INTEGRATING ENERGY SIMULATION IN THE EARLY STAGE OF BUILDING DESIGN

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ABSTRACT

This paper describes a project currently being conducted within the European project IntUBE (www.intube.eu). The aim of this project is to develop innovative ICT solutions which can contribute to reducing energy use in the building sector in Europe. The main focus of IntUBE is to model, store and process the energy information obtained throughout the whole building lifecycle in an Energy Information Integration Platform (EIIP). Our assumption is that such a platform would make an intelligent use of the energy information possible at the different stages of the building lifecycle, which in turn would result in a significant reduction in energy use. The project reported on in this paper focuses on modelling energy information at the early design stage.

INTRODUCTION

IntUBE (Intelligent Use of Buildings' Energy Information) is an EU research project funded by the FP7-ICT-2-2.3ICT (2008-2011) programme for environmental management and energy efficiency whose goal is to improve the energy efficiency of buildings through an intelligent and coordinated use of energy information. At the core of the IntUBE approach lies an Energy Information Integration Platform (EIIP), which stores energy information generated along the different stages of the building's lifecycle: conceptual design, design development, operation and retrofitting (RIBA, 2007). The information is organised into three repositories, each dedicated to storing/retrieving different kinds of energy information: a BIM repository for building descriptions, a SIM repository for the simulation results and a PIM repository for the monitoring data. In addition, a Reference Data server contains the metadata which facilitates access to the different

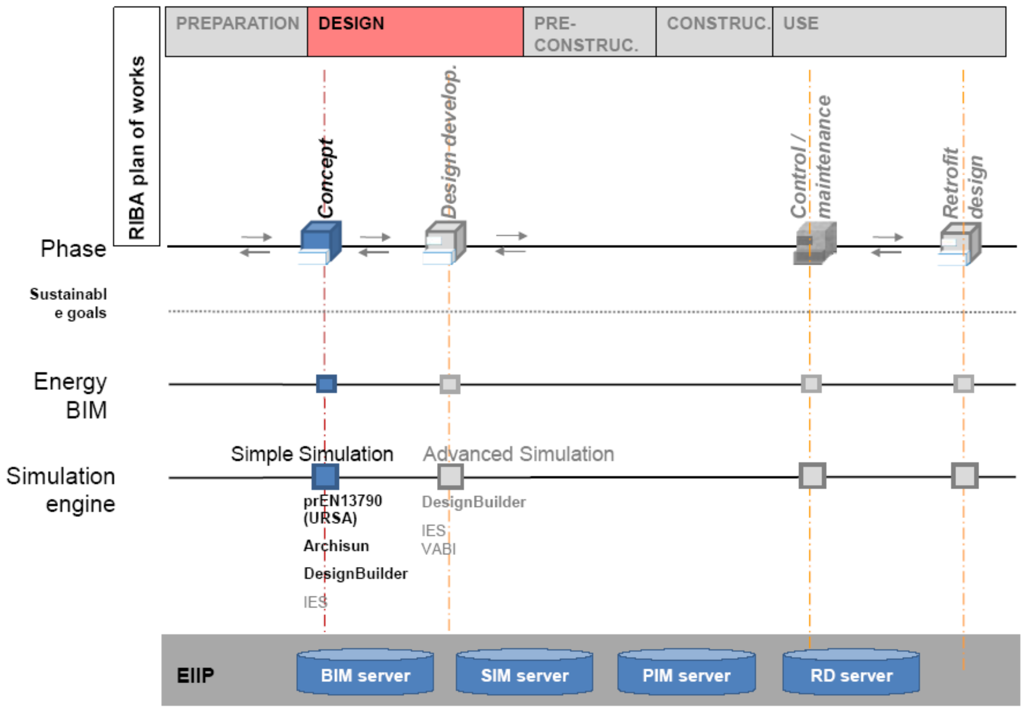

Figure 1. Structure of the IntUBE Energy Information Integration Platform

repositories (Figure 1). The platform supports different services facilitated and/or provided by different stakeholders, such as building modelling, energy performance simulation, monitoring and building control (BMS/NMS), data mining and energy audits (Figure 2).

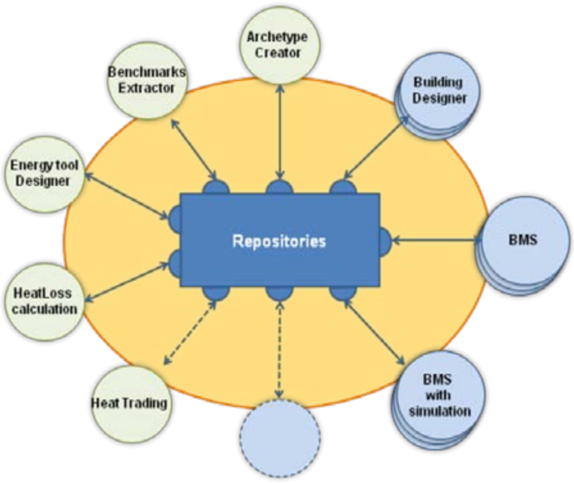

Figure 2. Stakeholders and services interacting with the IntUBE Energy Information Integration Platform

This paper presents the current status of the project in the area of building simulation, in particular the application of simulation tools at the early design stage. During the initial phases of building design, energy simulation may be used to take decisions that might help to substantially improve a building's energy performance. The information which might be obtained from the envisioned EIIP at the concept stage might include benchmarks or simulation input data generated from previous projects. On the other hand, the building design models and their simulated performances may be stored in the platform so that they can be accessed by other users as well (e.g., designers, software developers, researchers, policy makers, etc.). These processes of storing and retrieving information are performed through dedicated services accessing the platform's energy information repositories. The services can be performed asynchronously by different stakeholders, using a variety of tools which are external to the platform. Therefore, ensuring the homogeneity and compatibility of the data acquired from heterogeneous sources becomes a core issue in this project.

A specific methodology has been developed to store simulation models and the results in the platform. To facilitate the comparison between simulations performed with different tools, a form based on EU standards is used to store and retrieve data in the platform. Our ultimate goal is to demonstrate that such a methodology would help to transform information into knowledge, which would contribute in turn to reducing the energy consumption of buildings.

A residential apartment building in Spain is being used as a case study to develop and verify the applicability of the methodology. Other buildings are being used to populate the SIM repository with simulation data. Different building alternatives at the conceptual design stage have been created and simulated in order to compare their energy performance. These simulations have been carried out with Archisun and the URSA application of prEN13790.

BACKGROUND

There are some relevant precedents in the use of repositories to collect information on the energy performance of buildings such as EnerGuide, a comprehensive computer-based system developed by Natural Resources Canada to manage its energy efficiency-oriented programs. It is "a management information tool and central repository for tracking residential energy evaluations and measuring benefits from the energy evaluations delivered across Canada" (Blais, 2005). Energuide contains information about the existing building stock, whereas the purpose of the energy platform we are developing in IntUBE is to encompass the building's entire lifecycle, from design to construction and operation.

The need to share and compare information from different sources and at different stages of the building lifecycle calls for the use of standards (c.f. Clarke, 2001, pp. 308-309), particularly those being developed at the European level such as the group of norms developed to respond to the EPBD (Energy Performance of Buildings Directive, 2002/91/EC). These standard procedures encompass the definition of parameters and units to describe the building characteristics, the boundary conditions and the building energy performances.

The approach we have adopted for the IntUBE platform conforms to the EU policies on the energy performance of buildings, and by doing so it strengthens the development and application of standardized processes and methods in the field of energy performance and evaluation.

ENERGY INFORMATION AT THE CONCEPTUAL DESIGN STAGE

At each stage of the building lifecycle, it is possible to store and retrieve relevant information in and from IntUBE's EIIP using standard procedures. As the information stored in the EIIP grows, more useful data might be retrieved by future users (building managers, users, architects and engineers) which in turn may help to improve the energy performance of buildings at the different stages (design, operation, maintenance, retrofitting). In the study reported in the following sections, we address the use of energy information at the concept stage.

Work in progress

The decisions taken at the concept stage are crucial for energy efficient design (Clark 2001, pp. 4-5). However, detailed simulations are seldom feasible due to the lack of time and/or information available. Providing the designer with a computer-supported environment which facilitates access to data describing possible solutions and evaluating the energy performance of design variations would help to integrate energy issues into the early design phase.

At the conceptual design stage, the main stakeholder to be considered is the design team. In the design process of a building, the architect or engineer may use ICT to assess the information related to building energy. The tools used in this context are basically modelling and simulation programmes. These are the sources of the data that may exchange information with the EIIP at this stage.

The design team using the EIIP at the concept design stage will share information on different buildings that has been stored at different stages of the building lifecycle (concept design, design development, operation and retrofit design). As a result, these two questions arise:

1. What useful information do stakeholders provide the EIIP at this phase? A design team may store in the EIIP the information contained into the model as well as the simulations performed with different tools. The information thus provided represents the energy model of a building at the conceptual design stage.

2. What useful information does the EIIP facilitate to stakeholders at this phase? Conversely, the design team may obtain information from previous projects stored in the EIIP which inform the design process. In this regard, the most basic service that the platform provides the designer is the ability to browse similar building types in a comparable climate and with related characteristics (regarding form and shape, type construction, passive strategies, type of mechanical systems, etc.). In this way, the EIIP can assist the designer in taking design decisions which might have an impact on energy performance. In current design practice, this kind information, which may be very useful to develop proposals of building design, is also difficult obtain (Hand, 2008).

In these processes of storing and retrieving data, there is a heterogeneous variety of sources involved, namely:

- different technologies used at different stages of building lifecycle such as modelling tools, simulation tools, BMS and data acquisition systems (Dawood, 2008)
- different products for the same technology, such as modelling and simulation tools (Crawley, 2008; Dawood, 2008)
- different kinds of information related to the building's energy, such as simple simulation results, detailed simulation results and monitoring data.

Therefore, it is necessary to ensure the compatibility of the information obtained from these different sources using standard units and parameters collected through standard forms which are used in the processes of storing and retrieving data from the platform.

Furthermore, these forms are necessary in order to transform the information stored in the platform into applicable knowledge. Each of the three servers that make up the platform –BIM, SIM and PIM– has a specific form which represents a subset of the ontology which characterizes their corresponding domain knowledge: building, simulation and performance. To begin with, we have created a form to store simulation data to be used at the conceptual design stage (Table 1).

Table . Form developed for the conceptual design stage

FORM	
General data of the building	
Building name	-
Design alternative	-
Location	-
Year of construcrion	-
Useful floor area	m^2
Building use	-
People	-
Cost	€/m2
Climate and location	
Mean annual temperature	
Mean annual humidity	
Mean solar radiation	
Opaque & Transparent surface	
Area of building envelope	m^2
Thermal transmittance avarage of building envelope	W/(m^2?K)
Area of external building envelope	m^2
Area of transparent external building envelope	m^2
Area of transparent external building envelope by *Orientation j* (S,N,SE+E+O+SO+Horizontal)	m^2
Presence of special elements (Yes / No)	-
Class of construction (for thermal inertia)	-
Systems	
overall system efficiency for heating per carrier i	-
overall system efficiency for cooling per carrier i	-
Calculation OUTPUTS	
Tool / Method of calculation used	-
Annual energy needs for heating	MJ
Annual energy needs for cooling	MJ
Energy use by *carrier i* (Oil, Gas, Electricity,etc.)	MJ
Renew able energy generated in situ - thermal	MJ
Renew able energy generated in situ - electric	MJ
Energy evaluation - Primary energy delivered	MJ

The parameters included in this form are based on EPBD EN ISO standards, in particular:

- ISO 13790: 2008 Energy performance of buildings, which deals with calculating the energy use for space heating and cooling
- EN 15603: 2008 Energy performance of buildings, which covers energy use and energy ratings

The information regarding the building models and simulations created by the design team can be collected on this form and stored in the EIIP. In this way, it will be possible to compare this information with other simulations of the same building at different stages of the building's lifecycle, even if the simulations have been performed with different tools.

The form includes different kinds of information that are relevant for a building's energy performance:

- Building description, including its most general characteristics such as use, location, year of construction, etc.
- *Climate and location* data, to enable comparisons based on climatic characteristics
- Opaque and transparent surfaces, which describe the building construction and geometry
- Systems, to report on the performance of mechanical systems that influence buildings' energy use
- Calculation results, to record the predicted performances associated with the previous data

The information contained in a form can not be dissociated from the services which can be brought about by processing the retrieved data. It is not enough to identify the relevant data; rather it is also essential to define the processes by which the data is to be transformed into quality energy information which can help different stakeholders throughout the building's lifecycle (concept design, design development, operation and retrofitting) to take decisions aimed at optimizing the energy performance.

Case of study

To verify and further develop this methodology at the conceptual design stage, we have replicated a possible design process which a design team could have followed had they used standardized forms to store and retrieve simulation data in the EIIP. As a case study, we have used a recently completed 24-flat publicly subsidised apartment building in Cerdanyola del Vallès - close to Barcelona- which was built by a public housing institute (Incasol).

The rectangular building is aligned with the street. It measures 64 meters long and 12 meters wide. It occupies the maximum surface permitted by the building codes and has four stories plus an underground car park. The ground floor is used for offices and also as lobby. The first, second and third floors are for residential use.

The typical floor plan of the block consists of four dwellings around each of the two stairwells (Figure 3).

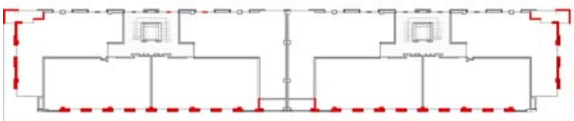

Figure 3. Cerdanyola residential building, typical floor plan. In red, solar wall façades.

The north-south orientation of the plot allows the façades to be treated in a way that contributes to improving their energy efficiency. In the south, east and west façades there are large openings to get light and energy from the sun. On these façades, opaque panels were built with a solar wall solution (marked in red in Figure 3). There are no large windows on the north façade. The openings on all the façades have solar protection.

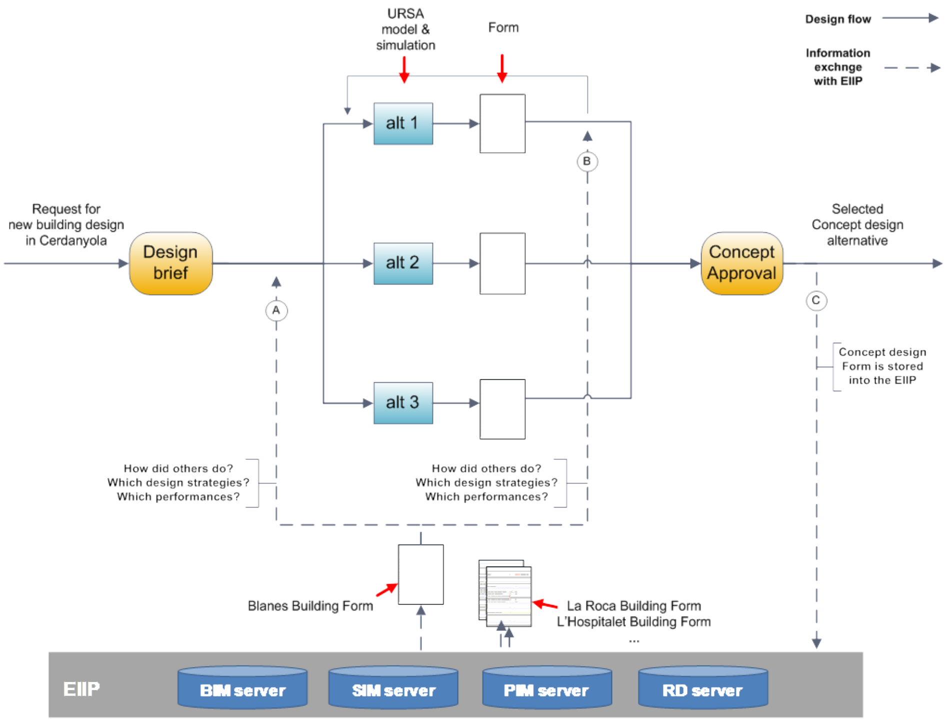

Figure 4 . Conceptual design process for the Cerdanyola building

At the conceptual design stage, the building has been modelled as a single zone representing all the flats, excluding the part of the building with other uses. Two programmes have been used to generate simulations of the design so that they can be stored and compared:

- Archisun 3.0 (Serra, 2000):
- URSA Excel application of pr EN13790 – Simple Hourly Method

Figure 4 outlines the conceptual design process for the building (see RIBA, 2007). The concept design starts when the design team receives the client's key requirements and identifies the main design constraints (including space and use requirements, budget, site conditions, applicable regulations, etc.). The URSA tool has been used in this scenario.

In order to develop several initial designs, the design team may search the EIIP for similar buildings which share some of the characteristics with the one to be designed. In fact, the team can see the design options adopted for other buildings (such as the building shape, the level of thermal insulation, the type, area and orientation of windows, mechanical and passive heating, cooling and ventilation, the type and area –if any– of solar thermal collectors, the type and surface of passive systems and different options for the inclusion of renewable energy technologies) and their energy performance.

To make this search possible, we have populated the EIIP repositories with simulation data from three other buildings –located in Blanes, La Roca and L'Hospitalet– which are similar to the case study. These are publicly subsidised homes from the same public agency. They share characteristics like area, construction cost and building technique, which make them comparable; however, they differ in location and in architectural expression.

Archisun was used to simulate the apartment buildings in Blanes and La Roca. The URSA tool has been used to simulate the apartment building in L'Hospitalet.

The design team used a standard form to search the EIIP for similar buildings and retrieve one or more specific buildings (process A, in Figure 4) in order to evaluate its design characteristics with regard to the desired performances. After that, the team created the different design alternatives for the Cerdanyola building. Two design variations of the original building (alternative 1, Figure 3) were considered in order to reproduce a possible design process of the building at the concept stage. In alternative 2 (Figure 5), the dwellings are entered through walkways placed on the north façade. In alternative 3 (Figure 6), no solar walls are used in the façade. It should be noted that when the URSA application is used for the Cerdanyola building, there cannot be any differences between alternatives 1 and 3 since the solar wall cannot be modelled with this tool.

Figure 5. Cerdanyola residential building, alternative 2. Walkways located on the north facade. In red, solar wall façades.

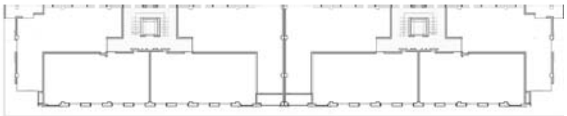

Figure 6. Cerdanyola residential building, alternative 3. Solar walls removed.

The information obtained from the similar buildings may be useful for creating design alternatives. For example, the design team noted that the insulation level in the similar buildings is roughly the same, and it used this value in the alternatives for the Cerdanyola building (see thermal transmittance in Table 2 and compare it to the one previously used in the building in Blanes, Table 3). In other words, the design team decided to take advantage of the know-how stored in the platform and use the data it provides as a design hypothesis. At this point, it should be noted that the use of standard parameters is fundamental in order to extract this input data from different buildings. Moreover, having easy access to the different energy information through the form speeds up the creation of design alternatives and provides valid inputs for the simulation. Furthermore, comparing the performance of the design alternatives with that of similar buildings can help to better adjust the design performance targets.

Once the three design alternatives have been modelled and simulated with the URSA tool, they are translated to the form (Figure 4) in order to be stored in the platform.

Now it is possible to compare the design characteristics as well as the simulation results of the alternatives with the similar buildings. Figure 4 (process B) shows that the design team may compare the energy performance of a design alternative with one or more similar buildings. In fact, thanks to this it is possible to have quick access to this information in a comparable format to verify whether the simulated performances are reliable, to detect possible anomalous results and, if necessary, to make the corresponding changes in the proposed design alternative.

Once the design team has created the three alternatives, they can be compared and decisions regarding the further development of the design can be discussed together with the client (c.f. Alanne 2004). The form of the selected design alternative will finally be stored into the EIIP (process C in Figure 4) together with the building model and the simulation. Subsequent users of the platform can take advantage of this information in other projects.

In process A and B, described in this scenario, the information on specific buildings is provided through the form. Much more helpful information is expected using the form to compare the design alternatives of the Cerdanyola building with typical buildings based on statistical information such as energy consumption benchmarks for similar buildings (see Blais, 2005). However, this kind of information is not yet available with the limited amount of data currently used in this case study. The population available will, in fact, be extended to buildings in the advanced design stage and in operation, and it will increase in each of these stages. Specific services to provide such processed information through the EIIP are currently under development.

Through this case study scenario, we can see that users can get useful information from the platform while also providing useful information to other users. In fact, while the design team benefits from the information obtained, at the same time the model and the simulation performed for the Cerdanyola building will contribute to populate the EIIP, thus benefiting future users of the platform. Using forms to compare simulation results

Table 2 and Table 3 provide a comparison between design alternative 1 –which corresponds to the design actually built in Cerdanyola– simulated with URSA (Table 2) and the apartment building in Blanes simulated with Archisun (Table 3). The buildings' energy models and corresponding simulations were both described with the same form.

The example shows that most of the information can be compared. However, certain kinds of data cannot be compared simply because the domain of each tool has its specific limitations. For example, opaque and transparent surfaces are described by different input parameters in Archisun and URSA. Whereas Archisun considers all the façades to be of the same kind, URSA provides for multiple types of façades. However, after being translated to a common form, these parameters can be compared.

On the other hand, in heating and cooling calculations Archisun calculates sensible plus latent energy use, whereas the URSA tool provides the sensible energy demand only. Therefore, the sensible energy demand is not comparable. Some parameters of the forms can be filled in for one tool but not for the other; however, the overall objective to have simulation results from different tools represented in a standard form has been fulfilled.

Table 2. Form of the design alternative 1 for the Cerdanyola residential building simulated with URSA

FORM		
General data of the building		
Building name	-	Social Housing Block - Cerdanyola
Design alternative	-	alternative 1
Location	-	Cerdanyola, Barcelona, Spain
Year of construcrion	-	2008 (expected)
Useful floor area	m^2	1703
Building use	-	residential
People	-	96
Cost	€/m2	...
Climate and location		
Mean annual temperature		...
Mean annual humidity		...
Mean solar radiation		...
Opaque & Transparent surface		
Area of building envelope	m^2	2885
Thermal transmittance average of building envelope	$W/(m^2 \cdot K)$	0.93
Area of external building envelope	m^2	1823
Area of transparent external building envelope	m^2	495
Area of transparent external building envelope by Orientation S	m^2	290.1
Area of transparent external building envelope by Orientation SE+E+O+SO+Horizontal	m^2	46
Presence of special elements (Yes / No)	-	Yes
Class of construction (for thermal inertia)	-	Heavy
Systems		
overall system efficiency for heating per gas	-	0.75
overall system efficiency for heating per *carrier* i	-	...
overall system efficiency for cooling per *carrier* i	-	no cooling system
Calculation OUTPUTS		
Tool / Method of calculation used	-	URSA application / ISO 13790 - Simple Hourly Method
Annual energy needs for heating (sensible)	MJ	148418
Annual energy needs for cooling (sensible)	MJ	0
Energy use by gas	MJ	197891
Energy use by *carrier i* (Oil, Gas, Electricity,etc.)	MJ	...
Renewable energy generated in situ - thermal	MJ	...
Renewable energy generated in situ - electric	MJ	...
Energy evaluation - Primary energy delivered	MJ	...
		values in red is information that cannot be obtained from this tool

Table 3 . Form of conceptual design for the Blanes residential building simulated with Archisun, from the EIIP population

FORM		
General data of the building		
Building name	-	Social Housing Block - Blanes
Design alternative	-	--
Location	-	Blanes, Barcelona, Spain
Year of construcrion	-	2010-11
Useful floor area	m^2	1264.47
Building use	-	residential
People	-	62
Cost	€/m2	...
Climate and location		
Mean annual temperature		...
Mean annual humidity		...
Mean solar radiation		...
Opaque & Transparent surface		
Area of building envelope	m^2	1992
Thermal transmittance avarage of building envelope	$W/(m^2 \cdot K)$	0.95
Area of external building envelope	m^2	1844
Area of transparent external building envelope	m^2	234
Area of transparent external building envelope by Orientation S	m^2	0
Area of transparent external building envelope by Orientation SE+E+O+SO+Horizontal	m^2	234
Presence of special elements (Yes / No)	-	no
Class of construction (for thermal inertia) by one	-	...
Systems		
overall system efficiency for heating per gas	-	0.7
overall system efficiency for heating per *carrier* i	-	...
overall system efficiency for heating per *carrier* i	-	no cooling system
Calculation OUTPUTS		
Tool / Method of calculation used	-	Archisun 3.0
Annual energy needs for heating (sensible)	MJ	...
Annual energy needs for cooling (sensible)	MJ	...
Energy use by gas	MJ	139400
Energy use by *carrier i* (Oil, Gas, Electricity,etc.)	MJ	...
Renewable energy generated in situ - thermal	MJ	...
Renewable energy generated in situ - electric	MJ	...
Energy evaluation - Primary energy delivered	MJ	...
		values in red is information that cannot be obtained from this tool

CONCLUSIONS

We have described a methodology based on the use of standardized forms which enables a design team to store and retrieve quality information from a platform and use it at the conceptual stage of building design. More comprehensive results are expected at the end of the project as the ongoing work in the different work packages is completed. Then, it will be possible to more precisely identify the services operating with the information extracted from the BIM, SIM and PIM servers (e.g., making predictions by means of simulations which are calibrated with the monitoring data). These services will be provided by different stakeholders (energy providers, consultants, technical teams, etc.) operating with the IntUBE EIIP, giving rise to innovative business models. The valid information they provide to the agents involved in different stages of the building lifecycle will contribute to improving the energy efficiency of buildings.

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