

RenoBIM: New tools for the competitiveness of timber construction

Asier Mediavilla
Tecnalia R&I
Bilbao, Spain



1. Context: why RenoBIM

During the last century most industries have been deeply transformed by technological progress, leading to a noticeable increase in productivity. However, this has not been the case in the construction industry, which remains as one of the least productive and digitalized, mainly due to the fact of its fragmentation. A huge number of companies with different skills and roles are involved throughout the life-cycle of a building, mainly (>90%¹) Small & Medium Enterprises (SMEs). This leads to a lot of manual and poorly coordinated processes, which lack industrialisation and automation. Many processes are not replicable and predictable.

The adoption of BIM (Building Information Modelling) offers an opportunity to reverse this situation. A digital model of the building guarantees more accurate data and better decisions, with significant time and cost savings. Together with prefabrication and robotization it is the basis for the Construction 4.0 paradigm. However, BIM is still mainly applied to new designs and less adopted for fabrication and construction phases and for retrofitting processes. Additionally, BIM software is still perceived as expensive, which requires investment in training and skills, only affordable by big companies.

RenoBIM tool, developed in H2020 funded BERTIM project, aims to overcome these barriers and demonstrate that BIM can be tailored to small companies' needs and enhance their competitiveness by optimizing their processes and enabling efficient collaboration with other companies. It has been applied to the energy renovation using prefabricated timber panels.

The main goal is to speed-up the early decision-making, identifying the most efficient façade renovation alternative, following the methodology created in BERTIM project:

- Check the project feasibility considering legislation, structure or building geometry.
- Laser scanning and BIM model creation (in-house or subcontracted, depending on the skills and resources).
- Energy simulation of renovation alternatives and identification of the most suitable product to use from the manufacturer's catalogue.
- Quickly design the façade splitting layout and export to CAD/CAM tools for final design for fabrication.

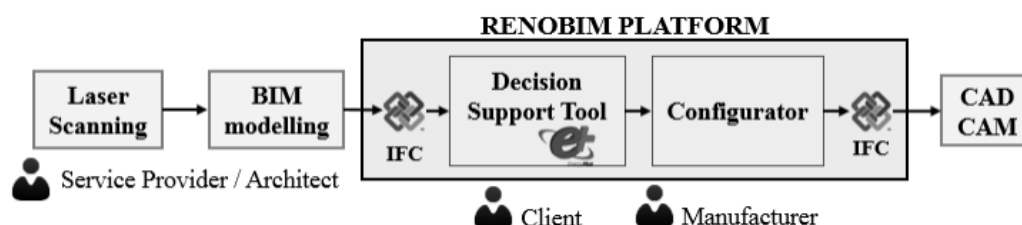


Figure 1: Overall RenoBIM workflow

This can only be achieved through Open BIM formats like IFC, the main standard for data exchange between BIM software tools. It makes the solution independent from any specific commercial software, thus with higher market potential. Additionally, the use of IFC has made possible to implement very innovative features, such as automatic running of energy simulations using Energy Plus, web visualization of BIM models, properly geo-referenced and a 2D drawing module, which produces a design exported to IFC.

RenoBIM can be used in different collaboration workflows between clients and manufacturing companies, based on IFC file exchanges. Depending on the project type, objectives and available data different usage scenarios are possible following the previous steps. The functionalities are grouped into two modules: Decision Support Tool (DST) and Configurator.

¹ Annual Report on European SMEs 2016/2017 (European Commission)

2. RenoBIM DST module

DST module supports the early decision making, by providing a cost-benefit analysis of potential renovation alternatives from an energy savings perspective. It is targeted as a marketing tool of the manufacturer to attract potential clients' interest by enabling them to estimate the savings using the timber panels of the catalogue. But it could also be used by manufacturers themselves to estimate the potential of their products.

Step 1: project context

The user specifies the context of the building: location, typology and use (single-family house or apartment block), age and other aspects. Currently, RenoBIM is only customized for residential buildings, since this is the targeted market in BERTIM project, but it can be extended to other buildings, adapting the database and the simulation templates.

Step 2: feasibility analysis

The user can check if the renovation of the building is technically or legally feasible with the manufacturer's technologies, considering the project context. Two types of restrictions are implemented. Generic BERTIM constraints include legislation (possibility to extend the building, to modify the façade or use timber for instance), type of structure or the status of the building, among others. They are always applicable. Specific constraints from manufacturers may include aspects like geometry complexity, free distance around, etc. Once the values for the building under analysis are entered, a feasibility check is run, and results displayed in a colour code indicating the fulfilment degree.

Restrictions

Please, fill in the following values for your building:
If you don't want to check a restriction or you don't know the value select "Don't check" :

Global restrictions of BERTIM process

ID	Name	Description	Category	Value
24	Structural typology type	How is the structural typology?	Structure	Timber/concrete structure supported by load bearing masonry
25	Presence of structural pathologies	Has the building relevant structural pathologies?	Structure	No
26	Maximum height between floors	Check the maximum height between floors	Structure	Not higher than 3m
27	Roof typology	Check the typology of the roof	Structure	Pitch without slab under the roof
31	Extension of façade	Can the façade be modified/extended according to the legislation?	Legislation	Yes

Feasibility check

Run feasibility check

Feasibility test failed!

LIST OF FULFILLED RESTRICTIONS:

ID	Restriction	Category	Target Value	Actual value
24	Structural typology	Structure	Equal to "Timber/concrete structure supported by load bearing masonry" OR "Reinforced concrete framed structure: concrete beams (edge reinforced), columns or slabs"	"Timber/concrete structure supported by load bearing masonry"
25	Presence of structural pathologies	Structure	Equal to "No"	"No"
31	Extension of façade	Legislation	Equal to "Yes"	"Yes"
32	Use of timber frame	Legislation	Equal to "Yes"	"Yes"
26	Maximum height between floors	Structure	Equal to "Not higher than 3m"	"Not higher than 3m"

LIST OF NOT FULFILLED RESTRICTIONS:

ID	Restriction	Category	Target Value	Actual value
3832	Hauteur Immeuble	Building geometry	Less than or equal to 5	6

Figure 2: Checking project constraints and running feasibility check

Although this functionality could be used by both the manufacturer and the building owner, feedbacks obtained during the validation of the tool suggest leaving it as an internal feature for the manufacturer because a building owner has no knowledge about manufacturers' products and processes, thus manufacturer should double-check clients' answers and review the results. Additionally, instead of filtering too early potential market opportunities, it is better if manufacturers double-check by themselves the feasibility of the project.

Step 3: building model creation or import

RenoBIM relies on a building model to carry out its cost/benefit analysis. At this point, similarly to previous steps, it is flexible enough to adapt to different starting situations. For example, when no more data is available, the user can manually define the basic parameters of the building (such as number of storeys, orientation, glazing ratio, shape type and basic dimensions, as well as shadowing or adjoining buildings' position and height) and a virtual building geometry is automatically created. This can be done by the building owner even before contacting the manufacturer or when the project feasibility is still unclear.

In a more advanced case, RenoBIM can automatically import a full BIM model in IFC format and process the geometry. This can happen when a contract is already done or when the owner has already a BIM model (not frequent for residential buildings). In any case (simplified virtual or detailed BIM) the model is converted to a web 3D format (using Cesium libraries) and displayed in RenoBIM.



Figure 3: Parametrically created geometry (left) vs imported IFC model (right)

The principle which should always be followed is to be able to reuse the same BIM model for different purposes. In this case of BERTIM the two main uses are: first, to serve as a detailed reference for CAD/CAM tools where to install the prefabricated panels and second, to serve for energy simulation.

For the first case, a guideline was produced on how to properly scan and model the building envelope and how to deal with aspects like openings, salient, etc. For the second case the guidelines include recommendations on how to create the internal spatial partitioning of the building. Only dwellings and common spaces have been modelled, not individual rooms inside each dwelling.



Figure 4: Point clouds (left), modelling of envelope (centre) and creation of spaces (right)

Step 4: conceptual energy and cost analysis

The final step in the DST is the simulation of different renovation alternatives and a comparison with each other and with the current situation of the building. The user indicates the type of envelope components (external walls, roof, windows and floors) in the building, if they have any insulation and inertia. Usually these aspects depend on the construction year, building typology and location. Then, the façades to be renovated must be selected. Each renovation alternative consists on adding to the current façades an extra layer, which corresponds to each of the timber panels in the manufacturer's catalogue (or variations in thickness and finishing of the same panel). Physical properties of the panels must be defined in the RenoBIM database, especially the thermal transmittance, as well as the unitary cost.

Based on the geometry and the thermal properties of both the existing building and the timber panels, RenoBIM automatically creates an input file for Energy+, one of the most popular and reliable energy simulation engines. The two main innovations offered by RenoBIM DST are:

- Use Energy Plus for both detailed approach (imported from IFC) and simplified approach (parametrically created geometry).
- Automatically run parallel simulations for each alternative, with no user interaction.

The first point provides a very flexible and robust simulation approach, using the same engine for all phases, adapting it to different levels of detail of the inputs (real geometry vs procedurally created). Since the same engine is used, the results are comparable. The second point allows using powerful dynamic engines by non-experts.

The Energy+ generation algorithms are based on previous research activities of Tecnalia in several EU projects².

Finally, an approximate cost and return on investment is calculated considering the total area covered by timber panels and the unitary cost of each, plus some possible correction factors, and transforming the yearly energy savings to saving in money, depending on the energy tariffs.

When the simulation is performed by the manufacturer, some filters can be applied, e.g. select different product combinations for different façades.

The screenshot shows the RenoBIM Configurator interface. The left panel, titled 'Current status of the building', allows users to select construction types for different building categories. The right panel, titled 'SIMULATIONS', allows users to select products for each facade (SE, SW, NW, NE).

Current status of the building

Select the construction type that best fits your building for each category, or define

ENVELOPE AND MATERIALS

External walls: Low inertia, no insulation (dropdown) Custom (button)

Floor in contact with ground: No insulation (dropdown) Custom (button)

Roof: Low inertia, low insulation (dropdown) Custom (button)

Windows: Simple glazing (dropdown) Custom (button)

SIMULATIONS

Please select which products to try in each facade:

	Facade SE	Facade SW	Facade NW	Facade NE
POBI_RW120_EPS100 Bardage Bois	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
POBI_RW140_EPS100 Bardage BOIS	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
POBI_RW140_EPS100 Bardage Métallique	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
POBI_RW120_EPS100 Bardage Métallique	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
POBI_INT_POLY_100mm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
POBI_RW120_EPS120 Bardage Métallique	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

☒ Use the same product in each renovation scenario

☒ The windows will be replaced

Figure 5: Defining current envelope characteristics (left) and simulation options (right)

For each simulated alternative energy consumption, energy savings compared to the baseline (current situation), investment in euros and return on investment (in years) are given. The description of the scenarios shows which panel is applied to each façade.

Scenario	Description	Energy consumption (kwh/(m ² ·y))	Energy savings (%)	Investment (EUR)	Return on Investment (Years)
Current situation	Current situation	219.0	0.0	0.0	0.0
Alternative 1	Facade NW = POBI_RW120_EPS100 Bardage Bois / Facade NE = POBI_RW120_EPS100 Bardage Bois / Facade SW = POBI_RW120_EPS100 Bardage Bois / Facade SE = POBI_RW120_EPS100 Bardage Bois	86.0	60.73	72346.964	10.0
Alternative 16	Facade NW = POBI_RW140_EPS100 Bardage Metallique / Facade NE = POBI_RW140_EPS100 Bardage Metallique / Facade SW = POBI_RW140_EPS100 Bardage Metallique / Facade SE = POBI_RW140_EPS100 Bardage Metallique	85.0	61.19	66410.803	9.0

Figure 6: Simulation results

3. RenoBIM Configurator

Once the most appropriate panel type is selected in the DST and the potential savings estimated, the next step is to make a first sketch using the RenoBIM Configurator module. The objective is not to produce a detailed design with all the constructive details of the system to be installed. Instead, it is intended for creating, quickly and easily, an optimized first predesign of the prefabricated panels, by saving a lot of time and quickly selecting the best configuration.

It is especially useful to facilitate the communication between the commercial department of the timber manufacturing company and the clients and architects who will develop the project. Nowadays, commercials often have problems understanding customers' needs and RenoBIM offers a way to collaborate and share through the web a 3D visual model of the predesign, which can be exported to IFC to be used in external design and engineering tools.

This final IFC contains the original building plus the extra layer of building elements corresponding to the prefabricated timber modules. For the façade splitting layout, a Web 2D drawing functionality is offered. The configuration process consists of 5 steps:

² <http://dsp.tecnalia.com/handle/11556/362>

Step 1 : Building configuration and panel type selection

Initially, the user uploads the IFC file of the current situation of the building, together with a DWG with the elevation view of the target façade. The timber panel selected in the DST is used here, and the configurator reads the panel properties from the database (thickness, maximum dimensions, etc.) and adapts to it. For example, the initial grid size will be adjusted according to the optimal size of the panel, as defined by the manufacturer. In addition, the user will have to define the distance between panels.

Step 2: Define sections and splitting

In this step, the wall section for the prefabricated elements will be defined. One or more sections can be defined. Within each area only a homogeneous group of panels can be placed. Then, openings can be created inside the section, which usually represent windows in the real building. Finally, the section is split into several panels using the grid. If a panel's dimensions exceed the maximum sizes, the configurator marks them in red as a warning to the end user.

Step 3: Select installation panels

The solutions developed in BERTIM project include two types of timber panels. The simple ones are just insulation panels with different finishing options and the most complex ones include an extra space for carrying all the piping needed for installation systems. These allow a deeper renovation of the building, including HVAC installations, with no need to enter the building. The user has the option to indicate which of the created panels will contain piping for HVAC, as it is the case in the corner panel of the example below.

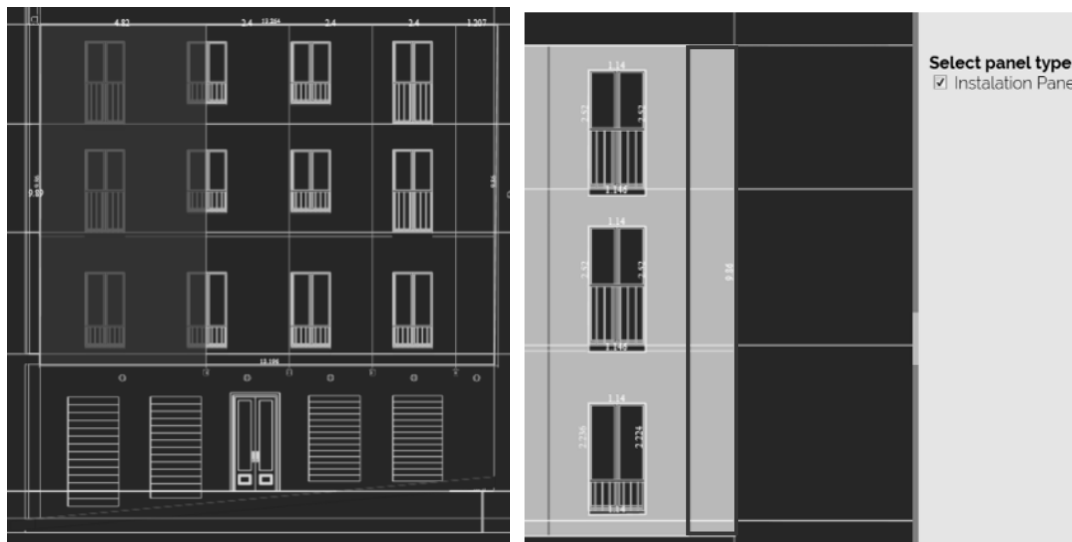


Figure 7: Creating too big panels (left, in red), defining panels for installations (right)

Step 4: Export to IFC

Once the configuration of the full façade has finished, the final step consists on the creation of the IFC file and download it to the local computer. The IFC export process creates additional *IfcBuildingStorey* entities, since the panels' position may not respect the actual storeys of the building. Then, each panel is exported as an *IfcWallStandardCase*, which will contain *IfcOpeningElements*, when they contain an opening, mainly doors or windows.

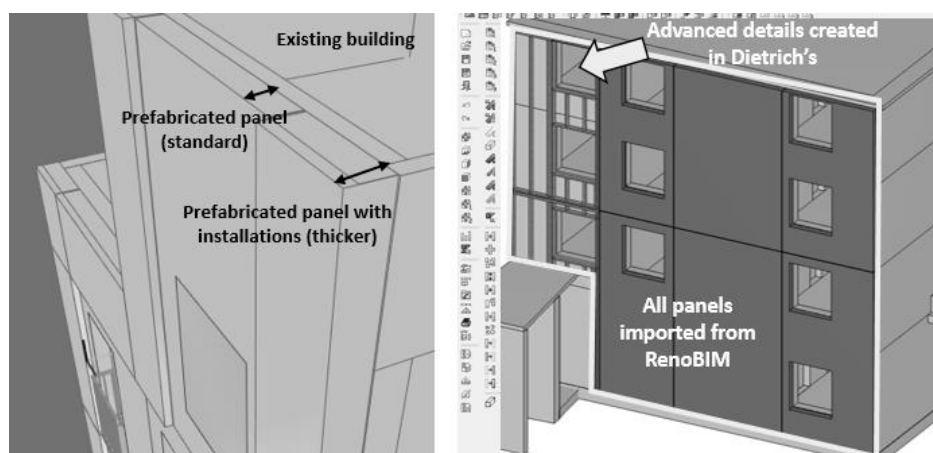


Figure 8: Renovation with installation panels (left). Import in Dietrich's tool (right)

Previous pictures show the result in the two test cases from the BERTIM project. On the left, a virtual demo building in Madrid, where the renovation contains HVAC installations (thicker). The result is visualized in an external tool (a free IFC viewer). On the right, a demo building in France, which is being renovated with BERTIM products. RenoBIM output has been imported in a CAD/CAM tool (Dietrich's), where additional design details have been added to some of the panels.

4. Conclusions and impact

This paper shows an example of integration of actors and tools in complex processes like building energy renovation with prefabrication, using Open BIM as the main driver, but at the same time flexible by supporting alternative simplified approaches. Several technical challenges have been faced during the development: create a BIM model adapted to renovation with prefabrication and energy simulation, automatic conversion from BIM to Energy Plus and Web 3D technologies and automatic generation of IFC files from web drawing interfaces, among others. By means of these automations, RenoBIM is ready to be used by non-expert users.

The focus in BERTIM project is the renovation of residential buildings with prefabricated timber panels and this use case has been successfully tested in RenoBIM. However, it offers a great extension potential to other contexts (other types of buildings or other types of products and processes apart from prefabrication).

The main benefits for a manufacturing company can be summarized as follows:

- The companies can optimize their processes, digitalizing and automating data flows.
- They can collaborate more efficiently with other companies and with building owners by sharing the information through the web using a BIM model.
- It gives them the opportunity to digitalize their product catalogues and integrate them in design and simulation tools. This allows easily reaching new markets.

In parallel, new challenges arise for the companies: they must develop new skills for adapting to this new digital context. Sometimes they can be developed in-house, sometimes they can be subcontracted outside, which means they must create new relationships and business models with external collaborators.

5. Acknowledgements

BERTIM project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 636984.