checks the quality of the work in order to ensure that it is executed as planned.

The quality checks during the first step are firstly related to the overall performance of the building: are the climate data correct which are inserted in the PHPP calculation Have the overall performance criteria been met? Roughly: for the ***Passive House Classic,*** a heating and cooling demand that is less than 15 kWh/m² year, or a heating and cooling load that is below 10W/m², primary energy use less than 60 kWh/m²a (PER). The primary energy is assessed using a system of factors called PER (renewable primary energy) based on the vision of 100% sustainable supply with renewable energy. The PE factors which are still common in the member states can be used in a parallel calculation. The more advanced classes ***Passive House Plus*** and ***Passive House Premium*** require noticeably higher energy generation from renewable sources.



Secondly, the energy calculation with the PHPP is compared with the drawings. Is the planned envelope in the drawings the same as that calculated in the PHPP? Is the airtight layer properly planned? Are thermal bridges avoided as much as possible? Are they correctly considered in the energy balance calculation? Are the windows suitable and has sufficient shading been foreseen for avoiding overheating? Has the heating, cooling and energy generation system been entered correctly? Will white goods and other appliances with a high level of energy efficiency be used? If the certifier is involved early enough, he can give additional tips for optimising the energy performance of the building.

Thirdly, for Passive House certification, the site supervisor must check and guarantee with his signature if the quality of the executed work during the construction phase, particularly in relation to energy efficiency is executed according to the drawings: has the insulation been correctly delivered and installed? Have the junctions been correctly implemented as designed? Have thermal bridges been avoided as planned? Have the residual thermal bridges been implemented as designed and have unplanned thermal bridges been ruled out? Has insulation of components including the pipes been carried out as required? Have the windows been delivered and installed as planned? Is the shading system available as designed? Is the airtight layer without any gaps and are the junctions correctly taped? Is the air exchange rate n50 at under pressure less than 0.6h-1? Have the building services elements and the building equipment been installed correctly? Is the insulation of the pipes executed as required? Is the ventilation system and the building control correctly adjusted? Although not part of the actual certification process, it is important that the specifications undergo a quality check to see if the required components, insulation and other details are correctly described.

Fourthly, the updated PHPP calculation and drawings based on the actually executed work are submitted to the certifier. He examines the updated PHPP calculation and the documents. The certifier will issue the certificate if the requirements are met.

More details on “Passive House Basics” can be found on Passipedia:
http://passipedia.org/basics
Information on PER factors and the new classes can be found here:
http://passipedia.org/certification/passive_house_categories
Information on Passive House certification and "Quality approved Certified Passive Houses" can be found here:
http://passipedia.passiv.de/passipedia_en/construction/quality_assurance Passipedia: Quality Assurance

It is worth mentioning that corresponding certificates for refurbishments and for buildings with mostly interior insulation are also available.

More details on EnerPHit certification are available here:
http://www.passipedia.org/_media/picopen/phi_building_criteria_draft.pdf

4.7.2 BREEAM

BREEAM, first launched in 1990, is an internationally recognised environmental assessment method and rating system for buildings. The method covers a wide range of sectors at the design and post construction stage. It asks whether an applicable building project satisfies certain predefined qualitative as well as quantitative environmental criteria and to what level.

Ratings are awarded where an assessment score falls between certain thresholds resulting in either an ‘unclassified’, ‘pass’, ‘good’, ‘very good’, ‘excellent’ or ‘outstanding’.

BREEAM In-Use is a scheme to help building owners, managers and occupiers reduce the running costs and improve the environmental performance of existing non-domestic buildings. It consists of a standard, user friendly assessment methodology and an independent certification process that provides a clear and credible route map to improving sustainability credentials of existing buildings.

The current version – BREEAM UK New Construction – covers issues under the topics of Management, Health and Wellbeing, Energy, Transport, Water, Materials, Waste, Land Use and Ecology, Pollution and Innovation. Within these topics credits can be awarded for the following checks and inspections:

- Commissioning of building services and building fabric, covering air tightness and thermography
- Aftercare – seasonal commissioning and post occupancy evaluation
- Inspections carried out during the construction phase
- Indoor air quality – testing and analysis

Further information about BREEAM is available at http://www.breeam.org/

4.7.3 Code for Sustainable Homes (CSH) and Home Quality Mark (HQM)

Up until recently the Code for Sustainable Homes (CSH) was used for assessment of domestic buildings in the UK. The CSH was an environmental assessment method for rating and certifying the performance of new homes based on BRE Global's EcoHomes scheme. It was a Government owned national standard intended to encourage continuous improvement in sustainable home building.

The Government carried out a Housing Standards Review, which aimed to simplify government regulations and standards into one key set, driven by Building Regulations. As a result, in 2015 the Code for Sustainable Homes was withdrawn and therefore no longer required as a planning condition for new approval.

Following the recent government review of housing standards, BRE has developed a new voluntary sustainability standard for new homes - the Home Quality Mark - that aims to allow developers to differentiate their product in the marketplace by recognising performance beyond minimum regulation and provide increased quality and choice for the consumer. The scheme is designed and developed for new build housing in the UK.

The consultation[19] guidance for the Home Quality Mark (HQM) came out in July 2015, with 4th September as the deadline for response. The final version of the standard is expected towards the end of 2015.

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[19] http://www.homequalitymark.com/filelibrary/Technical%20consultation/HQM-July-2015-TechnicaL-consultation-Final.pdf

The Home Quality Mark is expected to be structured in sections, categories and issues. The three sections are ‘Our surroundings’, ‘My Home’ and ‘Knowledge Sharing’ and the categories and issues are presented below. The benefit (in terms of improvement or quality to the building) has been identified for the relevant issues.

Credits under each issue are awarded based on evidence provided an assessor. Weightings are applied to determine the final result.

Home Quality Mark structure and associated quality checks

Sections	Categories	**Issues**	**Notes regarding the aim of the issue and quality checks required as part of HQM,**
Our surroundings	Site context	Land issue and visual impact	
		External spatial design	
	Movement & connectivity	Accessible public transport	
		Alternative sustainable transport	
		Local amenities	
	Outdoors	Ecology review	
		Maintaining and enhancing ecological value	
		Ecological management	
		Growing space	
		Recreational space	
	Safety and resilience	Flood risk	
		Managing the impact of rainfall	
		Security	
My Home	Energy	Energy performance and cost	To improve energy performance and reduce costs associated with the running of the homes and

			encourage increased rigour in calculating these
		External lighting	
		Low and zero carbon technologies	
		Impact on local air quality	To promote the use of the most efficient heating and hot water generation appliances and to minimise their impact on local air quality.
	Comfort and health	Indoor pollutants	
		Daylight	
		Loss of daylight to neighbouring dwellings	
		Sunlight	
		Internal and external noise	To reduce noise disturbance to occupants and people in outdoor amenity areas by promoting low levels of sound from external noise sources and building services.
		Sound insulation	To reduce noise disturbance by promoting good levels of sound insulation between neighbouring homes and different rooms within the homes. Criteria requirements includes a programme of pre-completion testing by a compliant test body or all relevant building elements registered, and performance of the constructions used to form internal partitions and floors.
		Temperature	To evaluate a home's risk of overheating early in the design, and give occupants tools to

			operate their home at the preferred temperature
		Ventilation	
	Materials	Environmental impact of materials	
		Life cycle costing	
		Durability and resilience	
		Responsible sourcing	
	Space	Drying space	
		Dwelling space	
		Recyclable waste	
	Water	Water efficiency	
		Water leak isolation	
Knowledge sharing	Home delivery	Commissioning and fabric testing	To ensure that homes and the systems within them are performing as intended at completion by encouraging thorough testing and commissioning throughout the development process. A total of 13 credits are available – 7 for commissioning and 7 for fabric testing
		Awareness and training	To increase awareness of the issues that result in the 'performance gap' and promote training that minimises this
		Communication	To promote meaningful collaboration, communication and management between stakeholders throughout the whole development process, in order to meet the desire performance targets – criteria assessment includes project delivery team

			consultation, HQM assessor, Sustainability champion
		Construction energy	
		Construction water	
		Considerate construction	To promote the environmentally and socially considerate, and accountable management of construction sites – a credit awarded for best practice (commitment to meet best practice under a nationally or locally recognised certification scheme such as the Considerate Constructors Scheme) and 2 credits for going significantly beyond best practice
		Waste arising	
		Diversion from land	
	User experience	Aftercare	To provide aftercare support during early occupancy of the home, in addition to the provision of construction warranties , to help occupants resolve any problems and get the most out of their new home
		Home information	To provide occupants with useful accessible information that helps them to get the most out of their home and engage with local environment and community.
		Monitoring and controls	Aim of this issue to is encourage efficient use of dwelling systems and services through the installation of monitors and controls that are user-friendly
		Post occupancy evaluation	Post occupancy evaluation and home performance data

It is expected that each issue within the HQM with be structured in terms of the aim, benefits, context (which will outline why the issue is relevant and the development of quality homes in sustainable communities), issue summary, assessment criteria, compliance notes, evidence (this will outlines examples of the type of information that must be provided by the developer and given to the Home Quality Mark assessor), additional information and appendices.

Further details about Home Quality Mark can be found at http://www.homequalitymark.com/

4.7.4 LEED

Developed by the U.S. Green Building Council (USGBC) in the early '90, Leadership in Energy and Environmental Design or more simply **LEED** (http://www.usgbc.org/), is a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighbourhoods; that is LEED is a certification program and globally recognized benchmark for the design, construction and operation of high performance green buildings. In other words LEED redefines the way we think about the places where we live and work providing building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions. It serves as a market-driven tool and third-party verified standard of sustainable design and operation across the entire building lifecycle.

From early '90 to now, LEED grew from a simple standard dedicated to new constructions to a more complex system of standards able to cover all the aspects related to development and construction process. Indeed nowadays LEED certification is so to be applied to all building types: commercial, residential, entire neighbourhood communities and works, throughout all the building lifecycle from design to construction, operations, maintenance and retrofit.

With reference to "LEED v3 - 2009 certification[20]" five rating systems categories are identified (Fig.:):

- **LEED Building Design and Construction (BD+C)**: *New Construction, Core & Shell, Schools, Retail, Healthcare, Data Centers, Hospitality, Warehouses & Distribution Centers, Homes, Multifamily Midrise.*
- **LEED for Interior Design and Construction (ID+C)**: *Commercial Interiors,, Retail, Hospitality*
- **LEED for Building Operations and Maintenance (O+M)**: *Existing Buildings, Data Centers, Warehouses & Distribution Centers, Hospitality, Schools, Retail*
- **LEED for Neighbourhood Development (LEED ND)**: *Plan, Build Project*
- **LEED for Homes (LEED HOMES).**

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[20] NOTE: LEED v4 will be mandatory after Oct. 31, 2016 - http://www.usgbc.org/articles/usgbc-announces-extension-leed-2009

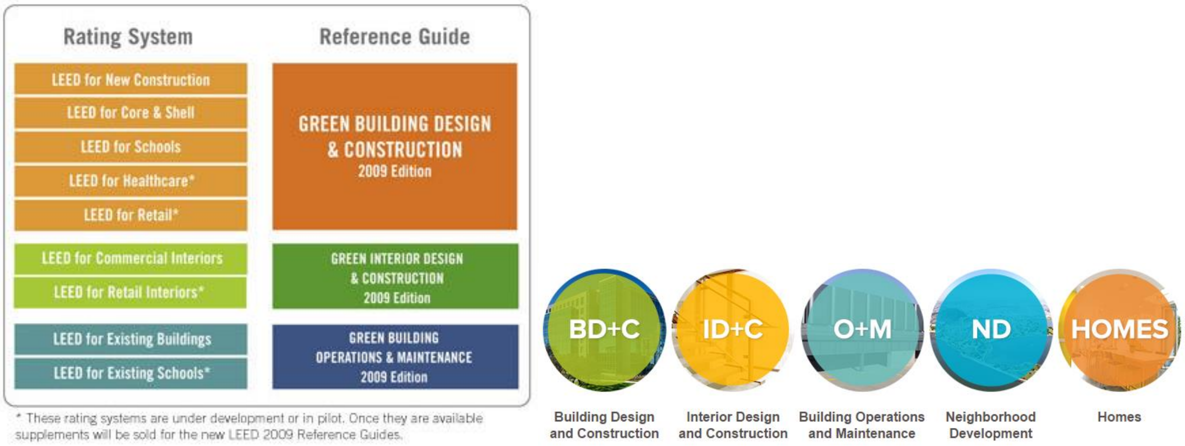

Fig.: LEED sections.

In general LEED certification process requires applying for **LEED credits**. This performance credit system aims to allocate points based on the potential environmental impacts and human benefits of each credit as better established in the user guide (Fig.:). Each of the performance categories also ha mandatory measures in each category, which receive no points. All the process has to be held managed and chaired by an accredited professionals – i.e. **LEED Accredited Professional (LEED AP)**.

Other stakeholders involved into LEED process are:

- Owner
- Architectural Designer(-s)
- Structural Designer(-s)
- Plant Designer(-s)
- Contractor / Sub-contractor(-)
- Building materials supplier
- Worksite Director(-s) and Inspector(-s)
- LEED Certification Body

About the certification, four levels are provided (Fig.:):

- Certified: 40–49 points
- Silver: 50–59 points
- Gold: 60–79 points
- Platinum: 80-110 points

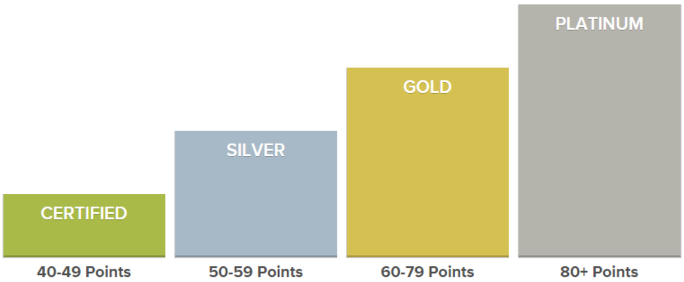

Fig.: LEED rating scale and affiliation images.

A fundamental prerequisite has to be guaranteed to participate in LEED that is a building must comply with environmental laws and regulations, occupancy scenarios, building permanence and pre-rating completion, site boundaries and area-to-site ratios. Its owner must share data on the building's energy and water use for five years after occupancy (for new construction) or date of certification (for existing buildings).

The more involved stakeholders during the LEED certification are the Designers, The Yard and Worksite Directors, Building material suppliers, the LEED Accredited Professional and Certification Body. The certification process involves many steps and the main quality checks regard the compliance with the Certification Body requirements (e.g. plans, techs info, material datasheets, drawings, materials need,…). The process could be facilitated by using B2S VCMP since all the information could be easily managed into the platform.

LEED recently launched API authorisation – this could be really useful to interface (if possible) B2S VCMP with LEED platform.

More information at: **http://www.usgbc.org** and **http://www.usgbc.org/automation.**

4.8 National specifics

In the following section the partners briefly introduce a selection of the regulatory framework conditions which influences the quality checks and the construction processes in their country.

4.8.1 Italy

The situation in Italy regarding the process around building permit and its approval involves different stakeholders and different public and private offices. Regardless the typology of the building it is mandatory to apply for a "building permit". Building must be built to the correct standards, which are laid out in the Local/National Regulations.

Summarizing the activities four steps can be individualised thus (Figure:):

- **design phase**: due by architects/engineers it regards the architectural, structural and plant design in which all the documents for obtaining the "Permesso A Costruire" will be provided, and all the details for building the construction on site;
- **project evaluation phase**: due by the government agencies. In this phase all the documents will be evaluated and modification and/or additions may become necessary. The project will fail if the documents don't comply with the regulations.
- **construction phase**: "built up the building" - due by construction company(-ies);
- **commissioning/handover phase**: final phase - evaluation of the whole process.

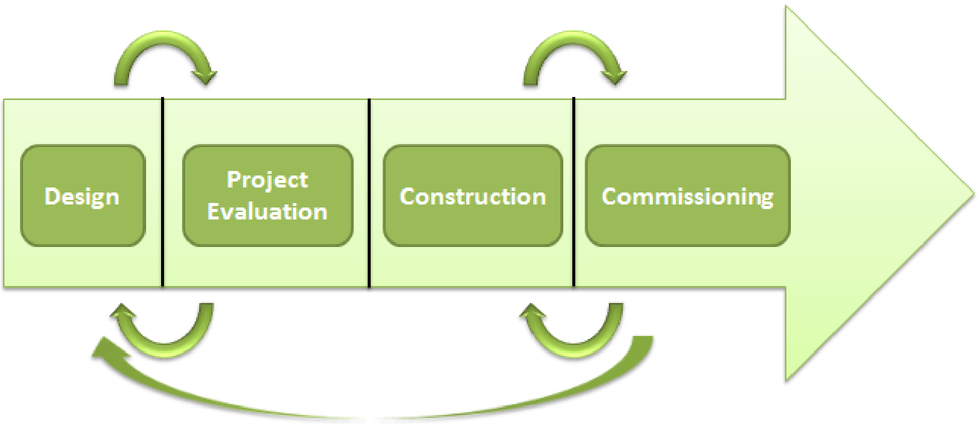

Figure: IBPs flowchart

A DESIGN PHASE

The **design phase** can be summarised into three stages:

- Basic design ("*Progetto Preliminare*") - the designer(s), i.e. architects(s) and/or engineer(s) considers the owner needs and compares them with the national and local standards and laws;

- Preliminary design ("*Progetto Definitivo*") – more detailed design. This document is used to apply for the building permit ("Permesso di Costruire"). The documents to be provided with the application for this permit are:
  - Architectural and structural design;
  - Heating and cooling design (so called “Legge 10”) – in general all the design plan;
  - Energy performance certificate (EPC);
  - Soil analysis report;
  - Safety design during construction;
  - Hygiene and health project environments;
  - Waste Disposal template;
  - Estimation of the costs and time schedule of the works;
  - “Wheelchair accessibility” – if needed;
  - Construction and demolition template – if needed;
  - Other additional document (e.g. archaeological heritage certification, ...) – if needed;

- Detailed/Final design ("*Progetto Esecutivo*")

B EVALUATION PHASE

In this phase all the documents provided in the design phase will be evaluated by several public authorities, each of them monitoring different aspects. We have summarised them into 2 macro-areas:

- *Local Authorities (e.g. municipality and/or district authorities;* structural safety department*)* – ensuring compliance of the design with the regulations relating to structural safety, energy consumption, spatial planning – e.g. is the plan in line with the zoning plans etc.)
- *Local Health Agencies* – ensuring compliance of the design with the minimum requirements in terms of rooms ventilation, quality of the air for particular building types (e.g. hospitals), size of the rooms based on their utilisation (e.g. minimum room height,…) and more. Within this, these agencies can be included the *Fire Department* ensuring the compliance of the design with the regulations for fire protection.

Modification and/or additions may be required. The project will be unsuccessful if the documents do not meet regulations.

The output of this stage is the “Building Permit” (in Italian “*Permesso a Costruire*”).

C CONSTRUCTION PHASE

Before starting the **construction phase**, several documents must be submitted to the responsible agencies:

- Building construction company data;
- Building permit ID;
- Construction starting date and presumed end date;
- Num. of workers employed during the work activities;
- Personal data of the safety coordinator, designer and inspector;
- Worksite director(s);
- Building designer(s) (architects, engineers,…)

In this phase the main agencies involved in the evaluation process are the *National Health Agencies (ASL; INAIL)* with the task of ensuring the health and safety in the workplace for the workers. A detail plan and design of the construction phase, in terms of time and related actions, must be included in the design for the final approval.

In 2004 a law was enforced by the Italian Government which requires all construction companies to have insurance cover which protects future building owners in case of damage due to construction errors or flaws for a period of 10 years after construction.

With this document the intent of the Government is to guarantee a higher quality standard and care during construction.

It is clear as the B2S VCMP would be a really useful tool in this context because with the VCMP construction companies will be able to demonstrate that a high quality of work was carried out and that the risks for future damage are minimised. This would allow construction companies to negotiate lower prices on the insurance policy with the insurance company.

D COMMISSIONING/HANDOVER PHASE

Represents the final phase of the process and corresponds to the evaluation of the whole process in terms of both “tests” (structural and plants) and “administrative” compliance with regulations and between the designed and the “as built”. It is conducted by private architects/engineers (different from the ones who designed the structure) who will check all the design documents (according to Italian regulation) and will conduct some test. If these tests are not satisfactory enough modifications and/or improvements can be required.

After the **commissioning/handover phase** owner can apply for “accessibility” (Italian “agibilità”). This document filled by the designer and signed by the owner show the compliance between “design” and “as built” (e.g. the thermal insulation has been designed and installed according standards, best practices,…).

It should be noticed when one needs to buy or rent a house the building owner (public or private authority such as construction companies or real estate agencies) has to provide the EPC and the “Decennale Postuma” document before formalising the sale or rental.

E CONCLUSIONS

Actually all the process presented here is almost totally paper based and dealt with “by hand”. As an example, starting from the lowest step of the process, the architect has to meet the client face-to-face and discuss with him/her his/her needs; then the architect has to integrate these needs into several design documents (e.g. reports, drawings,…) that demonstrate compliance with local, regional and national regulations (including EU codes and standard). All documents are submitted for approval to local authorities (e.g. municipality) and other special authorities that include the fire department and the structural safety department.

In conclusion, the direction in which Built2Spec is moving could have a huge benefit for the whole building process ensuring better information flow and therefore high quality end results.

4.8.2 France

In the case of the French context we observe strong similarities with what we can observe in others countries such as Italy or Spain in terms of procurement, design, construction or commissioning. However 3 major differences can be identified:

- Importance of the **“programming” phase**. The programming phase, when the “*Maître d’Ouvrage*” (owner or promoter) defines the main outlines and requirements of the project (surfaces, main objectives), seems to be carried out in a more formal way in France than in some others countries. As a consequence, in France it is considered as an integrant part of the construction project stages whereas in other countries it is not mentioned as a construction project stage but as a prerequisite.

- **Role of the architect**. In France the main architect often takes on several roles whereas in other countries different persons/entities would be involved. More precisely, the main architect is often both the chief designer, the tendering supervisor, and the main person responsible for the implementation of construction work (*Maître d’oeuvre*).

- **Architecture contest stage and design**. In some cases, especially for large public projects, the chosen procedure corresponds to an architecture contest, where several design teams are competitors. The selection is usually carried out after the outline design (*esquisse* stage), but sometimes more details are asked for, corresponding almost to more advanced stages of the design (*avant-projet*). Then one team is selected to go on with the detailed design.

Beyond these 3 considerations, we observe that implementing IDDS concepts involves a substantial change in the habits of the stakeholders. For example, the common legal framework of public construction projects usually implies a very sequential approach for the different design and implementation phases. That means for example that the choice of the design team that will be finally selected sometimes takes place once the design work is already well advanced. Developing a collaborative integrated approach in these conditions can appear much more delicate, especially if the project developer has to work simultaneously with several competing design teams! For these reasons, adopting the IDDS approach will be accompanied by sensible but necessary cultural changes in the French construction context.

4.8.3 Germany

Boundary conditions

A selection of German norms and regulations which are important for the building construction process are listed below:

German energy savings ordinance (EnEV)

Energy efficient construction has a long tradition in Germany which dates back to the 1980s. Currently the EnEV (energy savings ordinance) regulates the requirements for buildings with reference to their energy consumption. More stringent requirements will apply from 1.1.2016 onwards.

In the EnEV the main demand variable for new buildings is the annual primary energy demand compared with a reference building with identical geometry and dimensions and the given technical characteristics. Depending on the type of building, a limit value for the transmission heat loss based on the space enclosing surfaces must also be complied with in addition.

For the first time, the EnEV will stipulate the requirements for thermal protection in summer and allows the taking into account of solar heat gains.[21]

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[21] Source: Wikipedia EnEV (German language)

Another very important norm is the

DIN V 18599 Energy balances for non-residential buildings and special residential-use buildings

According to DIN V 18599, energy balances can be prepared for buildings. These follow an integral approach through collective assessment of the building structure, use and the system technology, taking into account their mutual interactions/interdependencies.

Construction of buildings/ maintenance of buildings

- Airtightness of the building / DIN EN 13829 - testing procedure for assessing the thermo-technical characteristics of buildings.
- Thermal bridges in the exterior envelope / taking into account in accordance with the main regulations in the EnEV with the associated DIN 4108 Supplementary Sheet 2 and further DIN norms.
- Geometric tolerances in above-ground construction are defined in the DIN 18202 for buildings, this specifies the minimum accuracies

Building application process (selection):

Proof of the following is required:
- Structural dimensioning/structural requirements
- Energy consumption less than EnEV requirements (see above)
- Fire safety concept / fire safety requirements for building components
- Proof of noise protection / Noise protection requirements inside the building and towards the outside
- Choice of ventilation system technology and dimensioning
- Geometric measurement of the building / corresponding with the building application documents

4.8.4 UK

The Building Act 1984 is the primary legislation under which the Building Regulations and other secondary legislation in the England and Wales are made.

Regardless of how well designed a home/dwelling is, it needs planning permission and must be built to the correct standards, which are laid out in the Building Regulations. It must be safe and structurally sound, from the foundations to the electrics, conserve energy and provide access for those with disabilities.

The Regulations are objective, unlike planning permission, and a dwelling will pass or fail according to this set of rules. UK Building Regulations set minimum standards for the design and construction of buildings to ensure the safety and health for people in or about those buildings. They are developed by the UK Government and approved by Parliament. These regulations apply to most buildings and include requirements to ensure that fuel and power is conserved and adequate access facilities to buildings are provided for people, including those with disabilities.

Building Regulations are regularly being updated, and consist of a number of parts. These include:

- Approved Document A (Structural Safety)
- Approved Document B (Fire Safety)
- Approved Document C (Resistance to contaminants and moisture)
- Approved Document D (Toxic substances)
- Approved Document E (Resistance to sound)
- Approved Document F (Ventilation)
- Approved Document G (Sanitation, Hot Water Safety and Water Efficiency)
- Approved Document H (Drainage and waste disposal)
- Approved Document J (Heat producing appliances)
- Approved Document K (Protection from falling)
- Approved Document L (Conservation of fuel and power)
- Approved Document M (Access to and Use of Buildings)
- Approved Document N (Glazing Safety)
- Approved Document P (Electrical Safety)
- Part Q (Security: Dwellings)
- Approved Document 7 (Workmanship and Materials)

The Regulations cover new buildings and extensions, but also major alterations to services, underpinning and some changes of use.

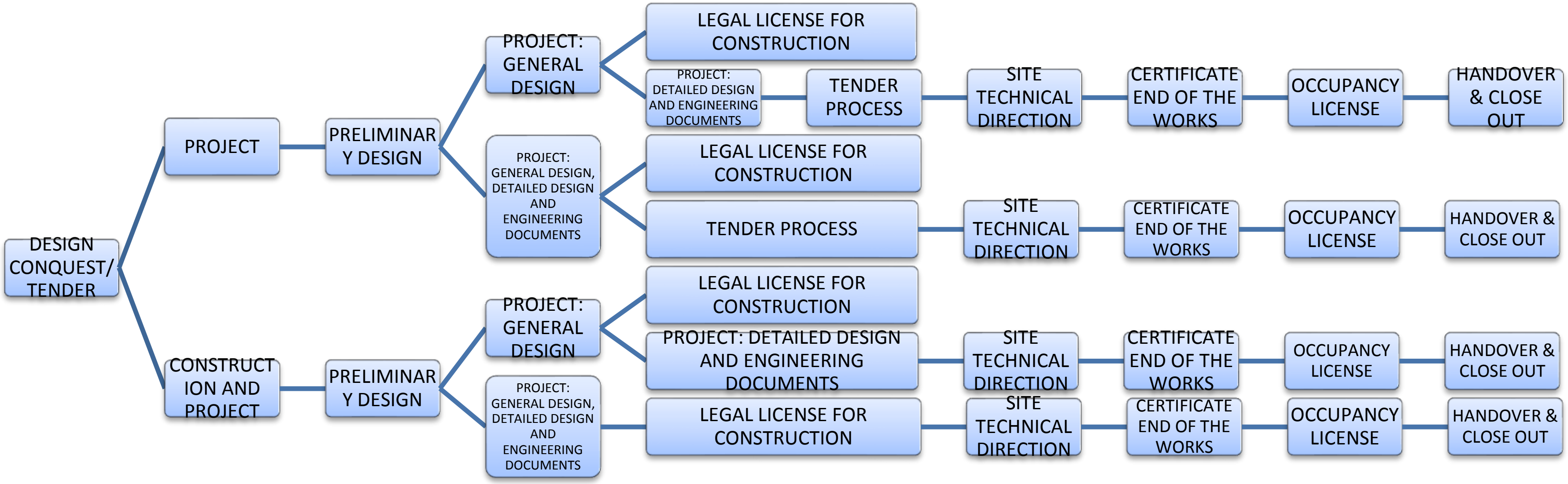
To obtain approval building control services of the local authority or an approved inspector is used. Building notice, which is a statement of the address and description of the work, giving building notice of intention to start work, must be created.

With both Building Regulations applications and building notices, building control will inspect the work to ensure compliance at particular stages. The inspector is notified when a particular stages has been reached, and gives 24 hours' notice for them to inspect the work.

When the project is finished, the approved inspector must issue a final certificate to the local authority to say that the work is complete, inspected, and that it complies with the regulations.

4.8.1 Spain

Steps of a construction project IN SPAIN:



All construction work requires compliance with the existing building regulations in Spain:

- LOE

"The Law 38/1999 of 5 November, Building Management, from which comes the Code, is fundamental pillar for the process of building. The Basic Law sets requirements for buildings and updates and supplements the legal configuration of the agents involved in the process of building, specifies their obligations and responsibilities and establishes safeguards to protect users'

-CTE

"The Technical Building Code, CTE, is the regulatory framework that establishes and develops the basic requirements of quality of buildings and facilities, and to establish that the Basic Requirements of the building are met, the law"

CTE is structured into several technical documents. We have detailed a selection of the norms affecting the B2S quality checks and energy performance:

CTE DOCUMENT	QUALITY CHECK
DB SI (safety in case of fire)	
DB SUA (safety in use and accessibility)	
DB HE (energy saving)	**ENERGY QUALITY CHECKS:** Energy Efficiency Certificate: signed by the designer (architect) or thermal installations designer (facilities engineer). It must include the signature of the promoter) HE0 Limitation of energy consumption of the building HE1 Limitation on energy demand of building
- DB SE (structural safety)	
- DB HS (health)	**AIR QUALITY CHECKS:** Should be the same as that defined at the project stage (the air quality conditions of the buildings are defined by the CTE- DB. HS3) **WATER CONSUMPTION QUALITY CHECKS:** Should be the same as that defined at the project stage (the water consumptions conditions of the buildings are defined by the CTE- DB. HS4)
DB HR (protection against noise)	**ACOUSTIC QUALITY CHECKS**: Should be the same as that defined at the project stage (the acoustic conditions of the buildings are defined by the CTE- DB.HR)

-OTHER TECHNICAL REGULATIONS:

"The regulatory framework of the building are mandatory technical regulations of other basic character, such as concrete instructions EHE, standard seismic construction, the Regulation of

Thermal Installations in Buildings, RITE, other industrial safety regulatory compliance etc. ., coexisting with CTE, and in principle are external references to it "

NORMAS U.N.E, EUROCODES

CONSTRUCTION WASTE QUALITY CHECKS: Construction and demolition waste management study (Royal Decree 105/2008, the Mº of the Presidency).

-OTHER LOCAL REGULATIONS

"The CTE, as established by the LOE, can be completed with the requirements of other regulations issued by the competent authorities. I.e. the regional and local regulations applicable in each case. "

(All definitions have been translated from http://www.codigotecnico.org/ official web of Ministerio de Fomento, Gobierno de España.)

4.8.2 Ireland

There has been a major problem for many years with the system of self-certification of compliance with the Building Regulations, which simply did not work as it had become a paper exercise with highly qualified certificates. There have been two major building failure scandals in recent years which reinforced the government’s intention to introduce more effective legislation for Building Regulation compliance. The Building Control Amendment Regulations 2014 (BCaR) became active on 1 March 2014. In summary this requires a detailed submission of drawings, calculations and information to the Local Authority Building Control Dept. at the Commencement Notice stage which demonstrates how the design satisfies all the requirements of the current Building Regulations. This submission is a legal document that will be held on file until the building is demolished.

This is a major change to the way the industry has worked in the past and requires a lot more detailed design work at an earlier stage with more fees required to be paid earlier by the client. There must be a Site Inspection Plan submitted for each Design Certifier or Assigned Certifier who has to be a registered architect, engineer or surveyor with PI insurance. Contractors and sub-contractors have to be registered and if they have any design input they must have PI insurance. The whole emphasis is on greater quality control and quality assurance with increased, mandatory recorded site inspections. This requires greater site management and record keeping by the entire supply chain. As a result specialist consultants have emerged to provide a service to those organisations which lack the internal management resources, knowledge or skills. As a result professional fees are going up and PI insurance premiums are expected to follow. The Royal Institute of the Architects of Ireland has only just issued on 1.12.15 a Code of Practice for Designer and Certifier Roles under BC(a)R which is an indication of how long it is taking the industry to adapt to this new legislation.

The BC(a)R process requires planned inspections by several parties and a system like B2S's would assist the whole industry to improve quality, reduce risk, provide evidence of compliance and achieve compliance.

Ireland's Building Regulations under Part L : Conservation of Fuel and Energy (2011) requires all new dwellings to achieve an A3 BER rating which indicates the dwelling should use less than 75 kWh/m2/yr for the uses measured. The recommended degree of airtightness is 5 m3/hr/m2 and (almost) all houses need to be tested for airtightness. If the airtightness is less than 5 m3/hr/m2 then the ventilation rate or system has to be improved. The designer is incentivized to use more detailed calculations for thermal bridging as the default figure is set conservatively high.

Since 2008 the Regulations have required a minimum amount of renewable energy on every dwelling: 10 kWh/m2 of thermal energy or 4 kWh/m2 of renewable electricity.

4.8.3 Netherlands

The situation in the Netherlands is moving in a direction where Built2Spec could have a large benefit to contractors. In order to explain this, the current situation in the Netherlands will be described first. The future situation will be described after that.

The current situation regarding quality checking is rather straightforward in the Netherlands. At the end of the design phase a building permit has to be acquired from the municipality. A request for a building permit is filed at the municipality and has to be detailed enough so the municipality can check if it is in line with regulations on the following aspects:

- Spatial planning: is the plan in line with the zonal plans etc.
- Aesthetic quality: does the plan fit within the aesthetic guidelines for that area.
- Building quality: is the plan in line with the building code. The building code describes the minimum requirements regarding safety, usability, sustainability, health.

If the plan is checked on these aspects, a building permit for this design is handed to the client. Sometimes a set of conditions is given with the permit. For instance: the building permit is only valid if a more detailed calculation of a certain floor is handed over to the municipality before a certain date.

The client then must build the building according to the plan which has been filed for the building permit. If, for whatever reason, changes are made to this plan a modification has to be filed. This modification has to be approved by the municipality.

The municipality has the possibility to visit the building site to check whether the building is being built according to the permit. If it finds (major) discrepancies it can stop the work and demand that a modification should be filed first.

There is no mandatory or regular check by the municipality at handover to check if the building was built according to the permit. All the changes which may have occurred during the building process should have been filed as a modification request. In practice small (and sometimes large) modifications are not filed as a permit and therefore many buildings differ (slightly) from the building permit.

To our knowledge the only mandatory information which has to be given to the municipality after the building permit is information regarding the start and completion of the building, this is documented on a 'blue card' (Dutch: "Blauwe kaart"), see annex.

Right now a fundamental change in legislation is being prepared by the Dutch government. In the preparation phase the industry is being consulted formally and informally through public events such as the congress "DE REGIE OVER KWALITEIT IN DE BOUW" in The Hague on October 20th 2015, which TNO attended. For the less complex buildings (dwellings, multi-family buildings, smaller office buildings etc.) the proposed process will be as follows:

There will be no building quality check when filing for a building permit. The check will be done when the building is completed, at handover. At this point the contractor will have to show that the building is built according to the building code. It will be up to the contractor to gather the necessary evidence that the building is built according to the applicable standards.

This is a large shift in responsibilities, procedures etc. Currently, this process is being developed and thought through. It is not yet clear what the exact consequences of this new legislation will be. Built2Spec could help the contractor very well in performing the required quality checks.

5 Conclusions

With the VCMP the Built2spec Consortium embraces the construction process in its complexity and will improve it through systematic quality checks, to the extent that the discrepancy between the desired and the actual energy-relevant behaviour of a building (performance gap) is significantly reduced or avoided completely. In the process, different innovative technologies will be involved and a system will be developed which is also open to future development.

The fact that it is possible to construct buildings which only use the planned amount of energy has already been proved in several studies. The Passive House Standard is also mentioned repeatedly in this respect. The central aspect is meticulous planning of the building, implementation that is in accordance with this planning, accurate adjustment of the building technology and instruction of the users and provision of advice particularly during the initial period of building operation. It is therefore proposed that the VCMP includes the entire process in its workflow.

Integrated construction processes are greatly facilitated through Building Information Modelling (BIM). An integrated approach such as IDDS even demands BIM, and construction experts are of the opinion that within a few years, construction without BIM will no longer be conceivable. The VCMP therefore utilises the opportunities offered by BIM. Access to the respective virtual building model is an essential part of this platform.

On account of the diversity of construction technologies and processes, it must be possible moreover to adapt the platform to the respective needs of users. However, it must also be open to automated processes such as those which are presently already found in the market, as well as for those which are still in the process of being developed.

The VCMP should make it easy for construction professionals to deliver a high quality of work. The words 'performance gap' should soon be a thing of the past, therefore the new VCMP will enable access to all important information and provide high quality planning documentation, and it will make easily comprehensible and implementable quality checks available, involving modern self-inspection technologies in the process and moving away from paper-based quality assurance applications.

Annex A List of quality checks

This list of quality checks covers the entire construction process, however it is not exhaustive. The list was produced in cooperation with the consortium members directly involved in construction projects.

Construction project

Stages	Areas of activity	Main Activities	Quality Check [QC]	How today?	How tomorrow?
1 - Basics	General aspects	Compile the development plan and information about possible building sites, acquire the opinion of public authorities and information about other framework aspects	Check using list of important aspects, if the basic information is available		Request data from public bodies on the internet and online survey of those involved in the project
	Architectural design1	Designer collects information about the general project framework, owner/investor searches for an appropriate plot and gives input. Designer checks plot in respect to existing building, town planning, neighbourhood, public services, and building regulations for the possible use with requirement-lists and take the owner's/investor's input into account.	Are all the owner's/investor's requirements considered? (use of a checklist of project goals, future use of the building) Are all the framework conditions collected for architectural design (existing buildings, neighbourhood, public services, +town planning framework, building regulations, etc.)		Request for proposal with standardised property descriptions online survey of those involved in the project with questionnaires, request information on legal boundary conditions from building regulation authorities, tool for preparation of the space allocation programme with filter function Image capture of the neighbouring environment, with "fish-eye" optic for example. Input data to simulations
	Architectural design1a (renovation project)	collecting geometrical and technical data of the existing building	Check if the data are complete and consistent		drones collect data, the data will be transferred and compiled into a 3D model
	Architectural design2	Choice for optimal building orientation	Orientation check, taking the project objectives into account. + Checklist for the first site visit		Quick selection via tool which combines calculation and CAD
	Ecological aspects	Research which environmental aspects are affected when building will be in use, including pollution related aspects of heating, hot water, electric power for ventilation and other devices, building materials and water consumption, waste water, lifecycle aspects and analyses concerning possible energy production.	Check with the help of a check list if all important ecological aspects are covered and if information about the framework conditions are completely available.		Database with different solutions and assigned use of resources with life cycle cost analysis
	Town Planning	Research which of the aspects of the master plan is affecting the project. Create a document which informs the owner.	Check with the help of a checklist if all important aspects are considered		Interactive development plans with list of suggestions for possible building development variants

	Renewables / Energy gain	Designer and technology experts collect information about the state of the art of renewables which relates to the respective building site and information about funding opportunities	Designer and technology planners check the actual technological opportunities related to the requirements of the project		Electronic system with information and selection aid according to area of use
	Setting for the next stage	Find appropriate experts for the next stage and propose a team to the owner/investor	Check if all aspects are covered? Check if the cooperation within the team will be ensured		Meeting will take place to confirm the good cooperation atmosphere
	Summary stage 1 - Basics	Results of stage 1: Information about framework conditions are available: - requirements of owner/investor are defined - public framework conditions - site conditions - experts involved in the next stage defined	Check with the help of a check list if - the requirements of the owner/investor are defined - the public framework is known - the site conditions are known - the team for the next stage is assigned	By checklists	By means of checklists, electronic evaluation of the available information with reference to planning requirements
2 - First draft	Room program	Owner/investor develops a room program in cooperation with the designer	Owner/investor checks with the help of a checklist if all his requirements are met. Designer checks with the help of a checklist if the required functionalities are incorporated.		Tool for preparing space allocation programme with filter function
	Preliminary Design	The whole design of the building with different views will be drawn up. Different alternatives will be visualised. Orientation of building (or other alternatives) will be tried out.	Designer checks if the dependencies of the design and the functionalities are not clashing, The owner/investor checks the building design, the room program and the functionalities against his requirements.		Tool for preparing drafts on the basis of specified boundary conditions
	Definition of the basic structural concept	First definition of the structural system and the basic material used Consultation of structural engineer and results of first calculations from structural engineer available Technology planners and designer check if the structural design has an effect on energy-relevant aspects. Energy expert and structural engineer identify those details which influence the energy-relevant performance, identify problems and sort them out	Check if all problems are identified and adequately tackled: either sorted out or a possible solution could be identified with the help of a checklist		Check selection of materials, dimensioning taking into account the selected uses, comfort requirements and aesthetical aspects
	Definition of performance framework	Decision which certificate the project is aiming at Definition of maximum heating demand Definition of maximum cooling demand, perhaps with help of an energy calculation program, Maximum primary energy use (with and without appliances) Requirements of the chosen certificate	Designer and technology planners compare the calculated planned demand and the other planned requirements against the project goal		Automatic allocation of selected certificate to the respective specific values, possibly with allocation to current public subsidies and grant programmes
	Definition of basic building service concept	Discussion of and decision on the basic building service concept, decision which technology/combination of technologies will be used	Does the building technology concept match the building plot situation, the ecological orientation, the client's wishes, the financial budget and other requirements of the building?		Tool for preparing a building services concept taking into account utilisation, comfort requirements and energy-relevant parameters
	Renewables, analysis and assessment of possible technical solutions	Discussion of and decision on the minimum share of renewables, decision which technology/combination of technologies will be used, cost/revenue analysis	Designer and technology planners assess the energy-relevant goals and preliminary design of technical solutions (solar, wind, geothermal energy, biomass and others)		Selection tool for system components for regenerative energies

	Calculation with energy balance tool/ first input for overview	Software use / Software input: building geometry, thermal building envelope, planned building services, user profiles related to energy consumption, use of renewable energy, climate data of the location	Checklist for planned building use and consumption profiles, the building envelope, solar protection, building technology and the use of renewable energy, results integrated in the design, are certificate goals met?		Energy balance calculation periodically synchronised with the design
	Setting for the next stage	Explore if all required experts for the next stage are on-board. In the case experts are missing propose new team members to the owner/investor	Check if all aspects are covered by expertise? Check if the cooperation within the team will be ensured		Meeting will take place to confirm the good cooperation atmosphere
	Time planning	Elaborate a time schedule	Check the time planning with all involved experts if realistic and within the given framework of the owner/investor		Synchronised time planning
	Cost calculation	Calculate the cost	Check costs against the planned financial budget		Synchronised budget planning
	Summary end of stage 2 - preliminary draft	Results: a preliminary draft is available from which it can be assumed that - the investor's requirements are put into effect - the energy-relevant requirements are achievable - the boundary conditions of the building plot are taken into account - it meets the legal provisions - it corresponds with the desired ecological prerequisites - it contains an approximate building services concept which is implementable - it fits into the financial framework - it can be realised within the given time-frame - the team for the next stage has been specified - it includes a rough concept for the use of renewable energy has - the building owner/investor has given the go-ahead for the next phase	Check, whether - investor's requirements have been complied with - energy-relevant boundary conditions have been fulfilled - the boundary conditions for the building plot have been taken into account - legal provisions have been met - the desired ecological boundary conditions have been met - the desired certificate is achieved - it contains - an as yet rough - building services concept which can be implemented - it fits the financial framework - it can be realised within the given time-frame - the team for the next stage has been assigned - it includes a rough concept for the use of renewable energy - the owner/investor has given the go-ahead for the next phase		Electronic assessment tool comparing requirements with the actual design
3 - Detailed design	Architectural concept 1	Further development of the preliminary draft through detailed elaboration. In this respect it is essential that the aesthetic and technical aspects of the preliminary draft are developed further as implementable planning solutions under consideration of the applicable regulations.	Check using a checklist whether the main boundary conditions of the preliminary draft have been maintained		3D model in internet server with allocation and depiction of requirements and owner's/investor's wishes
	Architectural concept 2	Final choice for openings and sizes (proportions but also in relation to energy performance) of the draft	Check if the requirements of the owner/investor are considered. Check the input of that data into the energy balancing tool		Interactive aid for developing strategy for preparation of the Detailed Design
	Architectural concept 3	Creating a finalised design that corresponds to the zoning plan, relevant regulations for hazard scenarios or safety and security levels of the intended building	Check whether the project-specific technical and building regulation aspects have been considered.		Control tool for checking completeness and as an aid for going through the different aspects

		Explaining of interdependencies of choice of materials to owner investor, Final clarification of choice of material	Check if owner/investor has made the crucial decisions and if he has understood the interdependencies. Check if the decisions are correctly incorporated into the details design, the energy-relevant calculation, and structural design.		
	Foundation / wall / roof / - typical details	Development of key details (typical details) and definition of the standard fabric of the walls/roofs/foundation, in order to be able to estimate the costs, time planning and the building physics characteristics for the project.	Check the constructive and energy-relevant influences on the current detailed design Define the complete airtightness layers as basic concept (the details will be elaborated in stage 5) Define the basic concept related to insulation (critical details will be elaborated in stage 5)		Internet tool with selection filters for finding detailed catalogues and explanations
	Transparent facade / windows / door 1 - typical details	Development of typical details and definition of the standard Uw and Ug values of transparent facade/windows/doors, in order to be able to estimate the costs, time planning and the building physics characteristics for the project.	Check the constructive and energy-relevant influence on the current detailed design		Internet tool with selection filters for finding detailed catalogues and explanations
	Transparent facade / windows / door 2	Preparation of the final design of the façade	Have the owner's/investors wishes been implemented? Have general aesthetic requirements been fulfilled?		Internet tool with selection filters for finding detailed catalogues and explanations
	Transparent facade / windows / door 3	Planning of the main window/door connections to the wall and the roof structure (thermal bridge free and airtight construction)	Have all thermal bridge free and airtight details of all essential wind/door connections and the wall and ceiling construction been worked out?		Internet tool with selection filters for finding detailed catalogues and explanations
	Transparent facade / windows / door 4	Planning of the solar protection in the context of the artistic design and the energy-relevant requirements	Have solar protection elements been provided for reducing the solar loads? Has solar protection been taken into account correctly in the energy calculation?		Internet tool with selection filters for finding detailed catalogues and explanations
	Transparent facade / windows / door 5	Planning of the main door installation situations at the walls and the constructive development of the thresholds and profile joints.	Has twofold continuous sealing been provided above and at both sides and at least single sealing at the threshold? Is it possible to install entrance doors in an airtight and thermal bridge minimised way (also at threshold)? Are brackets made of plastic or thermally separated steel brackets planned for attachment of brackets for window ledges (entrance and sides doors)? Are an insulated exterior sliding door with thermally separated profiles, installation in the insulation layer, and airtight connection to reinforced concrete wall or ceiling all around using sheeting planned?		Internet tool with selection filters for finding detailed catalogues and explanations
	Fire protection	Elaboration of a fire safety concept	Has a complete fire safety concept been worked out that is ready for handing over? Have the details been taken into account in the energy-relevant concept?		Interactive simple expert system
	General concept	Identification of critical details	Are all critical details identified? (e.g. by four-eye-principle check)		Internet tool with selection filters for finding detailed catalogues and explanations
	General concept	Solutions for critical details are worked out, possibly with involvement of additional experts (acoustics, building physics, earthquake resistance)	Have technical solutions been worked out for all critical details?		
	Structural concept	Finalising the structural concept and the structural calculations and drawings, Structural concept (concrete, steel, timber walls and frames/structural elements). Incorporation of soil expert report. Incorporation in the detailed design	Check if the completed structural concept is integrated in the architectural design completely and in an aesthetically satisfying way. Check the details		
	energy-relevant engineering	Further elaboration of the chosen energy-relevant standard, fine-tuning of energy-relevant calculation.	Check heating demand, cooling demand, ventilation and hot water demand with the energy-relevant balancing tool. Check if the aspects of energy-relevant engineering are completely incorporated in the design in an aesthetically satisfying manner		

	Building services concept	Further elaboration of the chosen technical solutions	Check each technical component of the heating, cooling, ventilation and hot water concepts. Is it available on the market for a reasonable price, can it be integrated in the project design under aesthetical, technical, noise protection and other pollution related considerations		Integrated electronic planning (energy, function) with technical product data sheets (BIM)
	Building services /heating - cooling - hot water	Detailed elaboration of the solution and specification of the aggregates and choice of technical elements on the basis of technical and energy-relevant requirements	Check energy generators, any storage, transformers and pipework with reference to the chosen energy-related, ecological, technical aesthetic and financial requirements		see above
	Building services / ventilation 1	Planning of overall volumetric flows and respective regulation	Does the mechanical ventilation system comply with the necessary hygienic air change rate? Has the number of persons been chosen for assessing volumetric flows?		see above
	Building services / ventilation 2	Planning of performance classification of the ventilation system	Has classification according to EN 13779 been agreed with the client in advance (IDA 3 is actually adequate for office buildings, IDA 4 has proved successful in school buildings)? Has temporary exceeding of the fixed amounts been stated as permissible?		see above
	Building services / ventilation 3	Planning the duct routing	Is automatic regulation according to demand possible? Is at least three-stage regulation of the volumetric flows by the user possible?		see above
	Building services / ventilation 4	Details of duct work	• Is ducting planned with low air velocities and low pressure losses (planned standard values: 200 Pa for non-residential buildings, 100 Pa for residential buildings and 50 Pa small housing units)? • Is the volume flow velocity restricted to 0.2 m/s • Has a cross-talk sound absorber been planned for each room?		see above
	Renewables	Evaluation of possible/optimal units of onsite and nearby RE production, checking of legal requirements.	Check the different components of production of RE, transport/distribution, storage and transfer, pipe/cable routing against the input of the energy-relevant balance tool.		see above
	Calculation with the energy balancing tool /final testing	Software use / software input for the energy balancing tool	Check input relating to following aspects: Completeness check Plausibility check Error check		see above
	Time schedule	Update of time schedule taking into account the specifications of the investor	Does the time schedule match the given time frame of the investor? Do the involved persons agree with the time schedule?		see above
	Finance plan	Update of finance planning taking into account the specifications of the investor	Does the finance plan match the given financial framework of the investor? Do the involved persons consider the finance plan to be realistic?		time planning integrated with BIM (4D)
	Setting for the next stage	Finalisation of all design and planning processes in the individual planning teams. Coordination of the formal boundary conditions for preparing the building approval documents by the various teams and consolidation by the designer	Check if all aspects are covered?		budget planning integrated with BIM (5D)

	Summary end of stage 3 - detailed design	Results: a draft is available - which matches the investor's requirements - in which the energy-relevant boundary conditions have been fulfilled - which takes into account the boundary conditions of the building plot - which meets the legal provisions - which fulfils the desired ecological requirements - which is suitable for achieving the certificate being strived for - which contains a defined building services concept - which fits into the financial framework - which can be realised within the given time-frame - in which the team for the next stage has been specified - which includes a concept for the use of renewable energy - the building owner/investor has given the go-ahead for the building approval application	Check, whether - the investor's requirements are complied with - the energy-relevant boundary conditions have been fulfilled - the boundary conditions of the building plot are fulfilled - the legal provisions are met - the desired ecological requirements are fulfilled - the desired certificate is achieved - the planning includes a complete building services concept that can be implemented - the design still fits into the financial framework - the project can be realised within the given time-frame - for the team for the next stage has been specified - the design includes a concept for the use of renewable energy - the building owner/investor has given the go-ahead for the building approval application - does the energy calculation and the drawings match with each other?		
4 - documents for building permit	Building approval documents 1	Preparation of the building approval documents for NORMAL BUILDINGS (according to the building regulations)	Check for completeness Description of the systems for the building approval application: - Floor plan - Property plan - Open space plan - Construction drawings - Description of building and utilisation - Proof of authorisation to present building documents - Representation of property drainage (where required) - Evidence of parking spaces (if municipal statutes apply) - Proof of clearance space - Representation of the ventilation, heating and drainage systems - Calculation of the extent of building utilisation - Calculations (built-up space and if necessary, areas) - Proof of preventive fire protection if different in application - Application for any deviations, exemptions, exceptions - Proof of expertise - Statistics questionnaire Do the energy calculation match with the drawings?		Online input for building authority with real time control
	Building approval documents 2	Preparation of the building approval documents for SPECIAL BUILDINGS (according to the building regulations)	Check for completeness/ additional documents for NORMAL BUILDINGS: Description of the systems for the building approval - Proof of structural stability - Fire safety concept		Preparation of the verification of thermal protection using the CAD software which is used for 3D input.
	Legal Licence by Municipalities		Check that the project complies with all existing regulations and containing the minimum documentation required to be processed		
	Insurance and external agencies	Report for insurances and external agency - Risk definition report related to geotechnical risk - Project review report - stability	Module to check the compliance with OCT reports Review and check: - Constructive report - Structural report - Structural calculations - Structural technical drawings		

	Insurance and external agencies	Report for insurances and external agency - Water tightness	Module to check the compliance with OCT reports		
5 - implementation design	Architectural concept 1	Transfer of the detailed design into the implementation planning, normally by changing the scale e.g. from 1:100 to 1:50. The technical aspects are further elaborated and the aesthetic, technical and legal principles and aspects of the detailed design in all areas are retained and detailed further. The aim is to create the conditions for implementation of the building. In doing so, paying attention to statics and energy-relevant calculation, and the concept for fire safety, noise protection, moisture transport, earthquake resistance and other technical requirements, comfort	Check planning details using the building description or other strategy papers, whether the main boundary conditions of the detailed draft have been maintained during further development. Check whether the technical requirements for statics, energy-related characteristics, fire safety, moisture transfer, absence of cracks, subsidence safety, noise protection, comfort and other special areas are adhered to. Plausibility check		
	Planning for roof	Further elaboration of the planning, according to the regulations and under the aspects to have the building sustainably damage free (condensation, cracks, water, noise, storm, harmful substances, harmful subsidence, fire, flood and earth quake, and other potential risks)	Check if the construction remains permanently damage free (condensation, cracks, water, noise, storm, harmful substances, harmful subsidence, fire, flood and earth quake, and other potential risks) e.g. by means of the four eye-principle and with the help of checklists Check U-values (if required), materials, construction, joints, evaluate if the planning matches the energy-relevant design with the help of checklists.		
	Planning for floor slabs	Further elaboration of the design, according to the regulations and under the aspects of keeping the building permanently damage free (condensation, cracks, water, noise, storm, harmful substances, harmful subsidence, fire, flood and earthquake, and other potential risks)	Check if the construction remains permanently damage free (condensation, cracks, water, noise, storm, harmful substances, harmful subsidence, fire, flood and earth quake, and other potential risks) e.g. by means of the four eye-principle and with the help of checklists Check U-values (if required), materials, construction, joints, evaluate if the planning matches the energy-relevant design with the help of checklists.		
	Detailed design of the transparent facade / windows / doors	Detailed design in accordance with the requirements, shading, fixing to the walls, ceilings, security, fire protection, noise protection, energy-relevant aspects, light transmission, aesthetic requirements, comfort	With the help of checklists, evaluate if the planning matches the requirements (U-values, materials, construction, joints, sustainable absence of damage, protection against overheating, noise, fire, security, aesthetics, etc.)		CAD software, with integrated calculation of heat flow and surface temperature, which also calculates detail solutions and indicates critical areas
	Consideration of building physics of the walls, roof, floor slabs	Identification of critical details, with regard to building physics - critical condensation - acoustic problems - fire protection problems - critical cracks - comfort - thermal bridges - problems with airtightness - other problems Optimisation of critical details	Check whether critical details have been recorded, if necessary through consultation with other external experts. Checking and calculation of details by building physics experts		Internet software, which has stored the necessary characteristics of the details but also allows modification by specialist planners
	Critical energy-relevant details	Identification of critical details in terms of energy Optimisation of critical details	Check if the principles of thermal bridge free design are complied with		Expert system with input of the 3D data with calculation of the heat flows and selection aid

	Critical energy-relevant details / thermal bridges 1	Details of insulation Details of joints Penetrations	Have building component connections been planned in a thermal bridge free or thermal bridge minimised manner? 1. Thermal insulation of the building components is implemented with the same thickness everywhere 2. Penetration of insulation layers are only executed using materials with an extremely low thermal conductivity 3. The thermally insulating layers and windows/doors are connected with each other without gaps and across the entire surface		see above
	Critical energy-relevant details / thermal bridges 2	Verification of the thermal characteristics of thermal bridges	Has individual proof been provided for thermal bridges in accordance with DIN EN ISO 10211 on the basis of the architect's details? Have subsequent changes in the details been checked and approved?		see above
	Critical energy-relevant details / thermal bridges 3	Planning of the penetrations through the heat-enclosing envelope area	Examples: • Are fall protection devices in front of floor-to-ceiling windows attached at the window frame or in the compound insulation system where possible? • Have railing posts of the roof terrace not been integrated into the insulation? • Has installation of the ventilation unit on the roof been carried out in a thermal bridge free manner on a load distributing reinforced concrete slab?		see above
	Airtightness1	Detailing of the airtightness concept	Check with the help of a checklist the joints, materials, practicability and critical details		Expert system with input of the data for presentation of details with selection aid
	Airtightness2	Building pressure test is stipulated: airtightness of the building envelope is verified with a pressure test when implementing the building	The value for the airtightness of the building envelope is predefined. Does the value match the energy balance calculation?		Checking and coordination of the trade disciplines with reference to the airtightness test
	Airtightness3	Airtightness concept	Is a concept for airtightness available for the building component assemblies on extensive areas as well as for all building component connections of the building envelope? Is the work for the connections for the windows and doors well-executed?		see above
	Airtightness4	Connections in the airtightness concept	Have the specifications of manufacturers of airtightness systems with regard to suitability of materials for connections (adhesive tape for wood and/or concrete) and their processing (substrate, pre-treatment, minimum coverage) been considered?		see above
	Airtightness5	Planning for interior surfaces	Example: Are plastered areas on the masonry continued all over up to the reinforced concrete surfaces? Also behind floor build-ups and behind the connection of interior walls and wall-mounted installations before mounting of the duct and other technical building equipment		see above
	Airtightness6	Planning for membranes	Has application of adhesive tapes and sheeting at the transition of building components (e.g. reinforced concrete to composite wood board) been designed with sufficient slack for changes in length and with sufficient bonding surface		Expert system with link to product data sheets and technical information sheets
	Airtightness7	Planning for installation of sheeting	Has integration of windows, exterior doors etc. into the airtight layer been planned appropriately? Has the principle of simple assembly been followed?		see above
	Airtightness8	Planning for penetrations	Has the number of penetrations of the airtight layer e.g. by pipes been minimised as far as possible? Have remaining penetrations been sealed carefully? Example 1: Penetration of the floor slab by pipes can be sealed using expanding mortar. Example 2: empty conduits should be connected to the airtight layer on the outside, and on the inside they can be filled with a permanently elastic sealing compound after the cables have been passed through. Example 3: Ventilation ducts are joined airtightly to the wall or ceiling constructions using a sealing collar (sheeting, no metal) and then covered with insulation.		see above

	Overall design (plan)	Checking that the overall design has taken into account: - water and vapour transport - acoustics - fire protection - building deformation - subsidence - expansion gaps	Check details of the construction documentation by referring to the building approval, the acoustics survey, fire safety concept and the structural engineering, as well as other special experts.		
	Structural engineering	Elaboration of the supporting structure planning and integration of the developed detail solutions into the construction documentation. Identification of critical points which affect other areas. Elaboration of solutions for critical details.	Check whether the structural details are completely incorporated into the construction documents. Have critical points, influences on sound and fire protection, energy-relevant behaviour, water and moisture transport, condensation, subsidence, changes in length etc. been identified? Are solutions developed and described in detail?		
	Building services / In general	Elaboration of implementation planning on the basis of detailed design. Completion of the building services concept with all details which are necessary for implementation	Check if the requirements of the owner/investor and the needs of the future users are finally met. Has all important information been collected, including the installation details and manuals? Is the energy balance calculation updated? Does the final detailed concept still match the energy performance targets? Have the drawings completed? Have all details for implementation been incorporated in the drawings? Are lists of details available describing the aspects to be mentioned in the tender specifications? Are the estimated costs known and are the costs below the planned budget? Are the future users already involved in order to elaborate appropriate user profiles for the building control?		
	Building services Sanitation	Actions: - Optional standards applied, if applicable - Horizontal sanitary installations. Description of the solutions adopted - dimensioning of installation	Do the sanitation meet the requirements of the owner/investor? Is the final decision made which sanitary ware is chosen? Is the description complete?		
	Building services / Plumbing	Actions: - Optional standards applied, if applicable - Identification, if different from the architect of the present project (@OHL: ??) - Criteria for design and installation description - Rush to the grid - System for hot water production. Combustible. Boiler room - Column distribution - Equipment of measurement and control situation. - Sanitary ware, taps and valves, complementary elements - Control of execution. Service tests. - Dimensioning of the installation	Is the plumbing correctly integrated into the design? Check penetrations! Are they correctly planned? Are the systems correctly designed? Is a complete and correct description available? Is a complete list of necessary elements available? Is hot water supply correctly designed?		

	Building services / Electricity	Actions: - Author (in case it is not the designer) - Optional standards applied, if applicable - Criteria for design and installation description - Red grounding - Bathroom counters situation. Switchboards, mechanisms. - Processing centre if any - Lighting, lighting levels according to uses and activities, signalling criteria safety lighting and lighting equipment - Dimensioning of the installation	Are the drawings complete? Is the planning for lighting complete? Does it match with the requirements of the owner/investor and the future users? Are detailed lists of required materials and parts available? Have energy efficient solutions for appliances been provided Does the user profile match the energy balance calculation? Is the energy balance calculation updated with the electric appliances and the user profiles? Are cables foreseen for automatic shading control?		
	Building services / Gas	Actions: - Author (in case is not the designer) - Optional standards applied, if applicable - Criteria for design and installation description - Running from the grid - Columns distribution - Measurement and control equipment - Control of execution. Testing service - Sizing the installation			
	Building services / HVAC	Actions: - Author (in case is not the designer) HEATING - Optional standards applied, if applicable - Adopted system, justification for the chosen fuel and storage - Criteria for design and description of the facility, generators, distribution networks, terminal units and related equipment - Dimensioning of the installation AIR CONDITIONING - Optional standards applied, if applicable - Criteria for design and installation description - Generators, distribution, terminal units and related equipment - Control of execution. Testing service - Dimensioning of the installation	Are the drawings complete? Does it match the requirements of the owner/investor and the future users? Are detailed lists of required materials and parts available? Have energy efficient solutions been chosen for appliances? Is the building sufficiently protected from overheating? Have energy efficient components been chosen? Is the energy balance calculation updated with the details?		Integrated planning of the building approval as a basis for building services planning
	Building services / Ventilation / natural	Further elaboration of the planning	Has the natural ventilation concept been incorporated into the energy balance calculation? Check if the natural night ventilation ensures restriction of overheating!		Electronic calculation of sufficient air exchange under different conditions (day, night, summer, winter, etc.)
	Building services / Ventilation - mechanical	Further elaboration of the planning			Processing of project on the internet server and with collision check
	Building services / Renewables	Further elaboration of the design	Is the energy balance calculation updated with the details of the renewable energy supply?		see above

	Building services / Fire Protection	Author (in case is not the designer) - Applicable regulation - Criteria for design and description of the facility required in each case: · Portable fire extinguishers · Hydrants · Alarm · External hydrants · Installation of automatic extinguishers · Dry column · Fire detection system - Control of execution. Functionality tests - Calculations	Check if the fire protection concept matches the detailed design and the required elements are incorporated in the drawings. Check if penetrations of the thermal envelope are thermal bridge free or are only minimal. Check if the energy balance calculation is updated with the thermal bridges of these penetrations. Check if the fire protection elements for normal use are well-insulated and airtight if they are within the thermal envelope. Does the fire detection system meet the legal requirements?		see above
6 - tendering and contracting	Tender documents	Generation of tender documents and the related specifications	Check if all aspects which are important for tendering and contracting are mentioned in the documents.		Expert system for generating tender documents for 3D data and BIM
Construction Company "needs"					
7 - Implementation and its supervision	**Start of implementation**	Handover to construction company	Are the drawings complete and updated?	visual check	
			Are all structural details incorporated in the drawing	visual check	
			Do the specification match with the drawings	visual check	visual check In the BIM those elements can be tagged which need to be mentioned with its properties in the specifications
			Are all building service elements incorporated in the drawings?	visual check	In the BIM model all elements will be visible
			Do the drawings match with the expert reports (soil, acoustics, fire protection, etc.)	visual check	partly BIM model
			Do the drawing match with the energy planning?	visual check with the help of a checklist	The energy balance calculation is done interlinked with the BIM model, mistakes will be detected
			Is the time planning realistic?	independent internal update of time planning	BIM model
			Can the budget be met?	independent internal cost calculation	Cost calculation with the help of the BIM model
			Are the targeted certificates incorporated appropriately in the drawings?	visual check	
			Is the design team available for question?	check of contract	check of contract
	Foundation	Excavation	Planarity	Standard topographic survey (laser, GPS)	Drones = topographic survey+GPS+ 3Dscan Static camera system (i.e. surveillance camera's with 'intelligence')
			Reduced level, geometry & location	Standard topographic survey (laser, GPS)	Drones = topographic survey+GPS+ 3Dscan
		Blinding layer (laying "soft" concrete)	Check the compliance with the guidelines Environmental temperature before the concrete cast	Thermometer	Mobile with thermometer app

7 - Implementation and its supervision			Thickness	Laser (ruler?)	Drones = topographic survey+GPS+ 3Dscan static camera system (i.e. surveillance camera's with 'intelligence')
			Foundation base level	Standard topographic survey (laser, GPS)	
		Laying formwork	Geometry of formwork with specific regard to position on plan, level and plumb.	EDM, laser, tape measure	Drones = topographic survey+GPS+ 3Dscan Automatic check between "designed" and "as built" within BIM environmental
			Compliance with the geometry of the structure with the designed	Ruler	Drones = topographic survey+GPS+ 3Dscan Automatic check between "designed" and "as built" within BIM environmental
			Axes alignment	Horizontal alignments are verified with "wire"	
		Laying reinforcement ("steel bars")	Material properties and working conditions according to eurocodes and national law, etc. Check the compliance with the guidelines	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications.
			Reinforcement: size, quantity, position, lap lengths, cover	Tape measure + visual	Drones = topographic survey+GPS+ 3Dscan
			Stirrups = diameter, distance et.	Ruler	
		Laying concrete	Material properties and working conditions according to eurocodes and national law, etc. Check the compliance with the guidelines and project specifications	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications; embedded sensors
			Concrete strength (cube test) Check compliance with the guidelines and project specifications	Laboratory tests	Laboratory tests; embedded sensors
		Driving piles	Compliance with the geometry of the structure with the designed	Visual, check of labels	Automated check between 'ordered' and 'delivered' Identification and traceability through built in markers (i.e. RFID tags).
			Location and depth. Control (right position, right depth)	Standard topographic survey (laser, GPS)	Drones = topographic survey+GPS+ 3Dscan and static camera system (i.e. surveillance camera's with 'intelligence') perform an automatic check between "designed" and "as-built"
			Loadbearing capacity of piles	Acoustic measurement.	
	Reinforced concrete vertical structural elements (COLUMNS, SHEAR WALLS, CORE)	Laying formwork	Compliance with the geometry of the structure with the designed	Ruler	Georeferentiated pictures (by drone or camera) + 3D scan -> automatic check between "designed" and "as built" within BIM environment
			Axes alignment	Alignments are verified with "wire"	
			Elements verticality	Vertical alignments are verified with "plumb line"	
			Correct location on plan	EDM, laser, tape measure	
			Formwork geometry, i.e. squareness, straightness, dimensions and verticality	EDM, laser, tape measure	
			Surface condition of formwork	Visual	Visual
		Laying reinforcement ("steel bars")	Material properties according to techn. data sheets (eurocodes and national law)	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications and guidelines in order to ensure compliance.

7 - Implementation and its supervision			Reinforcement: size, quantity, position, lap lengths, cover	Tape measure /ruler + visual check	Georeferentiated pictures (by drone or camera) + 3D scan
			Stirrups: diameter, distance, cover, etc.		
		Laying concrete	Material properties according to techn. data sheets (eurocodes and national law)	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications; embedded sensors -> compliance with project specification
			Concrete strength (cube test)	Laboratory tests	Laboratory tests; embedded sensors -> compliance with project specification
		Material acceptance	Material properties and working conditions, (technical data sheet) according to eurocodes and national law etc.	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications and guidelines in order to ensure compliance.
		Laying precast elements	Compliance with the geometry of the structure with the designed	Ruler	Drones = topographic survey+GPS+ 3Dscan automatic check between "designed" and "as built" within BIM environment
			Axes alignment	Alignments are verified with "wire"	
			Element verticality	Vertical alignments are verified with "plumb line"	
			Correct location on plan	EDM, laser, tape measure	
			Element geometry, i.e. size & shape	Tape measure	
			Element verticality	EDM, laser, tape measure	
		Joint construction	Compliance and good realisation	Tape measure + visual check	Tape + visual check
					Georeferentiated pictures / video (by drone or camera) -> automatic check between "designed" and "as built" within BIM environmental
	Vertical structural elements (wood,... straw, clay)	Material acceptance	Material properties and working conditions according to technical data sheet /eurocodes and national laws etc.	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications; embedded sensors -> compliance with project specification and guidelines
					Identification and traceability through built in markers (i.e. RFID tags).
		Laying elements	Correct location on plan, compliance with the geometry of the structure with the designed	EDM, laser, tape measure, ruler	Drones = topographic survey+GPS+ 3Dscan -> automatic check between "designed" and "as built" within BIM environmental
			Compliance with the designed geometry, i.e. Size & shape		
			Axes alignment	vertical alignments are verified with "wire"	
			Elements verticality	vertical alignments are verified with "plumb line"	
			Surface condition	visual check	
			Check the system evacuation rainwater	visual check	
		Joint construction	Ensure compliance with designed connection details and good realization	Tape measure + visual check	georeferentiated pictures / video (by drone or camera) 3D Scan + visual check

	Wooden or Steel vertical structural COLUMNS	Material acceptance	Material properties and working conditions, (technical data sheet) according to eurocodes and national laws etc.	Manual comparison of technical data sheets with project specifications.	Identification and traceability through built in markers (i.e. RFID tags). Automatic comparison of technical data sheets with project specifications; embedded sensors -> compliance with project specification and guidelines
		Laying elements	Compliance with the geometry of the structure with the designed	Ruler	EDM, laser, tape measure -> compliance with the geometry of the structure
			Axes alignment	Alignments are verified with "wire"	EDM, laser, tape measure
			Element verticality	Vertical alignments are verified with "plumb line"	EDM, laser, tape measure
			Correct location on plan	Laser, tape measure	EDM, laser, tape measure
			Element geometry, i.e. size & shape	Laser, tape measure	Tape measure
					EDM, laser, tape measure
			Surface conditions	Visual check	3D surface scanner
		Joint construction	Compliance and good realisation	Tape measure + visual check	Tape measure + visual check -> compliance with the project specifications and guidelines
	Brick walls	Material acceptance	Material properties and working conditions according to technical data sheet /eurocodes and national laws etc.	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications; embedded sensors -> compliance with project specification and guidelines
					Identification and traceability through built in markers (i.e. RFID tags)?
				Manual + industrial mortar production	Industrial production of mortar under controlled environment
		Preparation	Ambience temperature	Visual check of temperature	Automated ambience temperature check with warnings
		Laying brickwork	Wall verticality	vertical alignments are verified with "wire"	GPS + 3Dscan
			Correct geometry (length, width, height)	Ruler	3D-scanner
			Correct joint design	Ruler/visual	Ruler/visual
			Correct position and construction of corners	Tape	3D-scanner
			Correct evenness and surface condition	Ruler	Surface scanner
			Correct position of the openings	Tape	3D-scanner
			Correct position of built-in units	Tape	3D-scanner
		Joint construction	Compliance and good realisation	Tape measure + visual check	Tape measure + visual check -> compliance with the project specifications and guidelines
	RC horizontal structural elements (BEAM & SLAB)	Laying formwork	Compliance with the geometry of the structure with the designed	Tape, ruler	Georeferentiated pictures (by drone or camera) + 3D scan -> automatic check between "designed" and "as built" within BIM environment
			Axes alignment	Alignments are verified with tape and ruler	
			Elements horizontality	Horizontal alignments are verified with laser and ruler	
			Elements rising	Ruler, laser, tape measure	
			Correct location on plan	EDM, laser, tape measure	

7 - Implementation and its supervision			Formwork geometry, i.e. squareness, straightness, dimensions and verticality	EDM, laser, tape measure	
			Surface condition of formwork	Visual	Visual
		Laying reinforcement ("steel bars")	Material properties according to techn. data sheets (eurocodes and national law)	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications and guidelines in order to ensure compliance.
			Reinforcement: size, quantity, position, lap lengths, cover	Tape measure /ruler + visual check	Georeferentiated pictures (by drone or camera) + 3D scan
			Stirrups: diameter, distance, cover, etc.		
		Laying concrete	Material properties according to techn. data sheets (eurocodes and national law)	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications; embedded sensors -> compliance with project specification
			Compacting according to the guidelines	Visual check	Automated check of time and location
			Concrete strength (cube test)	Laboratory tests	Laboratory tests; embedded sensors -> compliance with project specification
			Concrete post-treatment		
		Material acceptance of precast elements (if applicable)	Material properties and working conditions, (technical data sheet) according to eurocodes and national law etc.	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications and guidelines in order to ensure compliance.
		Laying precast elements (if appl.)	Compliance with the geometry of the structure with the designed	Ruler, tape	Drones = topographic survey+GPS+ 3Dscan automatic check between "designed" and "as built" within BIM environment
			Axes alignment	Alignments are verified with "tape"	
			Correct location on plan	EDM, laser, tape measure	
			Element geometry, i.e. size & shape	Tape measure	
			Element horizontality	EDM, laser, tape measure	
			Element rising	EDM, laser, tape measure	
		Joint construction	Compliance and good realisation	Tape measure + visual check	Tape + visual check Georeferentiated pictures / video (by drone or camera) -> automatic check between "designed" and "as built" within BIM environmental
	Precast, Steel or Wooden horizontal structural elements (Beams)	Laying elements	Vertical displacement check before installing	Topographic survey + ruler laser	3D scan (by drone or mobile app) -> automatic check between "designed" and "as built" within BIM environment
			Vertical displacement check after installing	Topographic survey + ruler laser	3D scan (by drone or mobile app) -> automatic check between "designed" and "as built" within BIM environment
		Material acceptance	Material properties (technical data sheet)	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications; embedded sensors -> compliance with project specifications
		Laying precast elements	Correct location on plan	EDM, laser, tape measure	Drones = topographic survey+GPS+ 3Dscan -> automatic check between "designed" and "as built" within BIM environmental
			Check reduced level		
			Bearing length	Tape measure + visual check	

			Ensure each element in placed in its intended position - element identifier	Visual check	
		Joint construction	Ensure compliance with designed connection details (inclusive airtight joints if required)	Visual check	Automatic 3Dscan -> automatic check between "designed" and "as built" within BIM environment
	Wooden or Steel horizontal structural elements (SLAB)	Material acceptance	Material properties and working conditions according to eurocodes or specific national regulations	According to national and euro codes	According to national and euro codes -> compliance of the material with the guidelines
			Material properties and working conditions according to eurocodes etc. Surface treatment according to design	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications; embedded sensors
		Laying elements	Compliance with the geometry of the structure with the designed	Ruler	Drones = topographic survey+GPS+ 3Dscan -> automatic check between "designed" and "as built" within BIM environment
			Axes alignment	Axes alignments are verified with "wire"	
			Elements verticality	Vertical alignments are verified with "plumb line"	
			Vertical displacement check before installing	Topographic survey + ruler, laser	3D scan (by drone or mobile app) -> automatic check between "designed" and "as built" within BIM environment
			Vertical displacement check after installing	Topographic survey + ruler, laser	3D scan (by drone or mobile app) -> automatic check between "designed" and "as built" within BIM environment
		Insulation elements (thermal, acoustic,...) - air/water tightness - thermal bridges	- Material thermal/acoustic properties; - Thickness; - Installation according to the tech datasheet - Position inside the building	Visual check	Georeferentiated pictures / video (by drone or camera) Smart sensors / RFID -> automatic check between "designed" and "as built" within BIM environment
		Joint construction	Compliance and good realisation	Visual check	Georeferentiated pictures / video (by drone or camera) -> automatic check between "designed" and "as built" within BIM environment
	Precast horizontal structural elements (SLAB)	Material acceptance	Material properties and working conditions according to technical data, eurocodes + national laws etc.	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications; embedded sensors -> compliance of the material with the guidelines and project specifications
		Laying precast elements	Correct location on plan	EDM, laser, tape measure	Drones = topographic survey+GPS+ 3Dscan -> automatic check between "designed" and "as built" within BIM environment
			Check reduced level		
			Bearing length	Tape measure + visual check	
			Ensure each element in placed in its intended position - element identifier	Visual check	
			Compliance with the geometry of the structure with the designed	Ruler	Drones = topographic survey+GPS+ 3Dscan -> automatic check between "designed" and "as built" within BIM environment
			Axes alignment	Alignments are verified with "wire"	
			Elements verticality	Vertical alignments are verified with "plumb line"	
			Vertical displacement check before installing	Topographic survey + ruler, laser	3D scan (by drone or mobile app)
			Vertical displacement check after installing		

7 - Implementation and its supervision		Insulation elements (thermal, acoustic,...) - air/water tightness - thermal bridges	- Material thermal/acoustic properties; - Thickness; - Installation according to the tech datasheet - Position inside the building	Visual check	Georeferentiated pictures / video (by drone or camera) Smart sensors / RFID
		Joint construction	Ensure compliance with designed connection details and good realization	Visual check	Georeferentiated pictures / video (by drone or camera), 3D Scan + visual check
	Thermal envelope				
	ROOFS	See SLAB activities	Verify the slope of the roof	Vertical alignments are verified with "plumb line" EDM, laser, tape measure	Drones = topographic survey+GPS+ 3Dscan -> automatic check between "designed" and "as built" within BIM environment
		Insulation	Material properties (technical data sheet)	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications.
			Thickness	Tape measure	Drones = topographic survey+GPS+ 3Dscan
			Quality of installation	Visual check	Visual
			Specific details at openings		Drones = topographic survey+GPS+ 3Dscan -> automatic check between "designed" and "as built" within BIM environment
			Connection to adjacent walls		
			Penetrations		
			Thermal bridges		
	Walls	Construction	Material properties (technical data sheet)	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications; embedded sensors -> compliance with project specification
			Ensure wall construction is in accordance with project specifications	Visual check + pictures	Georeferentiated pictures / video (by drone or camera) Smart sensors / RFID -> compliance with tech. Data sheet
				Visual check	3D scan (by drone or mobile app) + Visual Check -> compliance between 'designed' and 'as-built' within BIM environment
			Position of openings	Tape measure	
			Weathering details at openings	Visual check	
7 - Implementation and its supervision		Insulation	Material properties (technical data sheet)	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications ->compliance.
			Thickness	Tape measure + visual check	3D scan (by drone or mobile app) + Visual Check -> compliance between 'designed' and 'as-built' within BIM environment
			Quality of installation		
			Fixing		
			Critical details		
			Specific details at openings		
			Junctions		
			Absence of gaps		
			Pipes and duct penetrations		
			Insulation and airtight layer		
			Unavoidable thermal bridges constructed as designed		
			Thermal bridges at balconies		
			Fixing of elements penetrating the insulation and the airtight layer		

			Protection of insulation against damages during the construction stage and after finalization, also against insects and rodents		
	Lower part of thermal envelope: Foundation/base slab	Insulation	Material properties (technical data sheet)	Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications ->compliance.
			Thickness	Tape measure + visual check	3D scan (by drone or mobile app) + Visual Check -> compliance between 'designed' and 'as-built' within BIM environment
			Quality of installation		
			Fixing		
			Critical details		
			Absence of gaps		
			Pipes and duct penetrations		
			Insulation and airtight layer		
			Unavoidable thermal bridges constructed as designed		
			Fixing of elements penetrating the insulation		
			Protection of insulation against damages during the construction stage and after finalization, also against insects and rodents		
	Windows, doors, vents	Delivery and installation of transparent components	Material properties (technical data sheet) window frames, glazing, spacers	visual check + pictures	3D scan (by drone or mobile app) smart sensors / RFID
				Manual comparison of technical data sheets with project specifications.	Automatic comparison of technical data sheets with project specifications -> compliance
			Quality of installation, position of installation	Visual check	3D scan + visual check -> compliance between "designed" and "as built" within BIM environment
			Protection of windows against damage during construction phase	Visual check	Visual check
			Check airtight connection to adjoining walls and slabs	Visual check	3D scan + visual check -> compliance between "designed" and "as built" within BIM environment
			Check thermal bridge free installation at all sides of the windows and doors (also at the bottom!!)	Visual check	3D scan + visual check -> compliance between "designed" and "as built" within BIM environment
			Check of function	Visual check	Visual check
			Check seals and water tightness	Visual check	3D scan + visual check -> compliance between "designed" and "as built" within BIM environment
		Shading elements	Component properties (technical data sheet)	Visual check	
			Quality of installation, position of installation	Visual check	
			Thermal bridge free and airtight (if applicable) fixing of shading elements	Visual check	Visual check
			Protection against damages during the construction stage and after finalization (if applicable)	Visual check	
			Quality of function	Visual check	Visual/manual/-- check
	General thermal performance	Thermal bridge free construction	Are the workers informed about thermal bridge free construction?		Confirmation by certificates
		Thermal performance	Thermal imaging (if applicable)	Thermal imaging camera (not typically carried out)	Thermal imagery using drones

7 - Implementation and its supervision	Airtight construction	Airtightness1	Airtightness test passed?	Air pressure airtightness test, smoke test (for air leakage detection carried out, but not typical)	UNOTT air pulse test, air pressure test -> air leakage test results
		Airtightness2	Material used for airtight layer and taping according to the specifications	comparison with specifications	bar code scanning
			Airtight layer fixed according to technical guidelines, specifications and design?	visual check + pictures	visual check + pictures
		Airtightness3	Airtight details implemented and completed as planned? Underground clean before taping? Taping has no gaps?	visual check + pictures	visual check + pictures
		Airtightness4	Are the others connections between different construction components and the penetrations in the airtight layer airtight executed?	visual check + pictures	visual check + pictures
		Airtightness5	Airtight layer protected against damages?	visual check + pictures	guided procedure
		Airtightness6	Are the workers instructed about airtight construction and informed about avoiding damages in the airtight layer?	verbal	guided procedure
	Acoustics	Acoustic properties	Acoustic test	Build in accordance with regulations	Acoustic measurements using mobile devices -> acoustic performance rating
	Heating	material acceptance	material properties - tech datasheet according to the designed	visual check + pictures	georeferentiated pictures / video (by drone or camera) smart sensors / RFID visual check -> automatic check between "designed" and "as built" within BIM environment
		Installation	Correctly installed and at the right position (with all sensors, displays, pumps, valves, thermostats etc.)		
		laying pipes	Check the position of the pipes - overlap and coordination between any other technical spaces		
			Check the pipes insulation if any		
			Check if the pipes and technical equipment is protected against dust and dirt and damages during the construction phase		
		system set-up	System correctly calibrated?		
	Cooling	material acceptance	material properties - tech datasheet according to the designed	visual check + pictures	georeferentiated pictures / video (by drone or camera) smart sensors / RFID visual check -> automatic check between "designed" and "as built" within BIM environment
		Installation	Correctly installed and at the right position (with all sensors, displays, pumps, valves, thermostats etc.)		
		laying pipes	Check the position of the pipes - overlap and coordination between any other technical spaces		
			Check the pipes insulation if any		
			Check if the pipes and technical equipment is protected against dust and dirt and damages during the construction phase		
		system set-up	System correctly calibrated?		
	Ventilation	material acceptance	material properties - tech datasheet according to the designed	visual check + pictures	georeferentiated pictures / video (by drone or camera) smart sensors / RFID visual check -> automatic check between "designed" and "as built" within BIM environment
		Installation	Correctly installed and at the right position (with all sensors, displays, pumps, valves, thermostats etc.)		
		laying pipes	Check the position of the pipes - overlap and coordination between any other technical spaces		
			Check the pipes insulation if any		
			Check if the pipes and technical equipment is protected against dust and dirt and damages during the construction phase		
		system set-up	System correctly calibrated?		
	Renewables	material acceptance	material properties - tech datasheet according to the designed	visual check + pictures	georeferentiated pictures / video (by drone or camera) smart sensors / RFID visual check -> automatic check between "designed" and "as built" within BIM environment
		Installation	Correctly installed and at the right position (with all sensors, displays, pumps, valves, thermostats etc.)		
		laying pipes	Check the position of the pipes - overlap and coordination between any other technical spaces		
			Check the pipes insulation if any		
			Check if the pipes and technical equipment is protected against dust and dirt and damages during the construction phase		
		system set-up	System correctly calibrated?		
		material acceptance	material properties - tech datasheet according to the designed	visual check + pictures	

Other Technologies (WATER, ELECTRICITY, GAS, TV, LAN, TELEPHONE, PV...)	laying pipes	Check the position of the pipes - overlap and coordination between any other technical spaces		georeferentiated pictures / video (by drone or camera) smart sensors / RFID visual check -> automatic check between "designed" and "as built" within BIM environment
		Check the pipes insulation pipes if any		
		Check if the pipes of the provider have sufficient distance to the building to allow undisturbed insulation of the outer wall.		
		Check if the pipes and technical equipment is protected against dust and dirt and damages during the construction phase		
	system set up/calibration	Check HVAC set point according to the designed (temperature, pressure, ...)		
		Check the position of the thermostats etc. … in each rooms		
National situation: example FRANCE				
Implementation	Roofs, facades, windows	Check if the implementation fits to the **"cahier de détail"** (document emitted by one contractor to the main contractor/designer, which describes the detailed planned implementation). Possible impact on energy performance of the envelope. There is one check and one reference document for each specific action/lot (insulation of the roof, insulation of the facade, implementation of windows, etc...)	The architect or supervisor (OPC in French context) has to check "manually/visually" on site. There is one reference document (cahier de détail) of each action of a contractor on a specific part (or "lot") of the construction project. In digital format or not.	Every reference detailed document prior to each implementation ("cahier de détail") is integrated in a numerical format on a common platform (VCMP or a tool associated to BIM). Thus the reference can be consulted on site. The supervisor can make series of quality checks, more quickly, and being sure of the reference to be compared to in each case. -> BIM/numerical platform assisted checks between "designed by contractor" and "as built", to be carried out by main contractor or work supervisor
Implementation	Connections/interfaces between separate lots (roofs, facades, windows)	The main contractor (or architect or chief designer) is responsible for the good **interface between the contractor lots.** Sometimes the boundary between the work of different contractors has to be defined, as well as the contribution of each contractor. There is a risk of low performance in these areas (e.g. quality of insulation in the junction between roof and facades, and how to avoid additional thermal bridges; "reservation" of location of penetrations of pipes prior to structural works,...)	"Manually" planned and managed on the construction site. Very time consuming and bad coordination can still happen. To be improved by technological support.	The interfaces will appear as "vigilance spots" on the platform/BIM. They will be accessible on site during the checks by the supervisor. The areas of responsibility of the different contractors will be highlighted (different colours on 3D model, or augmented reality) ->Different contractor lots represented and differentiated on the BIM/numerical platform. Interfaces between lots highlighted as "Vigilance spots"
Implementation of insulation layer	Roofs, facades	Quantitative checks to assess the **real thermal performance of a wall** to be compared with the designed performance.	In the best case, qualitative observation of thermal bridges.	Quantitative assessment on 2 aspects: - homogeneity of the performance (% of dubious surface, number of interruption in the insulation layer) - quantitative assessment of U-values, on site. -> The thermal performance of each part of the envelope will be characterized, through advanced inspection techniques, and thorough (replicable) protocols

7 - Implementation and its supervision	Implementation	All contractor works	Check that the **product ordered and installed on site is equivalent** to the product proposed during design (e.g. insulating material as regards thermal performance; inside ground coating material as regards aerosol emissions and air quality).	The supervisor must check the information visible on the product when available, note the reference, look for the characteristics (internet, databases), compare then to the information from the design.	The product implemented on site is automatically referenced through a numerical identification system (e.g. RFID), the actual characteristics are immediately accessible from the supervisor -> Product identification and traceability system
	National compulsory quality checks and reporting procedures: example SPAIN				
	COMPULSORY QUALITY CHECKS DURING CONSTRUCTION WORKS, BY LAW IN SPAIN:	Reception control of products, equipment and systems to be provided to works	Supplies Documentation control (Art. 7,2,1, CTE)	Suppliers give documentation to builder site direction, who will give documentation to Site Technical Direction (D.O).	All documentation to be controlled under a platform. To verify the product characteristics on site with smartphones. To verify if the product is approved, where to put and project specifications. -> compliance of the material with the guidelines
			Quality marks/labels or technical suitability assessments Controls (Art. 7,2,2, CTE)	Suppliers give documentation to builder site direction, who will give documentation to Site Technical Direction (D.O).	All documentation to be controlled under a platform. To verify the product characteristics on site with smartphones. To verify if the product is approved, where to put and project specifications. -> compliance of the material with the guidelines
			Lab control checks (Art. 7,2,3, CTE)	The tests were performed according to the planned schedule control, using approved and registered laboratories (RD 410/2010) Laboratories give the results of its activity to client agent (builder site direction) and always to executive tech. Director(D.O) Compulsory by CTE-EHE: a)Concrete b)Steel for passive reinforcements (only if they are made on site) (standardised reinforcement, welded mesh ...) (Reinforced ironwork)	All documentation to be controlled under a platform. To verify the product characteristics on site with smartphones. To verify if the product is approved, where to put and project specifications. -> compliance of the material with the guidelines
	COMPULSORY QUALITY CHECKS DURING CONSTRUCTION WORKS, BY LAW IN SPAIN:	EXECUTION CONTROL WORKFLOW general procedure for quality check during construction (non-exhaustive list of the main controls to be performed during the execution)		The register is written in the book.	All orders and actions available on line. The platform can summarize the actions as a list for the book of orders -> History of all actions and orders during construction activities
	COMPULSORY QUALITY CHECKS DURING CONSTRUCTION WORKS, BY LAW IN SPAIN: PROJECT COST CONTROL.	PROJECT COST CONTROL	CERTIFICATES OF WORK DONE Check the surface / volume and quality of units of work performed per month/end work	Visual check on site+documents+laser meter	BIM to have the model updated with measurements and characteristics(project cost control) georeferentiated pictures / video (by drone or camera) smart sensors / RFID

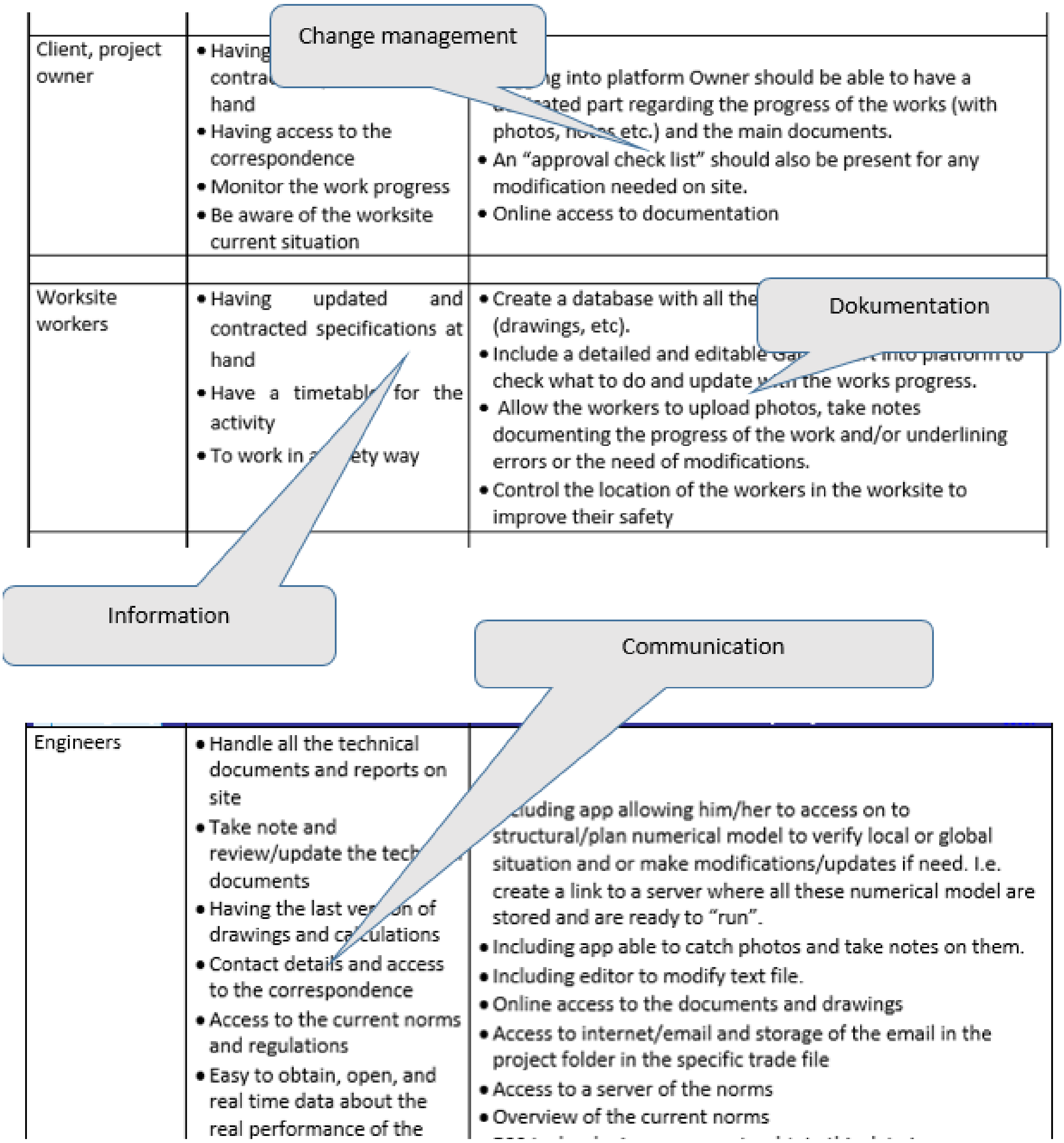
	ENERGY QUALITY CHECKS	ENERGY PERFORMANCE CERTIFICATE	Certificate according to CTE- DB HE	HULC tool http://www.codigotecnico.org/index.php/menu-recursos/menu-aplicaciones/282-herramienta-unificada-lider-calener	Energetic simulation of the building BIM HULC tool vs real performance of the building -> To obtain real data of the building for the final energetic certificate of the building
	ACOUSTIC QUALITY CHECKS	ACOUSTIC SELF INSPECTION TECHNIQUES	To check the acoustic performance of materials-systems into the building.	Measurements of the acoustic performance are not compulsory in Spain, but in some cases depending on use, and acoustic regulations.	On site Acoustic performance of the building BIM - > To obtain real data of acoustic performance of the systems and materials on site
	AIR QUALITY CHECKS	INDOOR AIR QUALITY	To check the air quality	Measurements of the air quality are not compulsory in Spain, but in some cases depending of use, and regulations.	On site air quality -> To obtain real data of air quality on site
	Project control by external Agent for Insurance (Organismo de Control Técnico OCT), for properties to obtain 10 years construction insurance	Project control by external Agent for Insurance	Final Report: Watertight (optional for 10 years insurance)	Checks the compliance of the execution viability regarding watertightness of: - Roofs - Facades - Basements	Module to check the compliance with OCT reports -> obtain real data to assess watertightness
			Final Report: Execution of works (optional for 10 years insurance)	Checks the compliance of the execution viability in terms of: "Report Foundation" "Structure" "printout façade cladding and covered"	Module to check the compliance with OCT reports
8 - commissioning	Commissioning	Airtightness check	Airtightness measurement	Air pressure test	Air pressure test, air pulse test -> pass/fail of airtightness according to design
		Acceptance of appearance	Compliance with design	Visual check + pictures	3d Scan, photospheres, etc. -> acceptance of the building
		Commissioning of building systems	Do they run according to the needs of the users		IT guided procedure
		Soft-landing	Is the soft-landing process installed?		IT guided procedure
		Involvement of future users	Are the users instructed?		IT guided procedure
		Snagging	Are all minor faults collected that need to be rectified?	Visual	Visual
9 - Documentation	Documentation	Collect the updated drawings and energy balance calculation as built	Are all drawings and the energy balance calculation updated?	Manually	Guided update procedure
		Collect the user manuals	Are all user manuals available?	Manually	Automated check of completeness
		Compile all documents related to building permit etc.	Are all documents collected?	Manually	IT guided compilation
		Documentation of building control commissioning	Is the documentation of the building control commissioning complete?	Partly manually, partly automated	Automated documentation
		Health and safety documents	Are the documents related to health and safety complete?	Manually	Guided procedure
		Snagging paper work	Has the process of rectifying the minor faults initiated? Are all deficiencies sorted out?	IT supported correspondence	Guided procedure IT communication and documentation in BIM
		Gas safe and fan testing	Have the systems passed the test?		IT guided procedure
		Final sign off	Are the formal documents complete?		IT guided procedure
		Building control paper work	Are all important aspect of the building control documented reported?	IT supported paper work	Automated documentation and report production
		Documentation of building control adaptation	Are the building control adaptations documented? (including reasons why adaptation was required)		Automated documentation
	National documentation e.g. UK NHBC documentation	Reports (NHBC): Technical Conditions Site Reportable Items Plot Progress Report	http://www.nhbc.co.uk/NHBCPublications/LiteratureLibrary/extranet/filedownload,32548,en.pdf	IT supported filling of templates	IT supported report production

		Sustainability and Energy Builder Responsible Items			
10 - In-use	In - use	Maintenance	Is a maintenance plan available?		BIM supported maintenance management
		Monitoring of energy consumption1	Is a system of simple monitoring installed?		Guided procedure
		Monitoring of energy consumption2	Are the data collected and documented?		Automated documentation
		Monitoring of energy consumption3	Is an instruction available for plausibility check of energy consumption?		Guided procedure
		Monitoring of energy production1	Is a system of simple monitoring installed?		Guided procedure
		Monitoring of energy production2	Are the data collected and documented?		Automated documentation
		Monitoring of energy production3	Is an instruction available for plausibility check of energy production?		Guided procedure
		Adaptation of building control1	Is clearly assigned who is in charge for adaption of the building control?		Guided procedure
		Adaptation of building control2	Is it ensured that all adaptions are documented?		Automated documentation
		Involvement of users	Are the users informed about the building and its usage?		IT guided procedure
		Occupant/user feedback	Is there a process installed that the feedback of the users is used for building control adaptation and for improvement of future projects?	Rarely happens, when it does it is usually paper surveys	Guided procedure

Annex B Examples for user need assessment

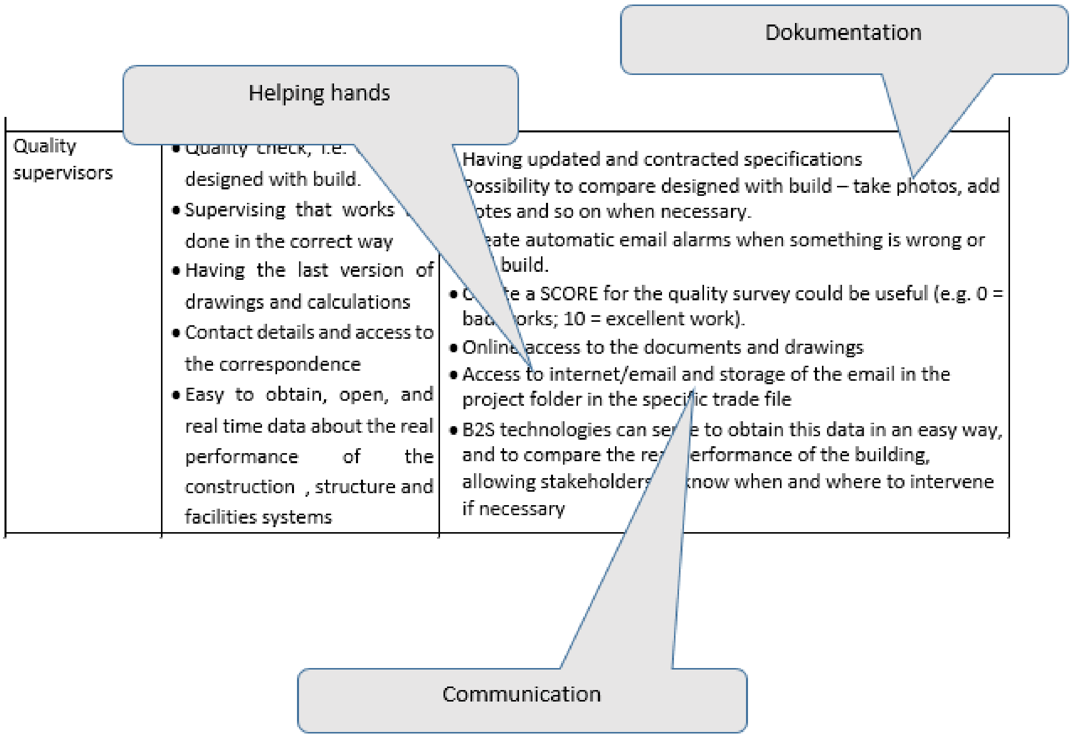
User group, the needs and how the platform could serve the needs

Excerpt from deliverable D1.1, section 4.3:



Client, project owner	• Having contra hand • Having access to the correspondence • Monitor the work progress • Be aware of the worksite current situation	g into platform Owner should be able to have a ated part regarding the progress of the works (with photos, etc.) and the main documents. • An "approval check list" should also be present for any modification needed on site. • Online access to documentation
Worksite workers	• Having updated and contracted specifications at hand • Have a timetabl for the activity • To work in a ety way	• Create a database with all the (drawings, etc). • Include a detailed and editable check what to do and update the works progress. • Allow the workers to upload photos, take notes documenting the progress of the work and/or underlining errors or the need of modifications. • Control the location of the workers in the worksite to improve their safety

Engineers	• Handle all the technical documents and reports on site • Take note and review/update the tech documents • Having the last ver on of drawings and ca culations • Contact details and access to the correspondence • Access to the current norms and regulations • Easy to obtain, open, and real time data about the real performance of the	cluding app allowing him/her to access on to structural/plan numerical model to verify local or global situation and or make modifications/updates if need. I.e. create a link to a server where all these numerical model are stored and are ready to "run". • Including app able to catch photos and take notes on them. • Including editor to modify text file. • Online access to the documents and drawings • Access to internet/email and storage of the email in the project folder in the specific trade file • Access to a server of the norms • Overview of the current norms

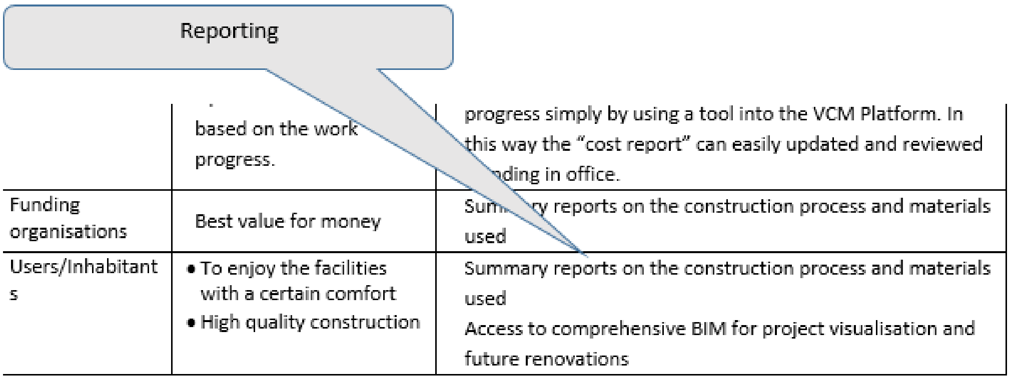


Dokumentation

Helping hands

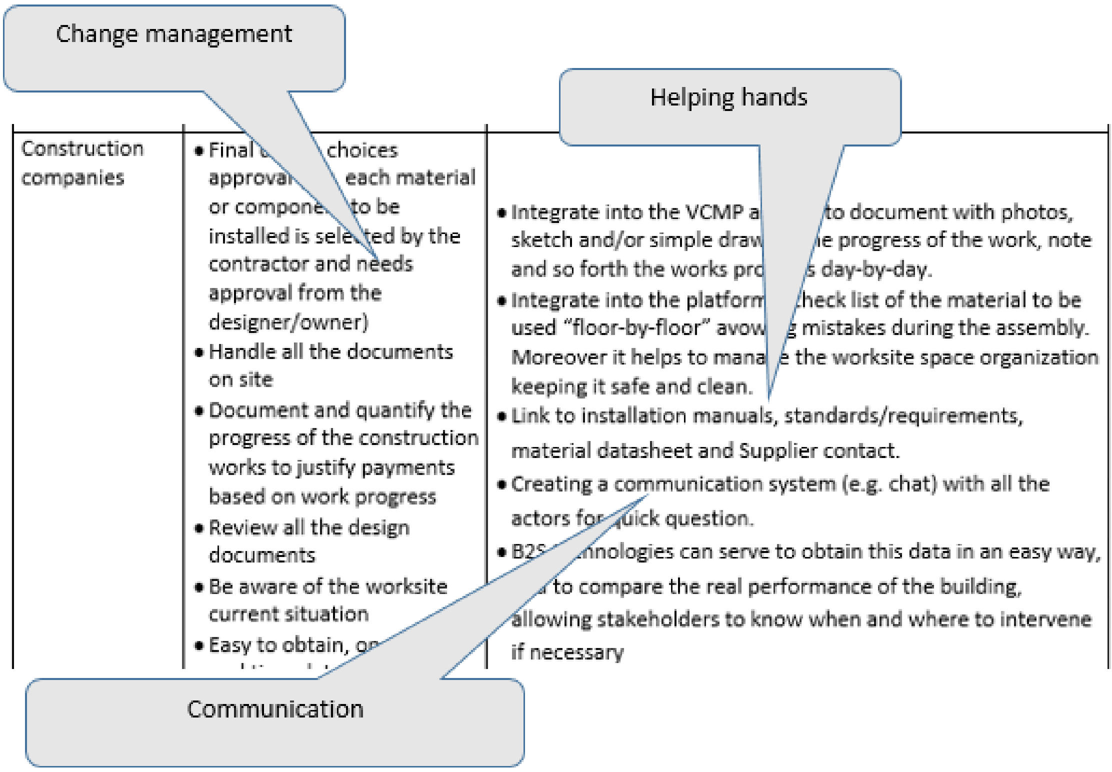
Communication

Quality supervisors	• Quality check, i.e. designed with build. • Supervising that works done in the correct way • Having the last version of drawings and calculations • Contact details and access to the correspondence • Easy to obtain, open, and real time data about the real performance of the construction , structure and facilities systems	Having updated and contracted specifications Possibility to compare designed with build – take photos, add otes and so on when necessary. eate automatic email alarms when something is wrong or build. • C te a SCORE for the quality survey could be useful (e.g. 0 = bac orks; 10 = excellent work). • Online access to the documents and drawings • Access to internet/email and storage of the email in the project folder in the specific trade file • B2S technologies can se e to obtain this data in an easy way, and to compare the re erformance of the building, allowing stakeholders know when and where to intervene if necessary



Reporting

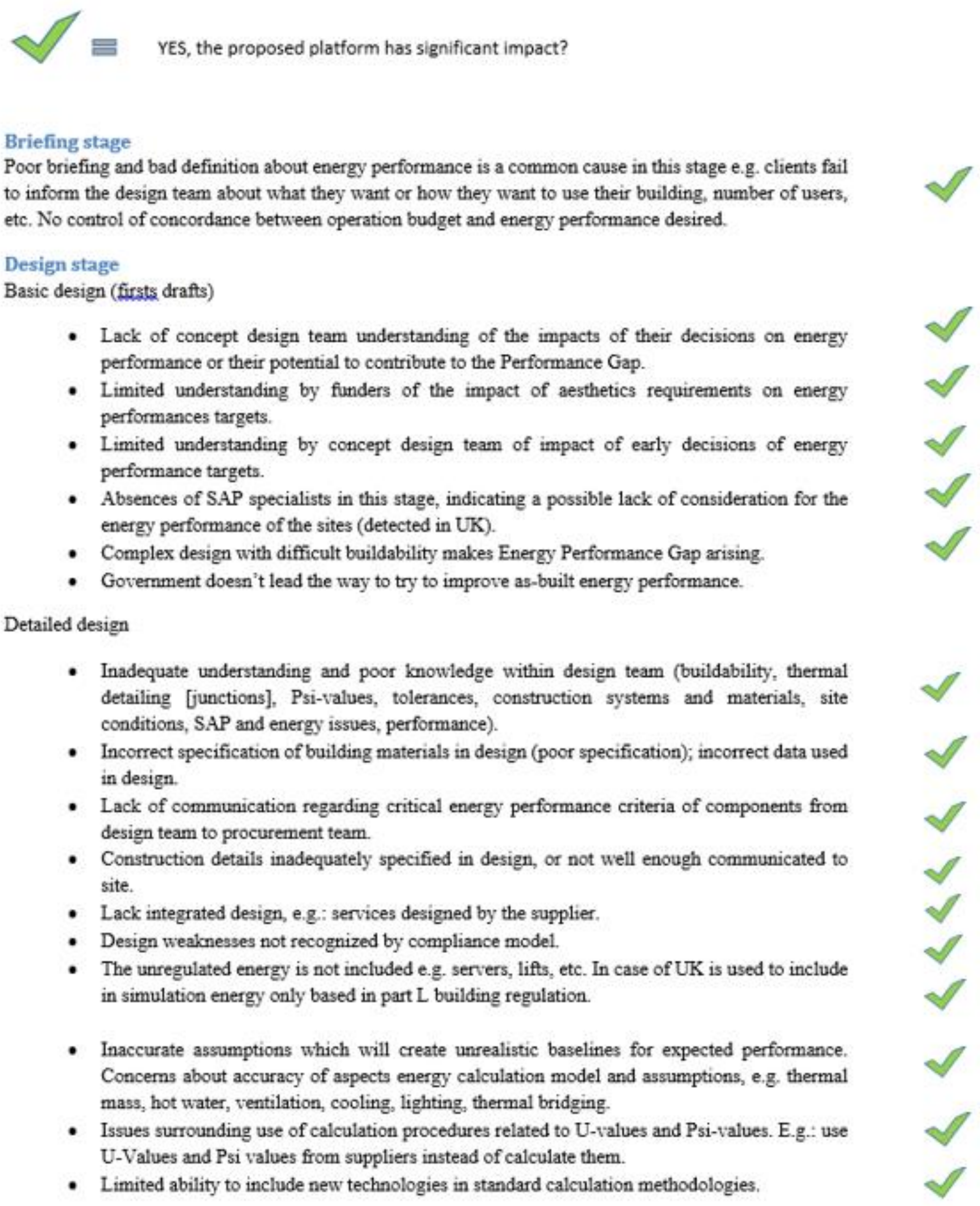
	based on the work progress.	progress simply by using a tool into the VCM Platform. In this way the “cost report” can easily updated and reviewed nding in office.
Funding organisations	Best value for money	Sum ry reports on the construction process and materials used
Users/Inhabitants	• To enjoy the facilities with a certain comfort • High quality construction	Summary reports on the construction process and materials used Access to comprehensive BIM for project visualisation and future renovations



Construction companies	• Final choices approva each material or compone to be installed is selected by the contractor and needs approval from the designer/owner) • Handle all the documents on site • Document and quantify the progress of the construction works to justify payments based on work progress • Review all the design documents • Be aware of the worksite current situation • Easy to obtain, or	• Integrate into the VCMP a to document with photos, sketch and/or simple draw e progress of the work, note and so forth the works pro s day-by-day. • Integrate into the platform heck list of the material to be used "floor-by-floor" avow g mistakes during the assembly. Moreover it helps to mana e the worksite space organization keeping it safe and clean. • Link to installation manuals, standards/requirements, material datasheet and Supplier contact. • Creating a communication system (e.g. chat) with all the actors for quick question. • B2S nnologies can serve to obtain this data in an easy way, to compare the real performance of the building, allowing stakeholders to know when and where to intervene if necessary

Annex C Impact assessment of the proposed platform on the performance gap

Causes of the performance gap from Deliverable 1.2 section 3



✓ = YES, the proposed platform has significant impact?

Briefing stage

Poor briefing and bad definition about energy performance is a common cause in this stage e.g. clients fail to inform the design team about what they want or how they want to use their building, number of users, etc. No control of concordance between operation budget and energy performance desired. ✓

Design stage

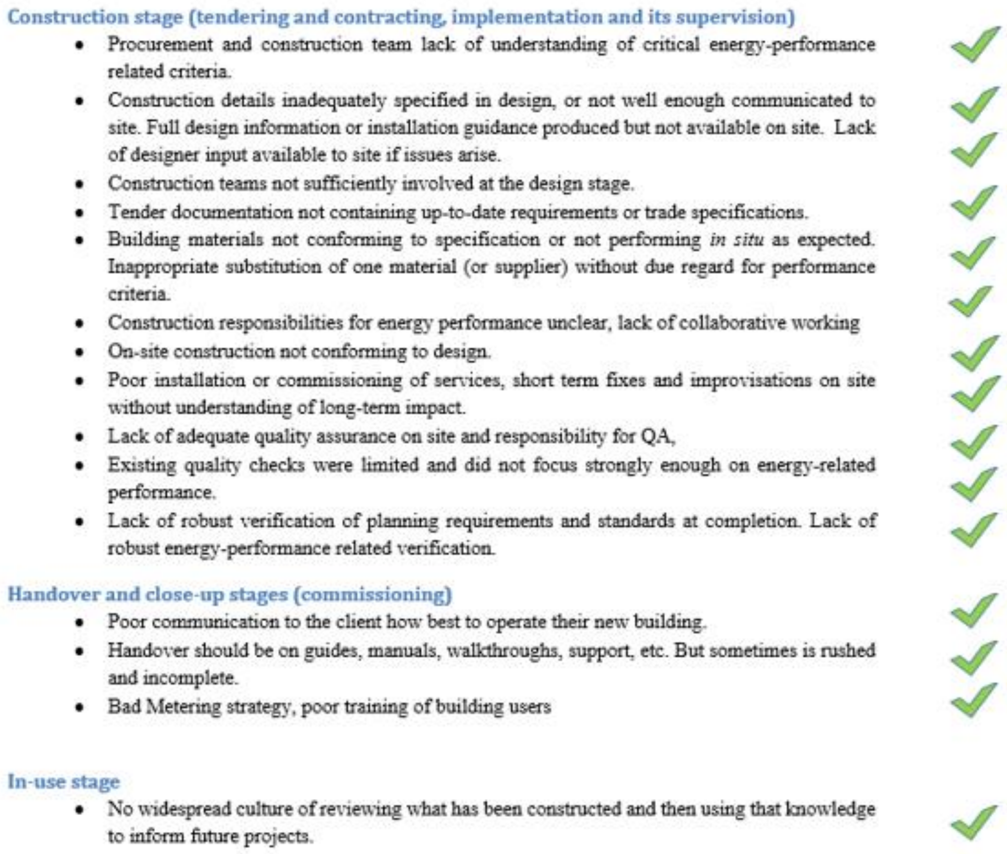
Basic design (firsts drafts)

- Lack of concept design team understanding of the impacts of their decisions on energy performance or their potential to contribute to the Performance Gap. ✓
- Limited understanding by funders of the impact of aesthetics requirements on energy performances targets. ✓
- Limited understanding by concept design team of impact of early decisions of energy performance targets. ✓
- Absences of SAP specialists in this stage, indicating a possible lack of consideration for the energy performance of the sites (detected in UK). ✓
- Complex design with difficult buildability makes Energy Performance Gap arising. ✓
- Government doesn't lead the way to try to improve as-built energy performance.

Detailed design

- Inadequate understanding and poor knowledge within design team (buildability, thermal detailing [junctions], Psi-values, tolerances, construction systems and materials, site conditions, SAP and energy issues, performance). ✓
- Incorrect specification of building materials in design (poor specification); incorrect data used in design. ✓
- Lack of communication regarding critical energy performance criteria of components from design team to procurement team. ✓
- Construction details inadequately specified in design, or not well enough communicated to site. ✓
- Lack integrated design, e.g.: services designed by the supplier. ✓
- Design weaknesses not recognized by compliance model. ✓
- The unregulated energy is not included e.g. servers, lifts, etc. In case of UK is used to include in simulation energy only based in part L building regulation. ✓

- Inaccurate assumptions which will create unrealistic baselines for expected performance. Concerns about accuracy of aspects energy calculation model and assumptions, e.g. thermal mass, hot water, ventilation, cooling, lighting, thermal bridging. ✓
- Issues surrounding use of calculation procedures related to U-values and Psi-values. E.g.: use U-Values and Psi values from suppliers instead of calculate them. ✓
- Limited ability to include new technologies in standard calculation methodologies. ✓



Construction stage (tendering and contracting, implementation and its supervision)

- Procurement and construction team lack of understanding of critical energy-performance related criteria. ✓
- Construction details inadequately specified in design, or not well enough communicated to site. Full design information or installation guidance produced but not available on site. Lack of designer input available to site if issues arise. ✓
- Construction teams not sufficiently involved at the design stage. ✓
- Tender documentation not containing up-to-date requirements or trade specifications. ✓
- Building materials not conforming to specification or not performing *in situ* as expected. Inappropriate substitution of one material (or supplier) without due regard for performance criteria. ✓
- Construction responsibilities for energy performance unclear, lack of collaborative working ✓
- On-site construction not conforming to design. ✓
- Poor installation or commissioning of services, short term fixes and improvisations on site without understanding of long-term impact. ✓
- Lack of adequate quality assurance on site and responsibility for QA, ✓
- Existing quality checks were limited and did not focus strongly enough on energy-related performance. ✓
- Lack of robust verification of planning requirements and standards at completion. Lack of robust energy-performance related verification. ✓

Handover and close-up stages (commissioning)

- Poor communication to the client how best to operate their new building. ✓
- Handover should be on guides, manuals, walkthroughs, support, etc. But sometimes is rushed and incomplete. ✓
- Bad Metering strategy, poor training of building users ✓

In-use stage

- No widespread culture of reviewing what has been constructed and then using that knowledge to inform future projects. ✓