BIMplement

Towards a learning building sector by setting up a large-scale and flexible qualification methodology integrating technical, cross-craft and BIM related skills and competences.

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Report: **extract of :**

D4.6 –implementation of selected pilot field labs and experimental sites

Prepared by: ASTUS, AVE, and all partners

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version table for deliverables

Version 1	Januray 11, 2021	First version

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extract of :
D4.6 –implementation of selected pilot field labs and experimental sites

1. Executive summary

In addition to reporting the implementation of BIMplement training programmes on real construction sites, this report presents the different application cases, the issues and difficulties encountered, and the solutions that have been designed and implemented to overcome them and answer closest as possible the needs of these sites. Each project has been analysed so to extract lessons learned from these experiments.
However, the projects here developed present real projects, includes companies' names and explicitly shows errors done on these projects. For these reasons, the full original report is not open access. Deliverable 4.7 presents the main lessons learnt and proposals for dissemination.

The original Deliverable D4.6 presents, for each partner countries, the results reached in terms of training for each pilot field labs and experimental sites, as implemented during the BIMplement project in the 5 partner countries.
These results are the following : **58 training actions** have been realized, on which

- 49 projects, with training implemented on construction sites
  - 38 new constructions, 437 427 m²
  - 11 retrofitting projects, 223 041 m²
- 9 training sessions, realized in training centres,

and in addition :

- 8 original training programmes and contents have been designed, and tested either on site, or in training centres
- 2 other actions : 1 to develop the design of airtightness BIM models, and 1 to implement public authority coaching to implement compulsory training.

The number of trained professionals : 1462 trainees

- 710 white collar workers, including 480 trained in training centres
- 752 blue collar workers, including 183 trained in training centres

These training sessions have been created/implemented within **17 pilots field labs,** and **45 experimental sites** that have been implemented in 5 countries.

The number of trainees reached is **1462 trainees** : **752 blue-collar workers**, and **710 white collar workers** from building companies, client's team or project managers' teams,
The majority of the blue collar workers have been trained in relation of a real project they were involved with.

The original deliverable is full of important and interesting information because it relates how each partners handled real on-site projects and training implementation, and presents some additional new tools that were not included in previous deliverables D3.4, D3.5 and D4.5. However, because the document contains very private data that concerns companies, architects and projects. In fine, this reason prevailed and partners decided for a confidential status.

This is why the present document has been realised. It presents the methodologies that have been developed and the main results and lessons learnt.

2. Methodology developed for this implementation phase

2.1. Organization & expected production

Three phases are included in this part of the project.

- awareness campaign
- pilot project (on-site or research projects)
- on-site experimental field labs

Their common objective is the improvement of nZEB site work.

These 3 phases are always needed.
However, depending of the cases, awareness campaigns will be quite different depending on the targets that have been prioritized by each partner.
Pilot projects have evolved during the project duration, compared to their initial description. In fact, some new issues appeared which drove partners to propose additional pilot projects.
Finally, a schematic (see Fig.1) has been produced to illustrate the complex relations that have been created and developed within the BIMplement project to settle the relations and productions in the BIMplement project.

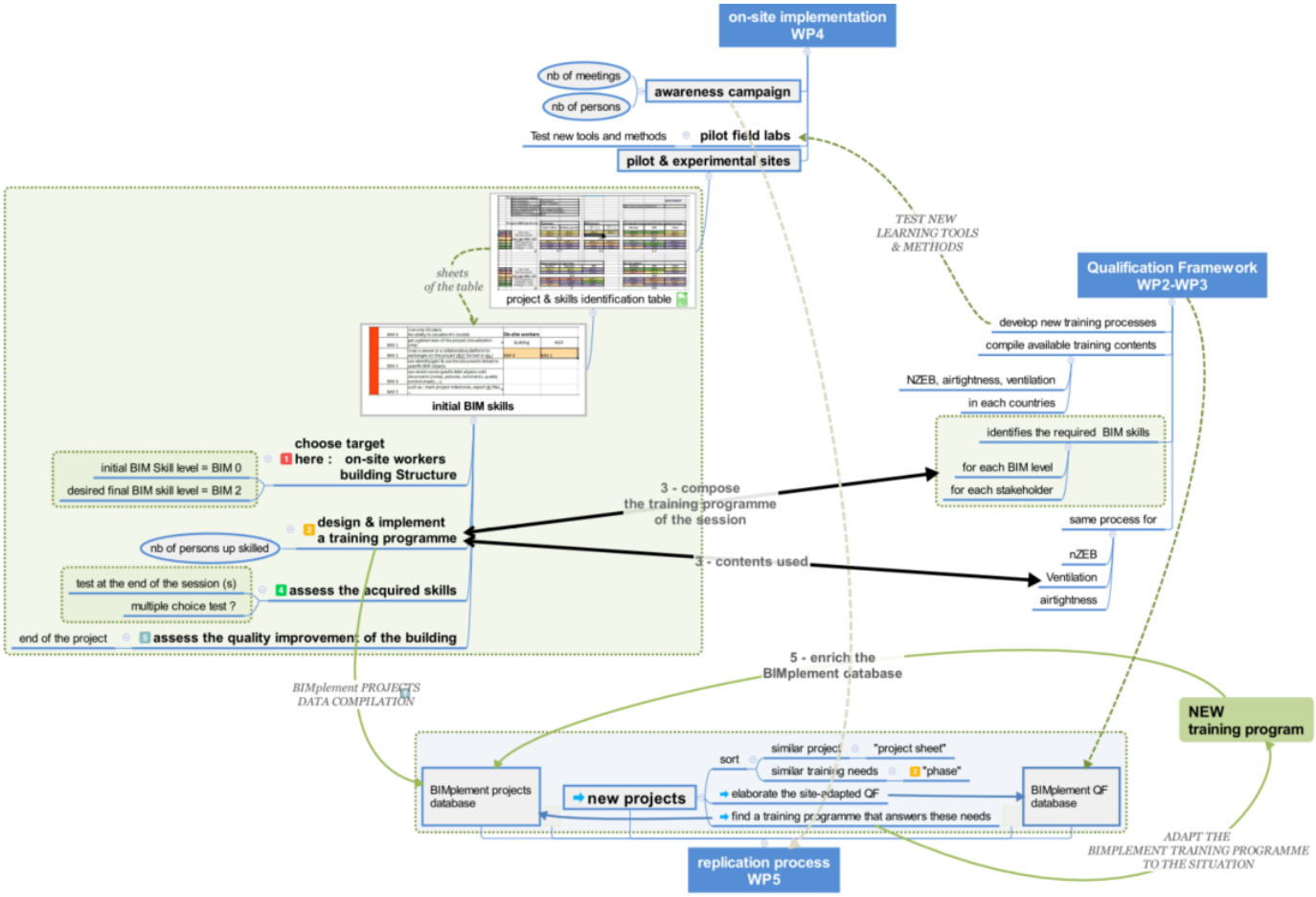

Illustration 1: work scheme that illustrates the BIMplement project functioning

This figure (1) shows the relations and exchanges that have been developed between the BIMplement steps. Before launching the pilots and experimental project, it has been necessary to list the type of skills that are needed for each type of project and for each kind of stakeholders, and the list of tools and training contents that have been collected at the beginning of the project. Then, for the dissemination phase, a set of pedagogical tools and training contents will be available and directly applied to the use of BIM to improve quality of nZEB building

2.2. Awareness campaigns

The BIM maturity level is different in each country, and for each type of stakeholders. The awareness campaign aims to bring/increase knowledge among each country's stakeholders and convince them to use the BIMplement methodology
Each country presents the method that has been implemented to reach the different targets.
A list of the meetings and contacts is drawn up, as well as the number and type of persons reached by these campaigns.
Finally, some recommendation are made per country in order to improve the method and increase the number of persons reached and convinced.

2.3. Pilot and Experimental field labs definition

2.3.1. Description of pilot projects and experimental field labs

Pilot fields labs are the place where have been experimented the tools described in deliverables D3.4, D3.5, and D4.5. These tools have been experimented and validated and/or improved during this phase.

Then, they have been tested full size during the experimental projects so as to check if they are valid in any cases.
At last, each country will be able to draft recommendations and proposals that will constitute the country's BIMplement guide.

2.4. Tools implemented on real projects

Based on the different tools identified in D3.4 and developed in WP4, the pilot and experimental field labs have tested different tools, depending on the sites, and often, depending of the clients' requests.
Two main approaches have been tested :

1) **BIM as a tool for a better implementation of project, and thus, participate in reducing the gap between design and execution phase**
    1) **On site use of BIM models** (D4.5 & §3). The aim is to have all stakeholders to use a BIM process from design to on-site implementation. The objective is to drive all stakeholders, and in particular Blue-collar workers from BIM_Level 0 (sometime BIM_Level1) to BIM level 2. This tool has been used mainly in France and Spain.
    2) **Improve on-site implementation thanks to the development on new skills related to BIMmodels.** This approach have been developed mainly in The Netherlands, Lithuania and Poland.
2) **Improving airtightness and ventilation through hands-on and on site training session. This approach have been developed in France only.**
    1) **On-site and hands-on training on airtightness and ventilation** (§ 4.1.1). Training sessions are implemented inside an especially designed container used as a training centre installed on the construction site.
    2) **Understand a BIM process with the BIM_Mobile container** (§ 4.1.2). Training sessions use the PraxiMobile Container as a full size mock-up to present a BIM model and explain the interest of its use to improve airtightness and ventilation implementation.

For each experimental field labs, the tool (s) to be used are indicated in the chapter headings.

3. Approach 1 : on-site use of BIM models

3.1. Methodology implemented for "on-site" pilot field labs related to BIM use on site

In France and Spain, the strategy has been to involve mostly SME and craftmen in BIMplement. They usually participate in projects in which BIM maturity is low, including for clients and project managers (architects and design offices). BIM models are usually "basic", and often, they are just 3D models that can be exported in ifc format, becoming a basic BIM model with mostly geometrical data and space data. This is why French partners choose to accept projects where there were only 3D models, whether architectural one, and sometimes 3D trade model (ex : Carpentry, Structure, Joinery or MEP).
In these cases, the 3D model has been transformed by the Master trainer, into a BIM model, thanks to an export into ifc format. Then, depending on the case, the model may have been enriched with documents in order to answer specific needs.

In the Netherlands, Lithuania and Poland, the strategy has been to involve large building companies and general contractors whose BIM maturity was a bit higher. The objective has then been

- to adapt designed BIM models for a better appropriation by on-site workers
- to develop and train on-site workers with additional tools related to the BIM model (ie. Quantity take-off)
- to implement feedback and exchanges between on-site workers and BIM modelers.

However, in all cases, the training objectives have been to explain the bases of BIM process on site, and demonstrate the interest of using BIM on site, during the construction phase, and by the Blue-collar workers (not only white collar workers).

3.1.1. How stakeholders are analysed ?

Each project has been analysed, along with the methodology presented in Deliverable D4.5.
- analysis of the stakeholders, and of their BIM and nZEB level (Table presented in D4.5 and in WP5 deliverables)
- analysis of the 3D or BIM model, and improvement of the exported ifc BIM model in order to use it during the different training sessions.

In addition to the analysis of available tools and document, a specific analysis of the stakeholders have been done. The stakeholders have been identified, as well as their relations in terms of BIM.
These relations are presented in the generic scheme here after (see Fig.2). They are represented as links that may appear at different stages of the project.
When applied to each project, a solid line means that a BIM process has been taken into account, and a dotted line means that BIM process is not implemented.

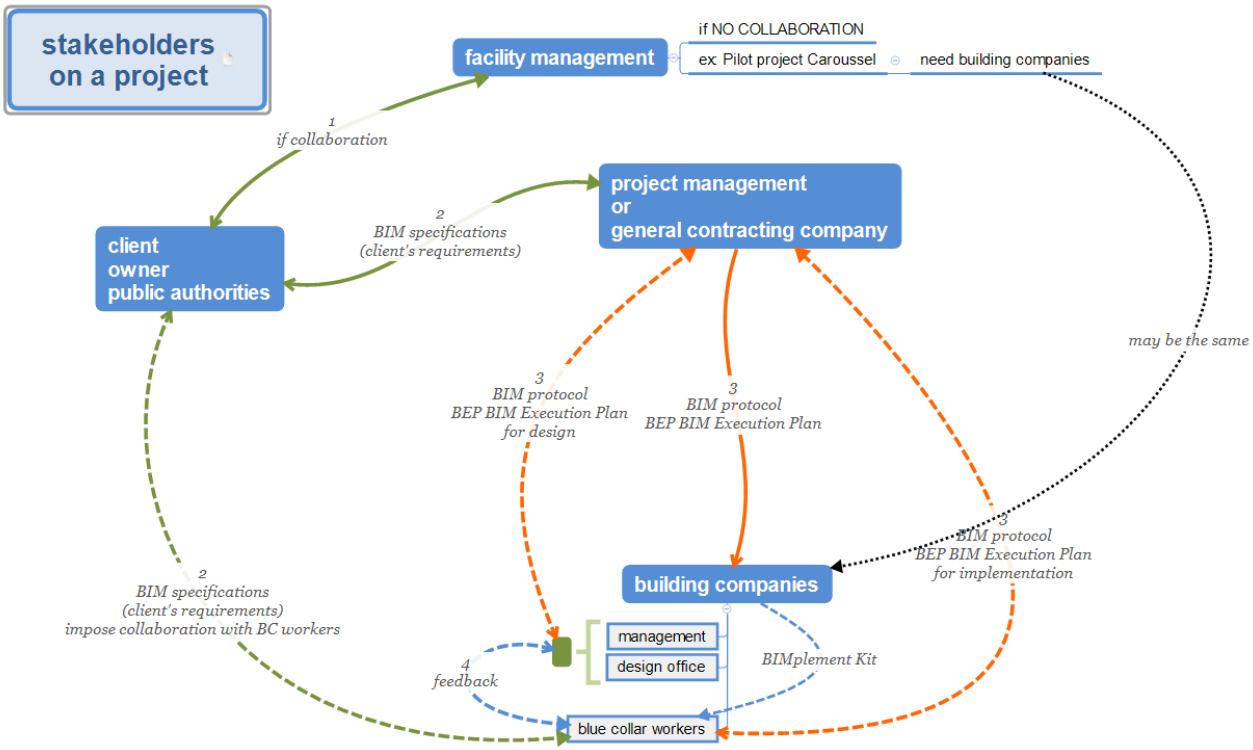

Illustration 2: identification of stakeholders, & links in terms of BIM process

However, this presentation appears quite idyllic and presently, no projects really implement such a process. And in fact, at the moment, the links and relations between stakeholders are much simpler (Fig.3). One of the aim of the training sessions is to explain the importance and interest of these new links, and this explanation has to be given to all stakeholders, from the client to the Blue-collar workers on site.

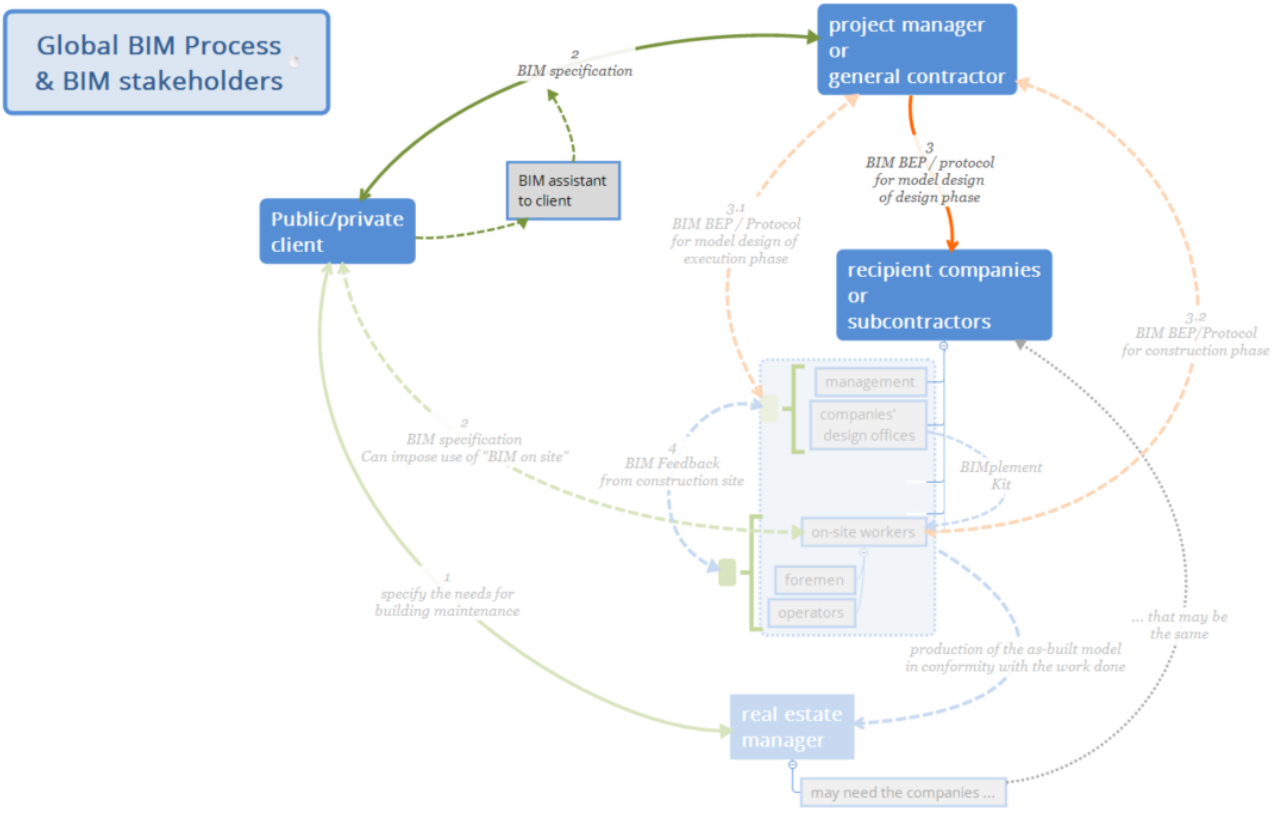

Illustration 3: Schematic of the real present BIM links between stakeholders

The questions underlined by this schematic are :

1. program level of the project

Why does the client request a BIM model ?
What for ? Is it for a better design ? A better implementation ? Or has he a collaboration with the facility manager that will maintain the building with the use of the as-built model ?

2. launching of the project by the client

Did the client drafted BIM specifications to the attention of the project manager ?
What is their level of details ?
Are there specific request in terms of objectives to be reached (nZEB, airtightness, IAQ …) ?
Are there specific request in terms of quality of the workforce, in terms of compulsory skills ?

3. BIM Execution Planning

Did the project manager drafted BIM Execution Plan (BEP) to the attention of the building companies ? What is its level of details ?
Are they actually applicable only to the execution design phase ? Or do they integer on site use of BIM ? Is an as-built model required ?
What are the batches that have to design their own trade model ? Will there be a BIM manager for synthesis ?

4. training of Blue-collar workers within the building companies

Do the building companies implement training session on the use of BIM on site for their Blue-collar workers ?
Is there a feedback organised within the company to evaluate if the data contained in the BIM model are relevant for on-site workers ?

The filling up of such a schematic gives a general overview of BIM process situation, in addition to the level of skills assessed in the “project identification table”.

3.1.2. How projects are analysed ?

3.1.2.1. stakeholders’ BIM level

In most projects experimented in France and Spain, and as shown in Fig.6, the BIM maturity level of building companies Blue-collar workers, but also of white collar office worker is low or very low :
→ BIM level = 0 or 1.
The explanation of this classification is given in Tab.1, which is an extract of the original identification table.

In this very common case, the objective is to drive the companies’ teams trained :

- from level 0 = no BIM knowledge
- to level 2 = ability to visualize a 3D model, exchange with other stakeholders, and to read and link documents to the BIM model

	Construction management/design/supervision team	
	BIM 0	Have no software to create 3Dmodels Can make 2D plans only
	BIM 1	Can use viewers to analyse the project manager’s BIM models
	BIM 2	Can use a viewer or a collaborative platform to exchanges on the project (BCF format or eq.) with the project manager
	BIM 3	Can create a discipline 3D model
	BIM 4	can use the other models (as a background map) to create his own model
	BIM 5	can create a BIM model that answers the BEP requests (geometry, properties, documents), **including the as-built model ?**
	On-site workers	
	BIM 0	Uses only 2D printed plans
	BIM 1	uses a digital tool that compile all the project documents
	BIM 2	Uses a viewer only to get a global visualization of the project
	BIM 3	Uses a viewer or a collaborative platform to exchanges on the project (BCF format or eq.), read attached documents …
	BIM 4	uses the BIM model to check “quality” point on site
	BIM 5	full integration of digital tools on site

Table 1 : training program, second training session in France

In addition, in many cases, additional training sessions had to be given to the clients, and sometimes to the project managers, in order to drive them also to level 2 as a minimum.

3.1.2.2. 3D & BIM models

As previously explained, in France and Spain, the focus has been given to companies that are still far from BIM processes. This means that, in most projects, the quality of BIM models are pretty low.
In fact, there are 3 different cases :

1. 3D Models only
   In this case, the architect has designed his project, based on a 3D model (Archicad for instance). The strategy developed in France by the BIMplement Master trainer has been then :
   - to transfer this 3D project into an ifc format, through the export function of architecture software, to have access to basic data (space, dimensions, level, …)
   - check it and make it accessible to project stakeholders via viewers
   - enrich this basic BIM model with documents (as presented in D4.5) so to improve on-site workers' project understanding and implementation.
2. One BIM model for the project
   In this case, the architect or project manager designed a BIM model, including architecture, and some equipment such as a global ventilation system. There are no additional trade BIM models. What has been done in this case :
   - check the data introduced in the BIM model. Usually, the ventilation system is only indicative and uses generic BIM objects
   - link additional data and documents, for instance : 2D electric or detailed ventilation plans, architectural details,
   - enrich the model with documents related to airtightness and ventilation, in order to improve on-site workers project understanding and implementation.
3. Several BIM models
   In this case, rare in the framework of BIMplement, the BIMplement master trainer has to
   - check the coherence between the different models, and possibly manage clask detection,
   - enrich the models with documents related to airtightness and ventilation, in order to improve on-site workers project understanding and implementation.

These models, whatever their level of precision, are then used to design the different training sessions.

3.1.2.3. BIM related documents

These documents are on one hand, the clients requests in terms of BIM toward the architect or project manager, and on the second hand, the requests of the architect or project manager toward the building companies, and possibly the on-site workers (see Tab.2).

	Client team
Text 0	no requests for any use of 3Dmodels or BIM tools
Text 1	Requests a 3D model , no data specification requested
Text 2	drafted generalist BIM specification
Text 3	drafted BIM specifications including a BIM object table
Text 4	Requests the use of professional BIM software, such as model checkers
Text 5	requests related to the use of a facility manager software (CMMS - computerized maintenance management system, CTM -Centralized Technical Management)
	BIM manager
Text 0	BIM specification ask for the uses of viewers to analyse the models
Text 1	BIM specification ask the BIM manager to manage the stakeholders BIM referents
Text 2	BIM specification ask the BIM manager to draft the BEP

Text 3	BIM specification ask the BIM manager to use a BIM software to check the geometric coherence between the different models (check geometrical conflicts)
Text 4	BIM specification ask the BIM manager to check the BIM object properties answers the requested specification
Text 5	BIM specification ask the BIM manager to draft the BEP
	Project manager Design team
Text 0	BIM specification ask for only 2D plans design
Text 1	BIM specification ask for architecture 3D model design
Text 2	BIM specification ask for 3D models used for a 2D plan export
Text 3	BIM specification ask for 3D model that answer the BIM specification requests
Text 4	BIM specification ask for 3D model that will allow other stakeholders to re-use it
Text 5	BIM specification ask the project manager to check his own model with a BIM software, and check the coherence with the other BIM trade models

Table 2 : client's BIM specification and Project manager BEP requests

This table has also been updated by the end of the project, to be coherent with the new BIM maturity level of skill, and detailed in D4.5.

In most cases, in France and Spain, Clients BIM requirements for "small" projects are level 0 or 1. The aim of French and Spanish partners is to convince all stakeholders that a basic - but correct and coherent - BIM model (instead of 2D plans) is compulsory to reach nZEB quality and efficiency, and demonstrate that such a model is of a great help for on-site implementation in accordance with design.

In The Netherlands, Lithuania and Poland, the large companies' design offices involved in BIMplement have a good BIM maturity. In most cases, on site workers are already using BIM models and the objective has been to improve processes, methodologies, and to adapt tools and feedback in relation with BIM models.

3.2. Lessons learned from "on-site use of BIM modles" pilot field labs

The main lesson learnt from these 4 French on-site pilot labs is : to **get building companies interested in using BIM on the work site** to improve their practices and reach nZEB implementation, all stakeholders have to be involved in a BIM process that is extended and applied to the execution phase, which means that it formally includes building companies.
For each stakeholders, the findings and proposals are given here below.

3.2.1. Clients, owners and promoters

Clients, whether public authorities or private owners, have the means to enforce the use of BIM on site, in order to improve White and Blue-collars' practices and reach requested energy efficiency objectives. This can be done when clients are accompanied to draft BIM specifications to the attention of their project managers that includes :

- BIM use for the execution phase, and not only during the design phase,.
- "Employers Information Requirements" (EIR) to specify the workers' skill level to be imposed on the construction site,
- and if this level is not reached, impose training sessions for all Blue-collar workers involved with energy efficiency, including in-site use of BIM models.

Thus, they can act on a large scale, and allow replication and dissemination of the process. Yet, it takes time to convince these stakeholders that it is worth investing this new technology.

In addition, clients have to improve their skills in terms of BIM specifications to the attention of design teams. In most cases, when BIM process was planned in his project, then:

- either "generic" contractual documents are used and they are not adapted to the project
- or BIM specification are adapted to the project, ... but, in general, for design ONLY, and rarely references are made to future use for property management... "we'll see later !»
- no mention is ever made of the use of BIM on work site by building companies

The proposals consist in improving the BIM specifications quality:

- it has to include an object table, even simple, that implies a questioning from the clients in terms of final use of the BIM model,
- this object table can help the client to make a clear difference between the execution model, the as-built model, and the model for facility management information system
- it has to ask the project manager to give a place to the building companies, during the execution phase, including adaptation of the BIM model for on site use and training for one site workers.

3.2.2. Project managers

BIM models are usually created by designers for their own design use only. In most cases, the client and the project manager were not aware that on site workers had specific needs for BIM models adapted to implementation.

If large French companies are used to design multiple complex BIM models, most French project managers are architects working together with a team of design offices (structure, MEP, HVAC, electricity …). They produce :

- either a 3D model that can be exported in ifc format, and then visualized with a viewer,
- or produce a basic BIM model, according with basic BIM specification from the client,
- or else produce a set of BIM model, in relation with different design offices.

In all cases, these models are intended for the design phase, up to the tender phase. They were never design in the view of being used on the work site for implementation. In most cases, building companies were nor aware of the existing models and were nor shown them.

The findings are the following :

- BIM objects are much too often misinformed and misclassified
- in the BEP, roles and responsibilities of stakeholders are nor clearly established, including for building companies
- when BIM models are transferred to the building companies, there are never any adaptation to the work site needs.

The proposals consist in improving the quality and the contents of the BIM model (s) at the design phase and for the tender:

- respect the clients' specification if existing
- if there is no specification, respect the basics in terms of data (BIM object data, classification, geo-localization, …)
- ensure absolute data consistency between models and tender documents

Then, before the site works starts, designers have to adapt their models for on-site workers to use them :

- simplify the models to let appear only parts of the building,
- add attached documents and instruction guides,
- propose to on-site workers to make feedback on the model,
- let them participate in the as-built model creation.

3.2.3. ***BIM managers***

BIM managers usually depend either on the project manager' team, and sometime on the building companies when they are experimented and wish to manage their own execution BIM models.
In all cases, the skills of the BIM manager and his role is not specified by the client or project manager.
When building companies are low level in terms of BIM, the BIM manager can help them to master the contents of the BIM models, while BIMplement trainers will ensure their skills to use the BIM models.

3.2.4. ***Building companies***

Most French SME have little or no skills and knowledge about BIM (low BIM maturity), contrarily to large ones that have invested this subject well in advance with their design offices. But in France, because they represent a large part of the construction sector, the focus and efforts have to be given to these companies. For this reason also, CONSTRUCTYS is most involved in the project, bringing a financial answer to this training issue.

Several reasons can explain this low level of BIM skills :

- Communication on BIM is mainly about design software
- No communication is made on the interest of using BIM models for implementation phase
- In many companies, executives are not trained to respond to BIM calls for tenders.
- They do not feel concerned, "it is no direct use", "it is additional work" ...

The training proposals to improve the employees' skills on BIM use are hard to take shape:

- Because a majority of SMEs' managers and design offices do not master BIM, they feel all the more reluctant to train their on-site workers. "Information and knowledge is power". So the trainers need not only to develop a technical approach, trainers also need to have a sociological approach when discussing with building companies, and so, convince them to extend training to on-site Blue-collars.
- Companies that are willing to train their design offices on BIM, do not feel to do the same with their on site workers, because company manager consider that operators are not capable enough ! Managers have to be trained first before reaching on site employees.
- It is interesting to notice that, on the other hand, companies agree for FIT training (see §4.1), both because training is made compulsory by clients and is given on the building site, and because companies have been most concerned ever since the implementation of the French regulation RT2012 in which airtightness is an important issue.

The training objectives for building companies are to use (not to design) BIM models instead of 2D plans, because this tool is much more powerfull. The training contents proposed for building companies Blue-collar workers aim to :

- visualize in 3D the work that needs to be done
- be able to communicate/exchange
- have easy access to digital technical documents linked to the BIM objects of the model
- be able to enrich the model with documents to prove the quality of the work on site
- participate actively in the creation of a digital as-built model

In addition, when companies manager or design team need to be up-skilled, a specific training will include an explanation o the concept of BIM process, and on the rôle ans responsibilities of all stakeholders.

However, training sessions are not sufficient to change practices :

- if possible as during BIMplement, training has to be applied to the real project implemented by the trainees, and so that they can directly apply the contents to their own experience on the project. Trainers may have to enrich the BIM models to make it more pedagogical.
- For SME, change practices and use BIM, in particular on a working site, is a real and hard challenge. Present and explain tools and process is not sufficient. They need a step-by-step support, by the client and the project manager who have to be convinced of the interest of it, or by a person appointed to do it (BIM project management or Contracting authority assistance).
- On-site workers will be much more willing to modify and improve their practices if they are considered as recognized stakeholders.
- Most of these issues can be managed in return of an important investment and involvement of the BIMplement coaches, and of master trainers and trainers.

3.3. Lessons learned from the "on-site use of BIM models training sessions

In addition to the first pilot field labs feedback (§3.2), a few more elements have been identified:
- awareness campaign are compulsory due to the low BIM information level of companies,
- clients are a key stakeholders, they have the authority to improve the whole and global BIM process that effectively includes building companies,
- communication has to be greatly improved to enlarge its comments in order to explain why and how building companies can be involved in a BIM process,
- training for companies have to be adapted to managers, on one side, and to blue-collar workers on the other side. Managers need to understand what means a BIM process and to be able to use viewers. From the BIMplement experience, 2 days training are necessary. Blue collar workers need to be able to visualize BIM models and to use viewers tools. It takes one day to reach this goal, but it is necessary to distribute the training into 1 or 2 hours sessions.

An extensive version in given in D4.7.

3.4. Research pilot field lab 2 : project "BIM model for airtightness"

3.4.1. The airtightness BIM issue

The BIM process that creates BIM models is adapted to almost any kind of construction system and building issues … and allows a much better representation of almost any kind of construction material, products and structures than 2D plans … but for airtightness !

Yet, this question is a central point to ensure a high energy efficiency quality of a building. In fact, two issues are related to this point :

1. there exist NO IfcObject related to airtightness. This means that, contrarily to ventilation for which it is possible to list and assemble any IfcObject that constitute the whole ventilation network, it is not possible, at the present time, to design a BIM model that includes airtightness solutions.
2. Airtightness comes within competency of a lot of different batches in a construction project : structure, plumbing, joinery, ventilation, electricity, HVAC, ...

An attempt has been made using the IfcOpening. This IfcObject is used by many BIM modeler in order to create holes with an object. For instance, create a hole to let the place to a duct or pipe, or to create a window in a wall. The aim was to link to this object any information related to airtightness. Unfortunately, these objects are not visible with most of the viewers. And when they are, most linked data disappear. Another solution had to be designed.
Within the BIMplement project, the research pilot project to be developed and then tested on several real construction site in France, and by the French BIMplement partners aims at creating a specific BIM model centred on all airtightness issues and at giving access to it to all on-site Blue-collar workers in order to bring them any information they need to implement products and material that may affect airtightness quality.
This project has been presented on BUILD-UP (https://www.buildup.eu/en/news/bimplement-project-greater-energy-efficiency-using-bim-airtightness-model) and Cordis Sites.

3.4.2. Process to create the airtightness modelling

The main issue of this BIMplement experience is to collect and integer in on-site BIM model that will be use by on-site operators any material/products/solutions to airtight a building.
During the development of such a project, several phases have been implemented, with the help and participation of all stakeholders :

1. the project manager (architect or design team) designs a BIM model, in which standard solutions are given to answer the airtightness issue. Attempts to take this issue into account has been given in 2011 (https://www.effinergie.org/web/index.php/49-premeabilite-a-l-air/permeabilite-a-l-air-du-batiment/932-documents-sur-la-mise-en-oeuvre-de-l-etancheite)
2. then the companies that answer a call for bid produce technical details (with the possible help of a manufacturer), including name of the products to be used. These explanations are part of the bid choice process.
3. at last, the chosen building company or the project manager simplifies the original BIM model for his site operators (§4.8.3). This phase has been greatly accompanied by the BIMplement partners, mainly by the French master trainer. In addition, training has been implemented both for the managerial level and for the site level, by the French BIMplement partners, to explain how to use and enrich a BIM model.

3.4.3. The design process of an airtightness BIM model

The design of a specific BIM model dedicated to airtightness requires the following steps :

1. check the quality of the BIM models and minimize all conflicts between models : structure, carpentry, joinery, MEP, electricity ...
2. identify all airtightness weak points, that usually depends on different batches, and that need to be treated (a mind map presents these points in D3.4).
3. establish detailed airtightness solutions to answer each of these issues (adapted products, technical design and implementation details, implementation instruction guide, sketches, videos, …). During the BIMplement experiment, this step has been done with the help of ILLBRUCK company, specialized in airtightness solutions,
4. extract, from the original BIM model, a “simplified” model where, for instance, Becoming actors, deleted as many elements as possible that are not related to airtightness weak points,
5. integer these data into the airtightness BIM model and enriched with attach technical files (documents, notes, pictures, technical guides, quality control sheets, ...) for a better implementation of airtightness on site . These elements have been adapted to all craftsmen and

trades involved in airtightness issue.

For instance, in picture 4, documents have been linked to the window-BIM-object : one pdf technical document, one video, and one quality control sheet to be filled by operator.

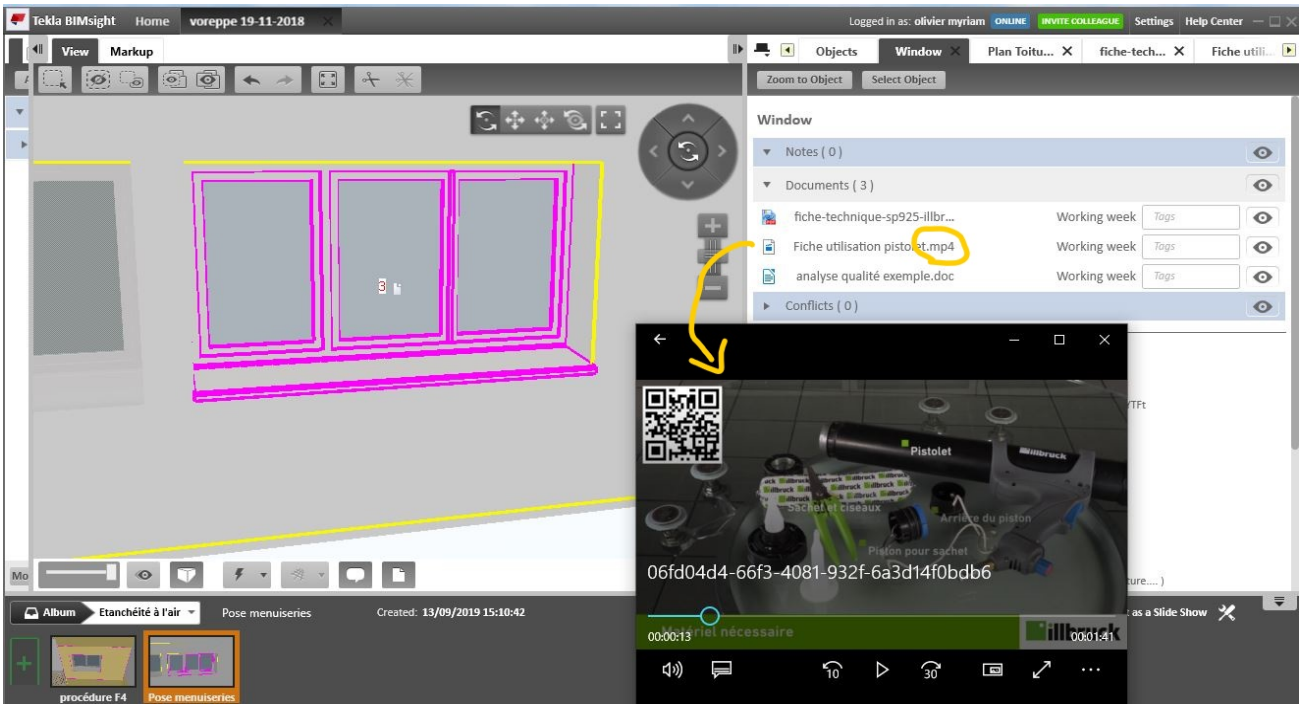

Illustration 4: 3 attached documents to answer a window airtightness issue

3.4.4. ***Implement the airtightness model on site***

The on-site use of BIM model training is of course needed previously to this phase.

1. Basics on BIM model ise : train the Blue-collar workers on how to visualize the projects with freeware viewers, train the Blue-collar workers to open documents attached to the model, to exchange with other stakeholders with notes, to attach a picture, to fill up a linked control quality sheet …
2. train the Blue-collar workers to manipulate the products and materials and implement full size and on-site the solution. This part has been done with the help of the ILLBRUCK company. Such a training can be done with the help on on-site& hands-on training as presented in the previous chapter §4.1,
3. make the link with the documents and data of the airtightness BIM model,
4. control the building airtightness quality during the construction phase, which means ask the operators to take pictures of implementation and link them to the BIM object in the model, and fill up control quality sheets from the BIM model.

4. Approach 2 : hands-on and on-site training for a better airtightness implementation

4.1. The PRAXIBAT & BIM-PRAXIBAT mobile center

4.1.1. ***Objectives & methods of the original PRAXIBAT mobile training centre***

The objective of this pilot field lab is to use the mobile training centre (PraxiMobile) to improve workers' on-site skills and practices on airtightness and ventilation. These experimentations are

conducted in projects situated in Northern France, where this original PRAXIBAT mobile centre is located.
However, different other French regions are having discussions to rent this container and implement similar training sessions.

4.1.1.1. Presentation of the original PRAXIBAT mobile training centre

The principle of the PRAXIBAT mobile centre is to operate practical training sessions directly on the construction site, because the airtightness issue is still not concrete and clear to most workers. During the BIMplement project, a container with real and full size airtightness solutions, presented in a container, is installed on the construction site (see Fig.5 &6).

Illustration 5: The PRACTEE mobile training container

Illustration 6: airtightness training inside the mobile PRAXIBAT centre

This pedagogical approach has been implemented on different experimental sites in the Hauts de France Region during the BIMplement project.

To implement on site this experimental approach, a specific financial support has been brought by the national PACTE programme called “FIT – Formation Intégrée au Travail” (worksite integrated training).

4.1.1.2. The training contents for on site workers

The training sessions take place on the construction site and last 15 hours, 7 of them in the mobile container. 4 sessions have been designed :
- 2 sessions are common for white and Blue-collar on-site workers.(module 1 and 4)
- 1 session is dedicated to on site managers (module 2),
- and only site operators take a session in the container (Module 3).

In the end, on-site workers training sessions last 15hours, and site managers training sessions last 11 hours.

Table 3 shows the content and breakdown of the training session.

Module	Contents of the FIT training session	Duration / Participants
Module 1	Topic : Basic energy efficiency awareness - Understand the importance of airtightness - Explain the thermal regulations and labels	Duration : 4 hours → **room on construction site** Participants : site operators, foremen, site manager
Module 2	Topic : site manager coaching about airtightness - Implement a technical monitoring of the construction of an airtight envelop - Communicate about an nZEB project - Design and improve "airtightness architectural details".	Duration : 7 hours → **room on construction site** Participants : foremen, site manager

Module 3	Topic : practical training for operators - Acquiring good practices on airtightness - Learn the different options technical - Understanding the strong and weak points of the constructive systems	Duration : 7 hours → **container** Participants : site operators, foremen,
Module 4	Topic : assess the work quality - Analyze the airtightness test report - Evaluate the airtightness test results - Learn the appropriate technical solutions to achieve the desired objective	Duration : 4 hours → **room on construction site** Participants : site operators, foremen, site manager

Table 3 : framework of the FIT training sessions inside the mobile PRAXIBAT centre

In the PRAXIBAT Mobile center, airtightness is the main subject of training. The trainees test products and material (seal, membrane, reinforcement band, impregnated joint sealing tape, ...) to treat different types of interfaces between joinery- structure (wood, concrete, masonry, …) and around ventilation and electrical ducts.
In addition, several ventilation mock-ups are explained to the trainees.

The expected impacts concern the following points :

- easier access to training for Blue-collar workers
- better quality of airtightness implementation

During the BIMplement project, this original device have been be tested on more than 20 experimental field labs (see § 4.2 and following).

4.1.2. The second version of the mobile training center, equipped with BIM

4.1.2.1. Description of the second version of the container

The pilot project also concerns a second version of a device designed from the original container. The aim of this new device is to train on the use of BIM on the work site, for site workers. The BIM training is based on the container BIM model so that trainees can see in the same time the BIM model and the final structure (see Fig. 7). The container and the BIM model focus only on airtightness and ventilation. All physical and technical solutions for both subjects (airtightness and ventilation) are presented in the container BIM model, and the BIM model includes all needed technical documents such as technical drawing, implementation documents … as presented in the pilot project “BIM model for airtightness”, §3.4.

Compared with the pilots projects where on-site use of BIM models is experimented, the training session realised with this new container is a different pedagogical approach on “how to use BIM to better implement airtightness and ventilation”.
This device merges two approaches for the site workers:

- get good practices and skills for on-site implementation of an airtightness BIM model,
- understand the interest of a BIM model enriched with documents through the physical visualization of the container.

4.1.2.2. Detailed presentation of the BIM version of the container

FIG 7 show a view of the BIM model of the mobile training container.

The definition level of this BIM model is the BIM level 2, integrating IFC format. To achieve the

level of detail of the BIM training model, the requirements of the GID sheets in the BIM EIR guide for Luxembourg have been implemented.

- The level of construction (or G Level) is sufficiently detailed and documented to serve alone as a basis for the site to carry out the work, ie the G400 development requirements.
- The level of detail of the information contained in the BIM training model (or I Level) is LOD350. All objects, elements or information are available and one have full access in the model to the real information on the products and works implemented. Idem for the level of detail of the documentation included

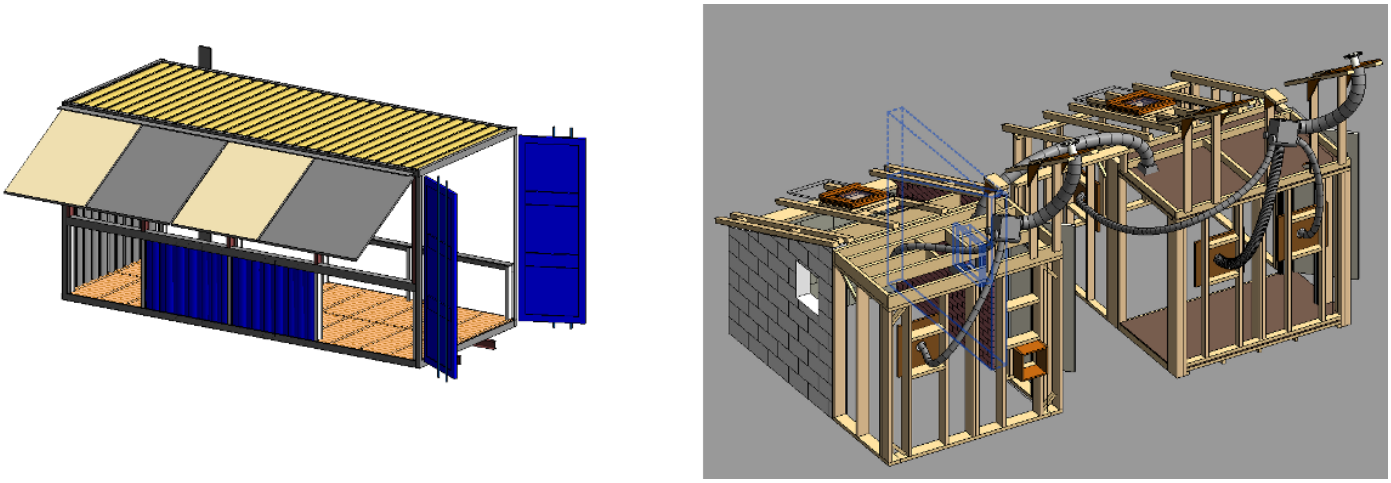

Illustration 7: BIM model of the original mobile center BIM model of the second training centre version

The BIM training model aims at a GID 444 level, with the exception that it does not include study reports (soil study, thermal study, …).

Two types of training programme have been designed, based on this device :
- improve airtightness and ventilation skills, while learning how to use a BIM model without realizing it (§ 4.1.2.3)
- efficient use of a BIM model to improve airtightness and ventilation(§ 4.1.2.4)

4.1.2.3. Improve airtightness and ventilation skills, while learning how to use a BIM model without realizing it (main target : site operators)

Experimental field labs shows that it is not so easy to get on site workers to improve their practice, related to their own trade. So, it is easy to understand that digital transition is far away from their concerns. The approach here developed aims at introducing BIM and use of BIM model …. without saying it clearly.
The training content is focused on airtightness and ventilation practice, and is identical to the "original container programme", described in §4.1.1.2. The difference lies in developed pedagogy: during the sessions given in a room on site, the trainer shows all data and information linked to the container BIM model, instead of presenting paper documents, slide shows, pictures …
This pedagogy is implemented in modules 1 and 3 for operators. The same pedagogy is implemented for site managers and foremen, modules 1 and 2. Module 4, return of experience stays the same.

4.1.2.4. Efficient use of a BIM model to improve airtightness and ventilation (main target : site manager)

The container is presented as a micro building, in which trainees are introduced to BIM by studying its BIM model. This programme allows the training of site workers when the project is not a BIM project.
The training contents aims at an efficient use of BIM, for site operators including site manager

and foremen. It is also implemented on site. Four sessions have been developed, addressed either to site management and to operators, or separately to each of them (see Table 4).
In the end, the training sessions aims to bring site workers, and especially site managers and foremen to BIM_level 2, as specified in §3.1.2, and contents are similar to those presented in D4.5, annex 2.

4.1.2.5. Presentation of the generic training sessions with the BIM-container

The training contents aims at an efficient use of BIM, for site operators including site manager and foremen. It is also implemented on site. Four sessions have been developed, addressed either to site management and to operators, or separately to each of them (see Table 4).
In the end, the training sessions aims to bring site workers to BIM_level 2, as specified in §3.1.2, and contents are similar to those presented in D4.5, annex 2.

Module	Contents of the FIT-&-BIMplement training sessions	Duration Participants
Module 1	Topic : presentation of the BIM process concept - BIM process mapping - Understand the importance of a BIM model - Visualize the performance link between a site model and energy issues	Duration : 4 hours → **room on construction site** Participants : site operators, foremen, site manager
Module 2	Topic : basics about nZEB and airtightness performance - Implement a technical monitoring of the construction of an airtight envelop - Communicate about an nZEB project - Design and improve "airtight architectural details".	Duration : 7 hours → **room on construction site** Participants : foremen, site manager
Module 3	Topic : airtightness complementary approaches (BIM & practice) - Acquire and validate good practices - Learn how to use on site a BIM model with a tablet / smartphone for one's batch and how to archive evidence of good implementation	Duration : 7 hours → **container** Participants : site operators, foremen,
Module 4	Topic : assess the work quality - Learn how to use a collaborative platform - Assess the appropriation of business models and of associated evidence of good implementation - Assess the improvement of air tightness and ventilation level - Learn the appropriate technical solutions to achieve the desired objective	Duration : 4 hours → **room on construction site** Participants : site operators, foremen, site manager

Table 4 : framework of the FIT&BIMplement training sessions

Additional training sessions can be implemented in the "original" container to get to a higher airtightness level through a hands-on training.
In the same way, additional training sessions can be implemented to improve the BIM skills obtained in the original container training, by applying them to a real BIM project.

4.1.3. Feedback, presented in Module 4

All training sessions realized along with the "original" container are done early enough for the building to be completed within the BIMplement schedule. Most of these projects specifications ask for a compulsory blower-door test upon completion. For these projects, a direct feedback is

realized with all stakeholders, in particular clients and building companies. Module 4 is dedicated to the presentation of this feedback and blower door test results to the site operators, and thus, confirm the skill improvement.
A similar feedback is expected on the "container+BIM" training in order to assess the improvement of results in terms of airtightness level of quality. When these tests were conducted before the end of the project, then a direct feedback has been possible. Or else, anyway, the client and project manager are able to check if the airtightness requirements have been obtained more easily or not, and if BIM have been an efficient additional tool.
As presented in the following chapter (§3.4), one optional objective is to design a specific airtightness BIM model for the project, that includes all documents the participants to module 4 feel necessary to add. This list of documents can be done from training sessions feedback.

4.2. Common explanations about "on-site and hands on airtightness training " (FIT)

All the following projects have been implemented in France only, in the **Region Hauts de France**. All of these projects have been initiated by one of the local Employment houses (Maison de l'Emploi), whose name is given next to the project title.
The training programme is identical in all cases, unless explicitly specified, and is presented in Table 3.
All training sessions received a financial support from CONSTRUCTYS, and a record is kept of all training session realized and attendance sheets for all these sessions.

An important point to be noticed for this original training process is that it took a great amount of time to each MdE BIMplement coach to implement these project. A precise enquiry done with the LLHC[1] Employment House makes explicit the time spending for each FIT project ;

- preparatory phase, before the call for bids :
  - administrative project management work → 2 days
  - choice of the project with the client → 1 to 2 days
  - adaptation of the call for bid to include the FIT process → 1 to 1,5 days
- on-site implementation of the project
  - participation to site meetings to explain the training programme → 1,5 to 2 days
  - organisation of the training sessions and validation by client and companies → 1 to 2 days
  - implementation of the session itself → 1 day
  - final assessment → 1 day

On these project, the BIMplement coach is the facilitator that accompanies the client as well as the building companies, and it includes picking up the trainees for their workplace on the construction site.

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4.3. Lessons learned from the container training sessions

Airtightness is a real and accurate indicator for building quality. In fact,
In addition, the blower door test value is an important data for nZEB building energy consumption. This value is also a data that is included in thermal calculation software. Its impact is very important when dealing with low energy consumption buildings.

Once clients get aware of this impact, they clearly understand the need for a better practice from operators, and are more likely to improve on-site training to building companies.

Building companies are, as usual, reluctant to “waste” 1,5 day work for training. But once the end of the training session, they understand that they need to upgrade their knowledge about airtightness and are much less reluctant to send their employees for training.

In the end, when an airtightness test is performed, **the results is always much better than expected**. This results drive the clients to recommand the on-site and hands-on training to improve building companies employees airtightness practices

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