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Department of Structural, Construction and  
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**BIM modeling for energy  
refurbishment**

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# Abstract

The expansion of population and consequently the increase in need of energy has raised the interesting topic of energy management. Moreover the 50 percent of the global population now live in cities and urban population is estimated to reach 70 percent of the total population in the world by 2050. This fact brings attentions to citys energy consumption. The purpose of this master thesis is studying application of BIM (Building Information Modeling) under European Dimmer project for a specific building in Torino and then expand the idea in urban scale by developing the concept of District Information Modeling. In order to have a clear wide view of this research, three European projects in the same field have been studied. The Projects are Optimus, Dimmer and Indicate which follow up the purpose of reduction in energy consumption, CO2 emission and cost of used energy by real time monitoring of connected buildings.

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Furthermore, I would like to thank my tutors Dr.Matteo Del Giudice for his kind cooperation, guidance and support by providing me all the data and information I needed during my thesis. Also Ms.Daniela De Luca whose advises helped me a lot.

Last but not least I want to thank my parents for their support not only during this thesis but throughout all of the years I passed in Politecnico.

Khodayar Chalabi

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# Chapter 1

## Introduction

In this chapter first the method of research i used during run of this thesis is introduced and then three European Projects who have worked in saving energy for smart cities are explained and compared and then as they have used the BIM method, I also made an introduction on BIM technique,its advantages and benefits and finally the DIM model, smart city and application of DIM in smart city is explained.

## 1.1 Method of research

### **Deductive and inductive methods**

There are two main approaches for reasoning, deductive and inductive. The deductive approach is based on already existing hypotheses which are tested in order to through logic reasoning confirm their accuracy (Research Methods Knowledge Base, 2006). An inductive approach is concerned with the generation of new theory emerging from the data. The method I used in this thesis is more close to deductive method as I had the idea of numerically changes in energy consumption of building after implementing new methods and then by practical case I tested the results I expected to reach at.

### **Quantitative and qualitative methods**

Qualitative Research is primarily exploratory research. It is used to gain an understanding of underlying reasons, opinions, and motivations. It provides insights into the problem or helps to develop ideas or hypotheses for potential quantitative research. Qualitative Research is also used to uncover trends in thought and opinions, and dive deeper into the problem. Qualitative data collection methods vary using unstructured or semi-structured techniques. The purpose with qualitative interviews is to identify and explore insufficiently known properties. The idea is to discover something which cannot be established in advance and acquire a deeper understanding of a subject. In a qualitative study a large amount of information is collected from a small sample size (Holme and Solvang, 1997). Considering the purpose and aim of this master thesis and as the availability of interviewees has been limited, a qualitative method was selected. Quantitative Research is used to quantify the problem by way of generating numerical data or data that can be transformed into usable statistics. It is used to quantify attitudes, opinions, behaviors, and other defined variables and generalize results from a larger sample population. Quantitative Research uses measurable data to formulate facts and uncover patterns in research. Quantitative data collection methods are much more structured than Qualitative data collection methods. In this thesis the main part which consists of analysis the changes that would be obtained by implementing BIM in the building are all done through quanti-

tative methods as I have precise numbers and ratios for any conclusions that I made. Moreover, in chapter 1 where I made a comparison over DIMMER, INDICATE and OPTIMUS the comparison is based on qualitative method just to make an order according to efficiency of method

### **Aim and Purpose of this thesis**

The purpose of this master thesis is studying application of BIM (Building Information Modeling) under European Dimmer project for a specific building in Torino and then expand the idea in urban scale by developing the concept of District Information Modeling. In order to have a clear wide view of this research, three European projects in the same field have been studied. The Projects are Optimus, Dimmer and Indicate which follow up the purpose of reduction in energy consumption, CO2 emission and cost of used energy by real time monitoring of connected buildings.

### **Research questions**

The research is structured in order to answer the following question.

**Now a days smart city is an important concept and attracts many attentions and in order to improve smart cities applying a kind of method of innovation technology would be helpful. Among different existing methods BIM is one of the best solutions. how BIM Method can be applied in order to amend energy and cost saving in urban scale?**

## 1.2 State of art

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### Title

INDICATE



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### FOCUS

urban objects and spaces, buildings, the electricity grid, renewable technologies, ICT, optimizing infrastructure, installing technology, and providing cost effective utility services.

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### PERIOD

1st October 2013 and it will last 36 months

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### Website

<http://www.indicate-smartcities.eu/>

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### Partners

The consortium is made up of a well balanced mix of Large Companies (ESRI R i. D Center Zurich AG and DAppolonia SPA), SMEs (Integrated Environmental Solutions Ltd and Future Analytics Consulting) , Universities (Trinity College Dublin and Dundalk Institute of Technology) and Public

Authorities (Ente Ospedaliero Ospedali Galliera and Louth County Council) from 4 different European countries (UK, Ireland, Italy and Switzerland).

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### **Test Sites**

3 test sites have been chosen, 2 in Dundalk (Retrofitting, Masterplanning), Ireland and 1 in Genoa (Ospedale Galliera), Italy.

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### **CONCEPT**

The INDICATE project will support decision makers and other stakeholders towards transforming their cities to a Smart City. This will be achieved through the development of an interactive cloud-based tool, which will provide dynamic assessment of the interactions between buildings, the electricity grid, and Renewable Technologies and Information Communication Technologies (ICT).

Recommendations will be provided with respect to the best technologies to install, the infrastructure that requires improvement to enable local balancing and the utility services that offer the best financial plan. To understand how the decisions made will affect the overall urban environment, a set of Sustainable Urban Indicators will be developed, which will account for the knock on effects from changes made to the buildings, infrastructure changes or introduction of new technologies, within the urban context. The decisions taken for the buildings will therefore be influenced by the potential impact on the city. The interactive cloud based tool has the following goals, each of which is discussed in detail below.

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### **AIM and SCOPE**

PLAN development through a dynamic simulation, energy-based decision support tool, which takes into account the buildings and their interaction with the urban environment;

REDUCE energy consumption and carbon emissions through an indication of the impact of best practice Energy Conservation Measures via Dynamic

Simulation Modelling;

INTEGRATE new technologies and services in the city to better manage supply and demand, via Dynamic Simulation Modelling, Graphical Information Systems (GIS) and 3D urban modelling which will reliably inform the impact of the integrated technologies;

OPTIMISE existing installed systems, to enable local balancing through demand response analysis and tariff analysis via Dynamic Simulation Modelling, which will model the interactions between the buildings the installed systems and the electricity grid, across multiple buildings in the urban environment.

---

## **Project Analysis**

The INDICATE tool has been designed to operate any stage of development; it can be used in a city where the buildings and their urban environment are at an early stage of development or redevelopment, or to optimise existing smart grid infrastructure or efficient technologies where they have already been installed.

To enable this level of analysis, the INDICATE tool will bring together a number of components including: simulation software developed in this project, the IES Virtual Environment, 3D urban CAD tools, the Esri CityEngine software, and a suite of energy related sustainable urban indicators; to create a Virtual City Model (VCM) ready for simulation. The VCM is fed with real urban data and processes this through the components outlined to assess the impact of any proposed changes to technologies, individual buildings, or larger changes at a district level.

---

## **OUT COME**

3D map of the city will be accessible to Local Administration and will allow them to understand the potential of the city and to decide if it could be useful to make this information available to the public; this information could be especially beneficial for stakeholders to use in the future development of the city

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**Title**

OPTIMUS



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**FOCUS**

weather conditions, buildings energy profiles, feedback provided by occupants, energy prices and energy production

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**PERIOD**

1st October 2013 and it will last 36 months

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**Website**

<http://www.optimus-smartcity.eu/>

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**Partners**

Fundacio Privada Universitat i Tecnologia (FUNITEC) Tecnalia ICLEI Local Governments for Sustainability Sense One Technologies Politecnico di Torino POLITO DAppolonia Savona University Campus **Coordinator** The National Technical University (NTUA)

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**Test Sites**

in three municipalities across Europe: Savona in Italy, Sant Cugat del Valls in Spain and Zaanstad in the Netherlands.

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**CONCEPT**

OPTIMUS is a package of web-based consulting tools for energy managers and energy consultancies, in order to make cities more energy efficient and sustainable. The purpose is to optimise the energy use in the city buildings

(municipal and educational buildings, buildings for entertainment and sports facilities, hotels, etc.), taking into consideration their interaction with energy systems (renewable energy systems, CHP, battery storage, etc.). Buildings are responsible for 40 percents of the European Union's (EU) energy consumption and 36 percents of its CO<sub>2</sub> emissions, one way to curb these statistics by up to 10 percents, without needing to change the existing infrastructure is to simply monitor energy use in buildings.

The key benefits of the OPTIMUS package are: Monitoring and evaluating the performance of the city / building, in terms of energy efficiency. Support of short term decision-making on energy planning, so as to reduce energy consumption, CO<sub>2</sub> emissions and energy cost. Offering of an advanced and intelligent turn-key solution addressed to any municipality that has as purpose to implement Sustainable Energy Action Plans (SEAPs). Implementation of state-of-the-art ICT technologies and analytics for energy optimization.

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## **AIM and SCOPE**

Application of advanced ICT systems

optimization of the energy use and increase of RES production

Significant reduction of energy cost and CO<sub>2</sub> emissions

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## **Project Analysis**

The OPTIMUS DSS works simultaneously with existing energy management systems, integrating five multidisciplinary data sources (weather conditions, buildings energy profiles, feedback provided by occupants, energy prices and energy production), in order to propose short-term action plans for energy managers.

This web based tool is able to show the 4 below indicators for all the buildings of the city connected to system and compare them weekly by their previous week:(energy consumption-CO<sub>2</sub> emission-energy cost-produced renewable energy)

for each DSS value it has one long term target then target by end of year (after implementation of selected plans) and current value. it allows user to compare them and see improvement or decline. The tool has ability to show all these data in three different levels 1- unique selected building;;  
2-aggregated buildings connected to system;;  
3-different zones of building;

The program has some suggested actions in order to reach the targets and user is able to accept or refuse each one of them. the actions are: Scheduling and management of the occupancy, set-point temperature, ON/OFF of the heating system, photo voltaic (PV) maintenance, the operation of heating and electricity systems and Scheduling the sale/consumption of the electricity produced through the PV system. And also: PV Maintenance Action Plan, PV Buy/Sell Action Plan and Energy Cost Optimization Action Plan All data are shown in numbers and graph interface and user is able to select exact day of his interest in order to see the monitored data. The other advantage of tool is asking for users feedback, occurred problems during applying each of suggested actions and then their final decision about the action.

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## **OUT COME**

The outcome is a web based interface with data related to 4 DSS indicators all these data are shown in three different levels

- 1- unique selected building
- 2-aggregated buildings connected to system
- 3-different zones of building

**Title**

DIMMER



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**FOCUS**

energy saving at district scale,

Integration of (BIM) with real-time data,

integrate different data sources: (BIM), (SIM) and (GIS)

Optimizing information exchanged

Visualizing in real-time energy related information in the building and district environment

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**PERIOD**

1st October 2013 and it will last 36 months

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**Website**

<http://www.dimmerproject.eu/>

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**Partners**

.Politecnico di Torino, Italy . Consorzio per il sistema Informativo, Italy  
. ST Polito, Italy . DAppolonia, Italy . IREN Energia, Italy . Clicks and Links, United Kingdom . Arup, United Kingdom . University of Manchester, United Kingdom . Oldham Metropolitan Borough Council, United Kingdom  
. CNet Svwnska Ab, Sweden . Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung, Germany

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## Test Sites

Turin and Manchester

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### CONCEPT

Whether it is conscious or not, the way you use energy is changing. There's talk about climate change, energy prices remorselessly rise and you may have solar panels on your roof. But is there a way to monitor these changes and help consumers to develop environmentally efficient behavior? The District Information Modelling and Management for Energy Reduction (DIMMER) project is set to be one of the first to provide insights on our energy future. Using sensors to gather data on energy use in districts and cities, researchers are building sophisticated computer models, which could provide the most complete view of smarter energy use in the future. Dimmer is trying to capture the true diversity of energy demand in cities and project how this will change when smarter technologies will be available. At a local level, the group monitors energy use by individual consumers. The researchers collate the data gathered to create district information models that represent energy use across entire areas. The models also take account of future advances in technology and possible changes in consumer behaviour. This project is developing interactive devices which tell consumers about any energy they may be wasting in their homes, helping them to take responsibility for their energy habits. The devices will be able to interact with consumers in real time

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### AIM and SCOPE

- . INTEGRATE Building Information Modeling (BIM) with real-time data and their extensions at the district level (DIM).
- . USE the web-based interface to provide feedback about energy impact of user behaviors;
- . VERIFY the interoperability of district energy production/consumption, environmental;
- . CREATE new business models for energy traders and presumes (pro-

ducer/consumer) exploiting user energy profiling.

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## **Project Analysis**

Its defined as tool which will support stakeholders in the transition towards smart cities by providing an interactive decision support tool for urban planning and design. The tool will assess the interactions between urban objects and spaces, buildings, the electricity grid, renewable technologies and ICT and recommend options for optimizing infrastructure, installing technology, and providing cost effective utility services. the expected results are a consistent reduction in both energy consume and CO2 emissions by enabling a **more efficient energy distribution policies**, according to the real characteristics of district buildings and inhabitants as well as a more efficient utilization and maintenance of the energy distribution network, based on social behavior and users attitudes and demand.

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## **OUT COME**

### **DIMMER benchmarking tool:**

This tool compares the energy performance of a selected building in different heating seasons and/or against other similar buildings (respecting the privacy) as well as assesses possible scenarios for building improvements

### **DIMMER dashboard:**

The Dashboard aims at providing stakeholder with a model for dynamic monitoring and management of energy consumption.

### **The district visualizer:**

The district visualizer allows visual access to a range of real time and static city energy data that can be manipulated and presented on a selected visual canvas for example map/model, and viewed in a collaborative mode including the use of virtual reality.

### **1.2.1 SIMILARITIES AND DIFFERENCES BETWEEN INDICATE, OPTIMUS AND DIMMER**

First and foremost on closer examination, the three projects were funded by the 7th framework programme of European Unions Research and innovation funding programme since 2013-2016

The main aim of these projects is reducing energy consumption and CO2 emissions with the adoption of ICT measures in order to create the prerequisites to help in the realization of a sustainable and Smart City.

On the other hand, these projects have a great toll on social impacts which are essential for every society and modernization of the city. All in all, DIMMER focuses mainly on raising inhabitants awareness of the importance of an energy reduction behavior, for both environmental and economic reasons. It seems DIMMER is more addressed to inhabitants of the buildings, the direct approach to the users is achieved by an easy and direct interface visualization, such as QR codes and AR (Augmented Reality) simulations which attracts all ages of people.

on the other side of consideration, INDICATE is especially interested in supporting decision mechanism for stakeholders (in the city realm, such as administration, private investors etc.) the INDICATE is considering all characteristics of places to recognize which areas are responding to their aim. more to the point, which scopes are the best one to invest their limited sources. finally, the OPTIMUS is going to manage the user-friendly interface accessible to both inhabitants and energy managers. On the whole, anybody with a username and password is able to use the facilities of these projects.

Moreover, while the DIMMER project focuses on a district building, the OPTIMUS centralize on the whole building and Different identified zones inside the building. At the same time, INDICATE is supposed to concentrate on the city level through the web application, especially by the city administration. This coordination during the project makes it possible to differentiate from others. From another point of view, the INDICATE cloud-based tool is

used for new and renovation buildings, while DIMMER and OPTIMUS outputs are related to existing buildings, and evaluate their performance from an energy.

There is a striking contrast between these models. The DIMMER and OPTIMUS project include an energy data survey in building through real sensors, while this real-time data flow is not part of the INDICATE project.

## 1.3 History of BIM

The starting point of separating roles in the construction industry was in 1452 when the Italian architect **Leon Battista Alberti** in his bilingual book *De Re Aedificatoria* (The ten books of architecture) distinguished two separate domains of design and construction from one architecture. In the fifteenth century, it was assumed that the construction process requires a staff of different professionals in order to obtain the final product. Later in 1957 two American computer scientists, **Dr. Patrick, J. Hanratty** developed first **CAM (Computer-Aided Machining)** software PRONTO, a numerical control programming tool. Few years later, **Ivan Sutherland** created first **CAD** software Sketchpad. In 1982 the first AutoCAD was demonstrated by Autodesk and then by the same year the Autodesk Company was founded by John Walker, a coauthor of the AutoCAD 1.0. From several years, annual revenue of the Autodesk Inc. is bigger than 2.5 billion dollars. Introducing this software did a lot with construction industry.

Building Information Modeling was created by **Charles Eastman** in the late 1970s at Georgia Institute of Technology. He used the phrase Building Product Model in his book, which was developed by **Phil Bernstein**. He is the first, who used term Building Information Model. Then later in the early 80s Building modelling based on 3D technology was introduced by Gabor Bojar, who smuggled two laptops from the west. This Hungarian scientist created the first BIM software for personal computer, such as ArchiCAD 1.0 in 1983. At those days Hungary was covered by the communist system, in

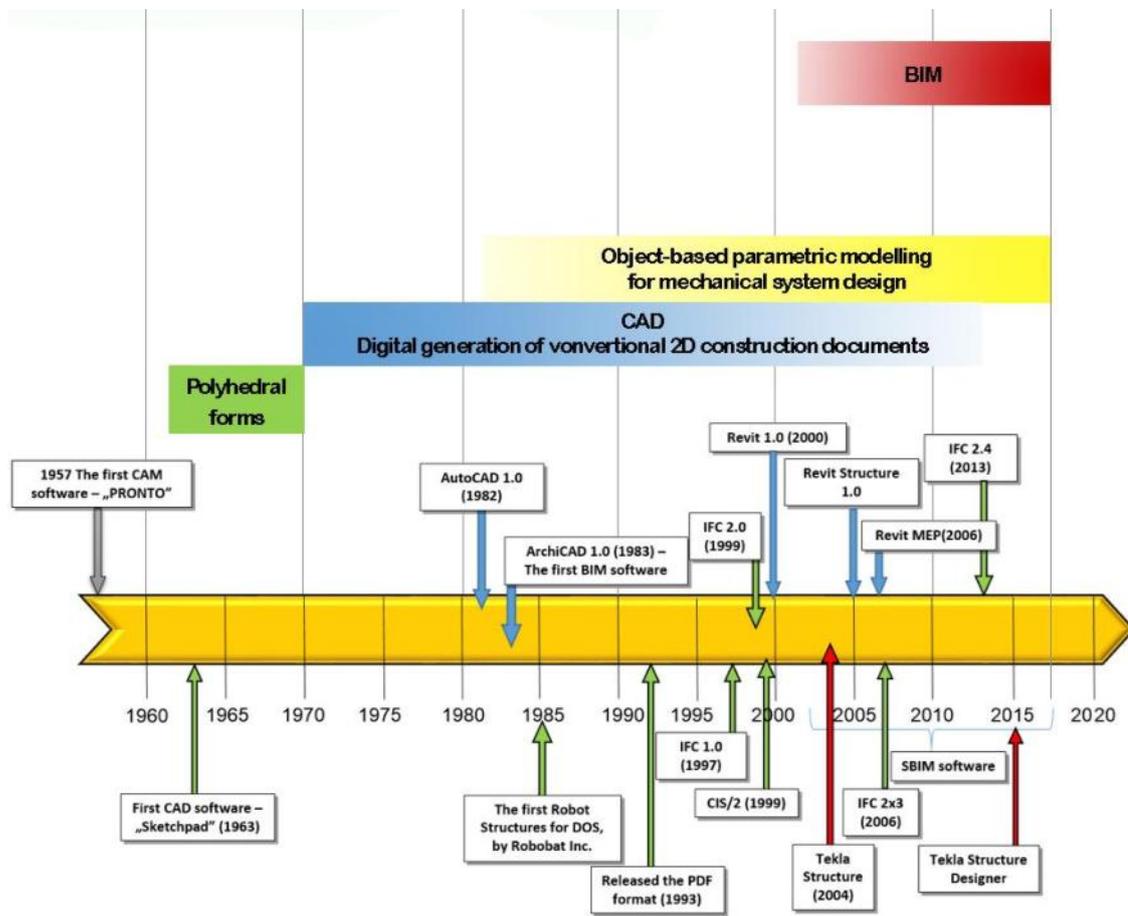


Figure 1.1: Development timeline of CAD and BIM systems

which all western technology was prohibited. In 1993 when the PDF format came to the market the main exchange format for 2D drawings was made. In 1994 a group of various people from AEC community gathered in order to solve the problem of compatibility of softwares from different vendors. This community defined as Industry Alliance for Interoperability created the first version of IFC file format in 1997. Then in 2000, Charles River Software has developed Revit in Cambridge, which was written in C++ and used the idea of parametric components.

As I mentioned before, the BIM concept was introduced at late 1940 but the first time in 2002, it has been used to define this new methodology of work, in which the virtual design, the implementation and the facility management are

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intertwined. The BIM methodology deviates from traditional representation in two-dimensional or three-dimensional objects by the CAD because the buildings were not considered as a simple model, but with families of detailed elements such as walls, windows, floors, etc. These three-dimensional models are beside fundamental parameters for the entire life process of the building and not only those related the graphical representation. This work contains two main different models of CAD and BIM. The first one focuses on the development of representation, on the contrary, the second one focuses on the search of the parameters, which will be attributed to the individual elements, considering future project developments.

### 1.3.1 CONSTRUCTION PROCESSES

Since very beginning of construction history, traditional 2D paper based drawings have always been used for construction and design then by rapid development of IT new opportunities for improvements of processes in construction industry have been discovered and applied.

First step was Using computer based drawing instead of paper based at very starting time, allowed work to be done faster as drawing technique become more flexible in terms of possibility to adjust quickly changes in drawings.

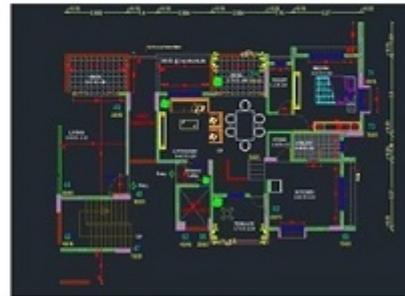
Second step was generation of three dimensional digital objects, which allowed creating 3D building models. With this feature due to possibility of visualization it become easier to understand volumetric geometry of buildings, make better architectural decisions. It also became possible to extract 2D drawings of the building like floor plans or section cuts. Making changes in 3D model they were reflected in all other 2D views respectively.

Third step was possibility to assign particular information to building model components. At this moment Building Information Model term was introduced and development process of such model was called Building Information Modelling technology. Figure 1.4

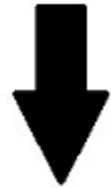
## CONSTRUCTION PROCESSES



Traditional paper based 2D drawings



computer based drawing



The generation of three dimensional digital objects



Building Information Model

## 1.4 BIM

The basic theory behind Building information modelling is well described by Thompson and Miner in 2007, in that; if all relevant data connected to a project were stored in a single online system, the project could be executed in a virtual environment first. When dimensions of time (scheduling) and costs are added to the model this enables easy cost-time- benefit analysis of different options almost instantaneously. (Thompson and Miner 2007) When developing such models for the entire project, more stakeholders, than it is practical today, can be included in the early phases of a project. These stakeholders can inject their business- and engineering knowledge into the design of the facility, its schedule and its organization; thereby improving coordination in all phases of the project (Fischer and Kunz 2006). The resulting BIM model, which is a data-rich, object-oriented parametric representation of the facility, will serve as a repository for data which can be extracted and analyzed to suite all different users needs throughout the buildings entire lifecycle (Azhar et al. 2008). BIM could be read as Building Information Model or Building Information Modelling (Granroth, 2011).

### Definition of BIM

A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update, or modify information in the BIM to support and reflect the roles of that stakeholder. The BIM is a shared digital representation founded on open standards for interoperability. NIBS (2007).

### The Meaning of BIM

What is the deep meaning of BIM and what aspects are hidden inside this name? However, the U.S. national institution of building science (NIBS, 2007) has divided the BIM scope into three commonly used categorizations; BIM as a product, BIM as a process, and BIM as a facility life cycle man-

agement tool.

BIM as a product refers to the actual model as an intelligent digital representation of data about a facility (NIBS, 2007). In order to qualify as intelligent is not just a 3D representation based on objects enough. It also has to include some information or properties beyond the graphical presentation (CRC construction innovation, 2009), and it is primarily this information in BIM that leads to the biggest benefits for the industry (Granroth, 2011). The view of BIM as a product is sometimes called the underdeveloped view of BIM due to that it just considers the model (WSP group, 2011).

The view of BIM as a process considers the process of developing a BIM model (the BIM product) and using it in order to reach project efficiency (WSP group, 2011). At this level of BIM also the social aspects such as; synchronous collaboration, coordinated work practices, and institutional and cultural framework are being dealt with. Most companies that today state that they are working with BIM are looking at this level of BIM and focus on finding processes that enable them to deliver good and profitable projects. The key point from this view is that BIM is a marriage between technology and a set of work processes.

The last and most demanding of these views is BIM as a facility lifecycle management tool. This view sees BIM as management tool, by focusing on a sustainable, verifiable, and repeatable information based environment in order to guarantee well-understood information exchanges, workflows, and procedures, throughout the building lifecycle (NIBS, 2007). This view is extra interesting for client organizations for having this long-term perspective.

### **Building Information Model Life-Cycle**

For Studying the projects in depth, the first stage is to determine what is the purpose of BIM project and measuring its benefits. The next step is to choose software tools, delivery method, and type of process and create all specifications in order to run the project. The next step is to select team members, create strategies and method of evaluation and modifications. The team member should be selected painstakingly, because subsequent changes

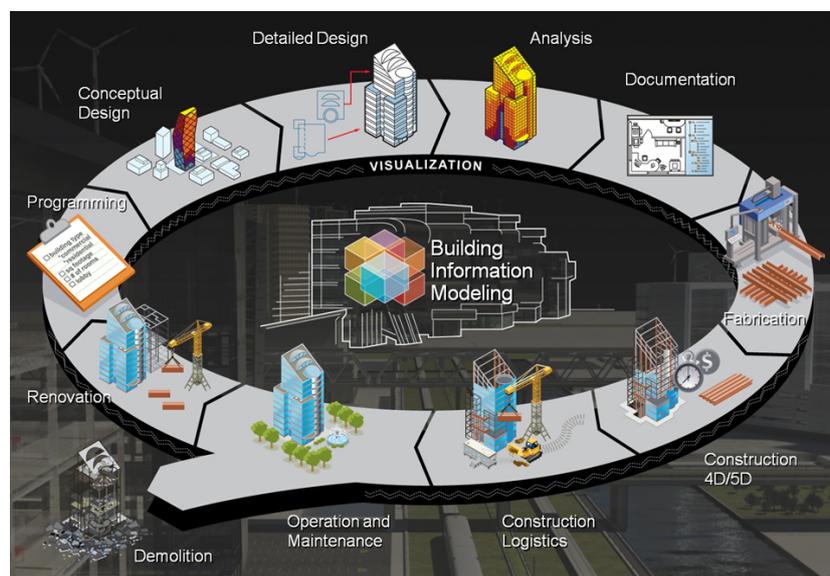


Figure 1.2: Building Information Modeling throughout the lifecycle of a building <http://www.impressedilnews.it/files/2017/09/BIM.Illustration.jpg>

lead to delays and lack of efficiency in team. After that the conceptual model can be created. After the whole process of ac- capitation. The detailed model can be created while the analysis process is carried out. Another team members should study the budget, construction schedule and cost estimation. Then designers would design the model with high level of details and all necessary information. Next step is to create documentation of shop drawings for fabricators. Finally, the documentation is created for contractors. There is also possibility to initiating the BIM process during advance construction phase. Applying BIM model will be efficient at any time. it is shown in Figure 1.2 Today, BIM technology and process can be seen in all the Architecture, Engineering, Construction and Operations (AECO) industry across the world. Over the past years, incredibly effort has been put to strengthen the three-dimensional BIM with 4D, 5D, 6D, 7D .Figure 1.3.1 Visualization means design structure in 3D, animation, rendering and walk through. Time means scheduling of construction, project phasing simulations. Cost means pricing and estimating. Sustainability means conceptual energy analysis, LEED tracking. Facility Management means Building Lifecycle Management (BLM), BIM Maintenance Plans and Technical Support. Nowadays,

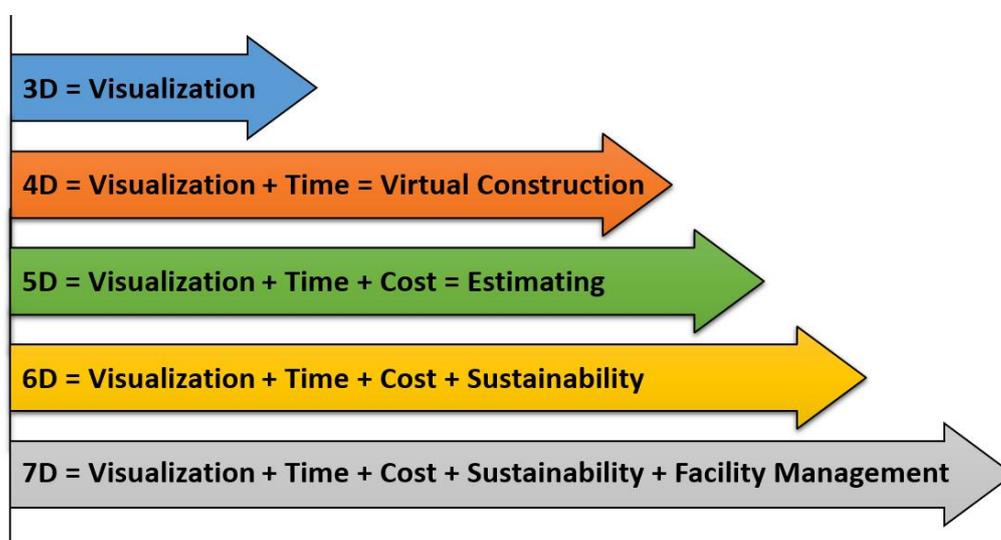


Figure 1.3: The graph presents the BIM dimensions

we can see the change of mentality of owners and Architecture/Engineering (AE) firms about the concept of BIM and using 3D modeling to support both the preconstruction and the construction process. Many new terms, concepts and BIM applications have been developed such as 4D, 5D, 6D and 7D. The D in the term of 3D BIM means dimensionl and it has many different purposes for the construction industry. 3- Dimensional means the height, length and width. 4D BIM is 3D plus the factor of time, which in the context of BIM used in construction planning implies, the project schedule; 5D BIM is 4D plus cost estimation; 6D BIM is 5D plus site, which means a 3D building model linked with a 3D site model, and the integrated model should also carry all the project schedule and estimation information; and even the concept of 7D BIM has been brought up, which is BIM for life-cycle facility management (Review of BIM, 2011). Through a wider and wider application of BIM, certain benefits of using this computer-aided technology have been found out and confirmed. The key benefit is its accurate geometrical representation of the parts of building in an integrated data environment allowing for a more coordinated production of documents in 2D and 3D, it provides a better visualization of the design which would help the owner to confirm if the final building would meet his/her expectations; meanwhile,

BIM as a single integrated information resource, would make the communication and coordination among project participants much easier. Some other benefits of BIM are faster and more effective processes, better design, controlled whole-life costs and environmental data, better production quality, automated assembly, better customer service and lifecycle data for facility management (Azhar, 2011). After having a review on usage of BIM and peoples idea about it was clearly understood that, the 3D, 4D and 5D BIM are more and more frequently used with the support of BIM technology in the planning, organization and scheduling of projects. However, most of the discussions associated with BIM are concentrating on modeling the building solely, not much has been found regarding BIM for the corresponding site in which the building is located. To date, there are few studies and systematic implementation of integrating the site and building into one single model. The benefits of using BIM concept to define site conditions are mentioned in some research paper, however, none of them has provided an in-depth discussion focusing on, what are the strength and weakness of using BIM and what are the detailed feasible methods of applying BIM concept in defining site conditions and technology support that we can use in the real world, not to mention the topic of linking site and building model together.

### 1.4.1 BIM Maturity Model

The BIM Maturity Model contains four levels of development as shown in figure 1.4 following each level is briefly described. The levels are illustrated in

#### **Level 0**

This level requires communication of data either the paper documentation or electronic, the exchange data is linear and asynchronous. Entire documentation should be made in 2D technology and no 3D data is needed. In zero level the interoperability is on the basic level.

#### **Level 1**

In this level during design process a Common Data Environment (CDE) according to standards BS1192 is used. It is a simple collaborative environ-

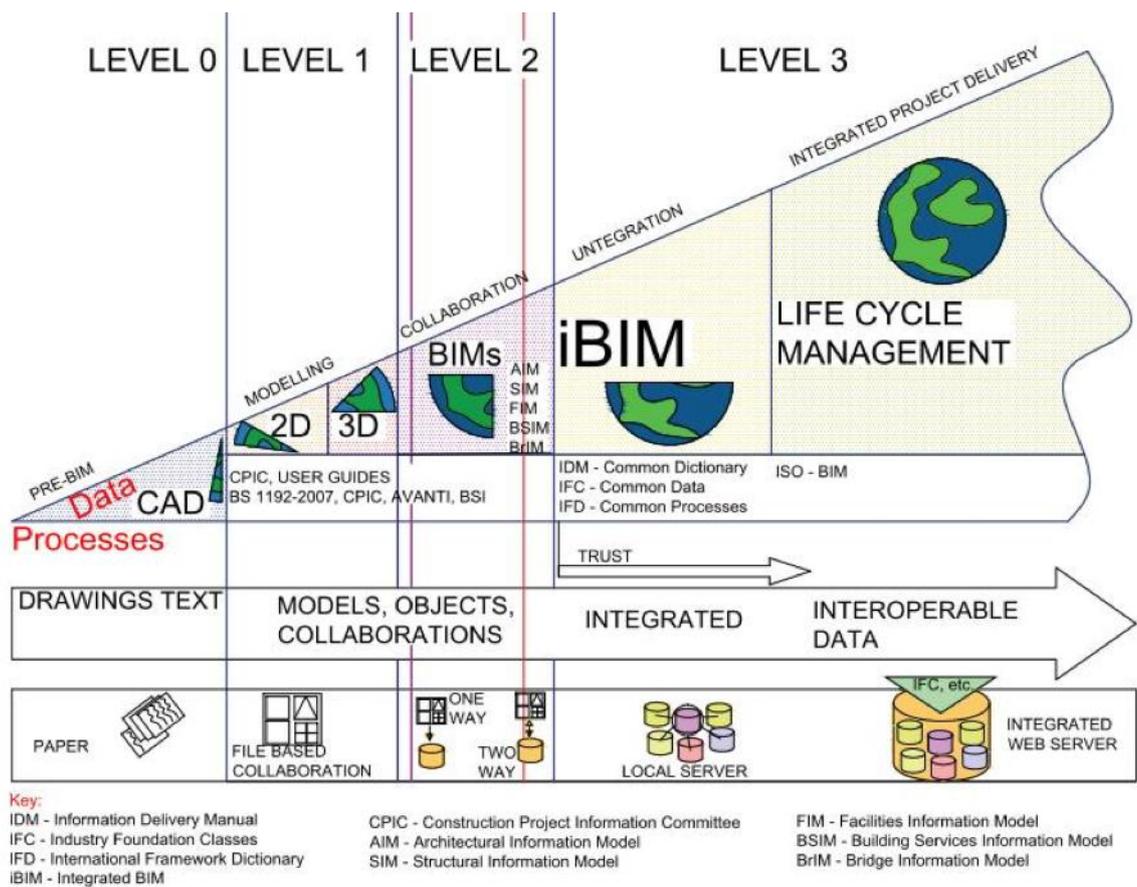


Figure 1.4: The graph presents the BIM dimensions <http://bimtalk.co.uk/bim.glossary:level.of.maturity>

ment designed for everyone from AEC industry. This system avoids repeat of mistakes, reduce time and cost, reuse information to support cost planning, estimating and management. Entire documentation should be made in 2D or 3D technology. Model does not contain useful data, which can be shared with other team members. In practice, it looks like: each engineer creates single-disciplinary models: architectural model, structural model and MEP model. The exchange file format is DWF or PDF etc.

### **Level 2**

The model of construction should be created in BIM software and delivered in digital version, transferable without security. Without security means, the model should be collaborate by proprietary formats e.g. Revit file format. rvt between Revit architecture and Revit structure, and by non-proprietary formats e.g. between ArchiCAD and Tekla Structures using the IFC file format. In second level of BIM Maturity Model all data are shared between all team members involved in the project. During this process adopted additionally 4D (time analysis) and 5D (cost estimating) process. The delivery file should contain 3D models in native format, drawings and documents in Portable Document Format (PDF).

### **Level 3**

This level requires fully integrated and collaborative process with data exchange and with systems. It provides the facility management and life costing data. Entire process of sharing files, thoughts, remarks should take place in the cloud by proper web services. This full integration can be achieved by model server technologies. This level allows user complex analysis.

## **1.4.2 Benefits of BIM**

One of the main advantages of using BIM technology is supporting all the process starting from feasibility study stage and continuing through whole building lifecycle. The Major benefits presented by Chuck Eastman for each building project lifecycle phase are described below.

### **Pre-construction phase**

In feasibility stage client will determine the size of the project considering his motivation for investing and budget. The estimation of the project at this point is very rough. But it is still not desired to spend a lot of time on cost estimation which at the end appears to be significantly over budget. Using BIM tools approximate building model can be linked to cost database and project price would be calculated instantly along with model creation/modification process. Already in early stage when only schematic model is available it is possible to evaluate building functionality and sustainability using analysis/simulation tools. This allows defining right project development directions in early stage which increases the overall quality of the building.

### **Design phase**

Entering the design phase 3D model is already available from previous stage so we don't need to change the 2D drawing, there is also possibility to extract accurate and consistent drawings for any set of object or specific view of the project. The advantage is that, after each modification of 3D model all the 2D visual representations are modified respectively. Also there are automatic evaluations of 3D models in terms of satisfying a set of requirements for instance; Area of certain type room that has to be of particular size. Estimators using BIM can extract quantities which can be used for cost estimation. At the beginning estimations are made based on available quantities like areas then the more detailed design is done the more accurate estimations can be performed. Continuously monitoring of projects help for making better decisions both in term of cost and quality.

### **Construction and Fabrication**

By simulating the construction process, using 4D BIM, the construction can be monitored day by day and reveal potential problems on the site and opportunities for improvements. And before real construction, identify any problem between systems from different disciplines. This is valuable because would speed up construction process, reduces risk of project cost raise due to clashes and help to find solutions for fix mistakes before they happen in reality also minimizes probability of legal disputes. In case design changes



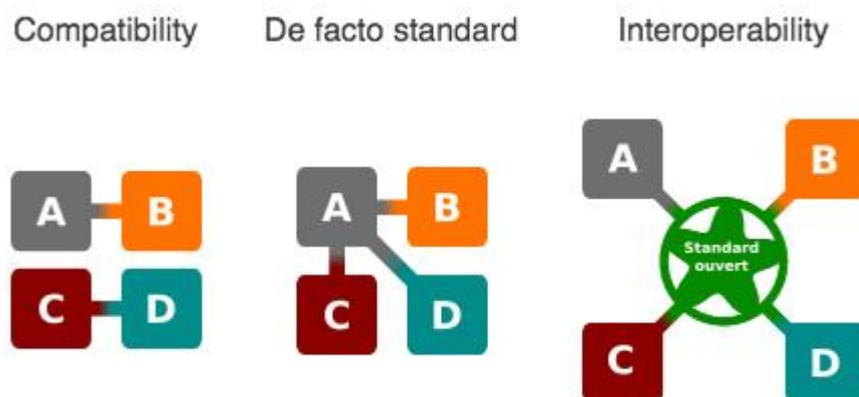


Figure 1.6: interoperability working group

explore further. In NBMS-US (National BIM Standard United States) is defined interoperability as: An exchange of information on the software level between different applications, when each of them must have its own structure of internal data. Interoperability is achieved through a party mapping of each application participating in the exchange between the internal data structure and a universal or vice versa.

For BIM interoperability, there is another just as important driver. In the construction industry where one-off projects teams are assembled across different organizations, disciplines and phases you want the different disciplines and tools to share information with each other and you want data generated in one phase to be usable without re-entry for the next phase. And this is possible only with having interoperability. The Figure 1.6 shows the interoperability working group. It is presented under the heading degrees of interoperability. However, we would argue that the two first categories are not real interoperability.

we use Wikipedia to clarify; When a vendor is forced to adapt its system to a dominant system that is not based on Open standards, it is not interoperability but only compatibility. The U.S. National Institute of Standards and Technology found that users bear direct costs of almost 16 dollars bil-

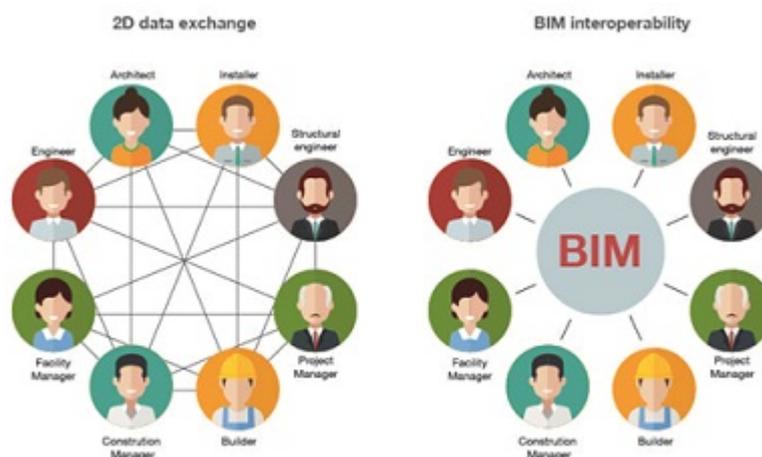


Figure 1.7: BIM interoperability vs 2D data exchange

lion annually from time wasted due to inadequate AEC software ability; a fact instantly confirms the lack of interoperability between software programs of today. (Gallaher et al., 2004) Companies like Autodesk, Graphisoft and Bentley Systems have each developed AEC operable software packages within separate file-formats, challenging the interoperability between the professions preferred tools that is developed by the building SMART alliance (founded 1995) which through NBIMS (U.S National Building Information Standard) and the IFC file format works toward interoperability and open standards to the built environment. (building smart, 2011) As I mentioned before, Interoperability means capacity of exchange information between different applications, Figure 1.7, also we know that BIM involves the interweaving of various professional roles from different disciplines. The advantage of interoperability is in the exchange of a single parametric model, which can be analyzed by all users, so it would reduce errors and waste time while designing or analysis the data.



Figure 1.8: Private Exchange Format

Interoperability addresses the need of passing data between different applications without loss of relevant information. The advantage of Data exchange between two applications can generally be performed through one of the four encoded processes:

Direct connection between two specific BIM applications

Private exchange format

Public exchange format

Exchange formats based encodings XML

### **Direct Connection**

it is integrated connections between two applications, could be done through the execution of dedicated commands inserted within the software. The direct links are usually very frequent between applications belonging to a common software house; they are not missing however.

### **Private Exchange Format**

it is a file format developed by a specific organization so that related proprietary applications are able to interface with each other. Among the private exchange format most well-known is the format DXF (DATA exchange Format) By the software company called; Autodesk and much used in the exchange of information between programs developed by the company itself. Figure 1.8

### **Public Exchange Format**

These formats, such as IFC using open extensions, so do not belonging to any software company. These two extensions, encoded by international standers, are able to transfer data between different application heterogeneity, from the geometric characteristics to the types of used materials, documents related from the project to relationships and constraints that exist between the individual model parts. For instance; IFC (Industry Foundation Classes)



Figure 1.9: Public Exchange Format



Figure 1.10: Green Building XML (gbXML)

is an open-data format developed by Building SMART, formerly known as the International Alliance for Interoperability (IAI). IFC is a neutral and independent file format that does not belong to any particular software vendor. The IFC is also independent of any vendors software development plans. The goal with IFC is to facilitate the information exchange between different programs developed by different software companies (Building SMART, 2011).Figure 1.9

### **Exchange Format Based Code XML**

XML (Extensible Markup Language) is a language that allows the coding of syntax contained within text formats. The extension of XML is developed by the international non-governmental organization W3C-World Wide WEB Consortium, and how IFC is an open format. It is a format supported by many applications dedicated mainly to the execution of analytical tests. One of the extensions best known is the gbXML (Green building XML) useful for coding of model data by software and web applications for simulations and energy audits.

### **Green Building XML (gbXML)**

The gbXML enables web based applications to automatically interact with each other, with no or minimal human intervention. When documenting in XML both computers and humans are able to interpret the information.

This brings the opportunity to exchange information via internet easily and efficient (Cheng and Das, 2014). Furthermore, XML allows people to create their own customized language for exchanging information within their domains of interest. Therefore, the implementation of the actual data model or schema, with their associated semantics, can vary significantly (Dong et al., 2007). The gbXML format facilitates the data transfer of building information stored in a BIM towards engineering analysis tools. Building information like building geometry, schedules, weather data, HVAC systems, rooms, lighting and thermal zone related data can be accommodated. This supports the interoperability between design software and engineering analysis tools and eliminates the need for time consuming plan take-offs. Figure 1.10

## 1.6 DIM and smart cities

If we increase the concept of BIM to multiple buildings and urban scale it would be called DIM (District Information Modelling) which is totally new and update version of BIM. In a wider view from building scale to an urban scale if we consider the integration of buildings for example in case of energy saving or in concept of smart cities then we can use the evolution of BIM which is named DIM. Figure 1.11 The need for studying DIM comes from our need to not only study and focus on unique building but to integration of smart buildings which is called smart cities.

DIM (District Information Modelling) is conceived as the natural evolution of BIM from building to urban scale, in order to deepen several topics related to Smart Cities, for example energy savings and CO<sub>2</sub> emissions. Work at district scale involves the management of a large amount of data, where information no longer recalls a single building but heterogeneous construction, composed of private and public buildings and their energy sources. For this reason, have been established standards and a common methodology to be used, which has identified several domains: The Building Information Modeling (BIM), the Geographic Information System (GIS), the Energy Analysis Model (EAM), the System Information Model (SIM) and Building Automa-

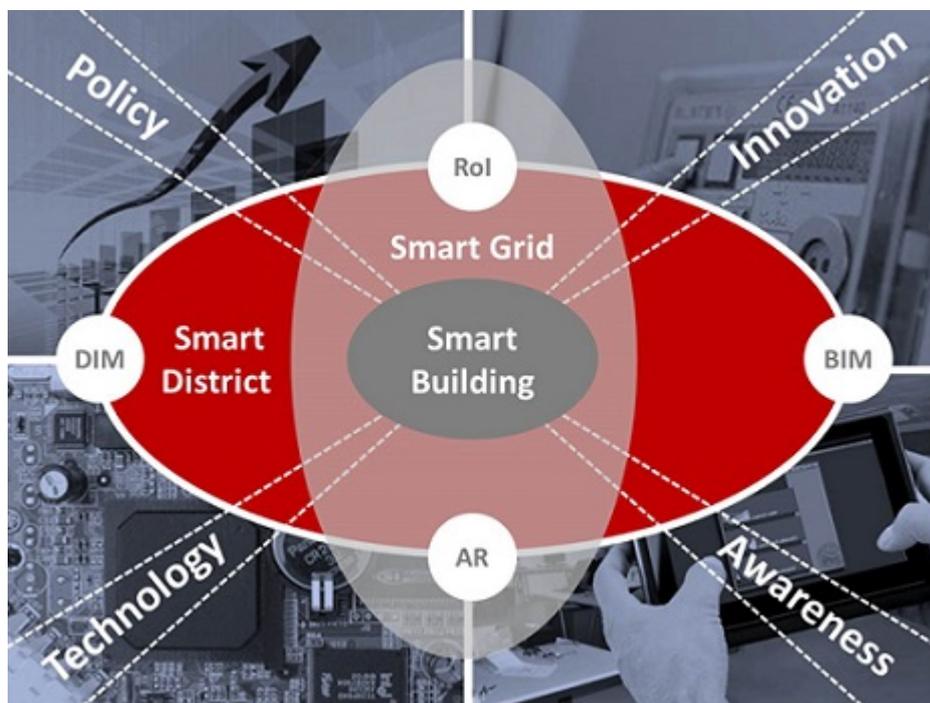


Figure 1.11: District Information Modelling  
<http://www.drawingtothefuture.polito.it/what-we-do-2/gis/>

tion System (BAS)

Each domain contains different information depending on the business areas. The BIM domain collects all the information in the construction scale from design and analysis up to the management and maintenance phase. The GIS domain collects information in urban and district scale useful for the development of analysis of macro-systems for the evaluation of energy-saving policies. The EAM domain collects data resulting from the energy simulations at the district level and building. On the other hand, the BMS works with domain static and dynamic data from the sensors and hardware devices of control systems for building automation. Finally, the SIM domain consists of the information on the primary of the district energy systems.

### 1.6.1 Difference between BIM and DIM

BIM is technologically driven, whereas DIM tends to be socially driven. DIM projects are derived to focus on occupant engagement and stakeholders, social constructs, norms and values, team collaboration and project management, interpersonal relationships and communication, and value chains. To reach out to this thought process, DIM projects use brainstorming, focus groups, conducting interviews, circulating questionnaires and surveys, and conducting workshops. All these participatory research tools are stakeholder oriented. The data obtained, is then utilized to develop digital tools like DIM. All these efforts will ultimately result in increasing the capacity of stakeholders to collaborate and interact more productively in order to reduce waste of resources, while developing energy efficient designs. Figure 1.12

Nowadays the attentions toward climate changes beside everyday increase of moving from small villages toward cities forced the word for being more responsible about cities in energy point of view. The concept of smart cities has been developed very rapidly during last decades it takes advantage of real-time information, coming from various fields and they can meet the users needs and desires by using ICT, Information communication technology, and the data coming from the various services.

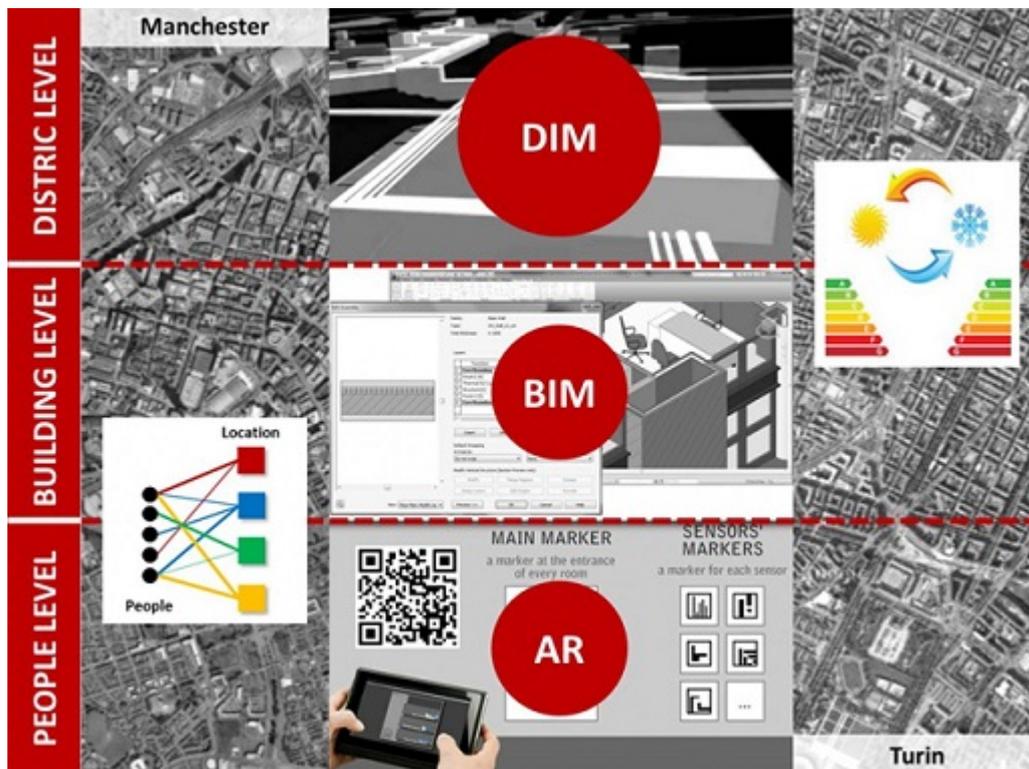


Figure 1.12: BIM and DIM <http://www.drawingtothefuture.polito.it/what-we-do-2/gis/>

In addition, ICT technologies are reportedly the key players against climate change. The teams at Horizon 2020; with nearly 80 billions of funding available over 7 years (2014 to 2020), are trying to combine real-time sensor data with BIM and GIS models, in an effort to create district models, and to move from Smart buildings to Smart cities. Which means applying DIM.

# Chapter 2

## Dimmer project

In this chapter the European project, called DIMMER is introduced then the goal and the objective of the project and the effects of this project in energy consumption are explained in details

### 2.1 DIMMER

The DIMMER (District Information Modelling and Management for Energy Reduction) system integrates BIM and district level 3D models with real-time data from sensors and user feedback to analyze and correlate buildings utilization and provide real-time feedback about energy-related behaviors. The overall objective is to create a District Information Model (DIM) and Management system. It enables access through personal devices of energy-related information for energy and cost-analysis, tariff planning and evaluation, failure identification and maintenance, energy information sharing. The following features are included: i) real-time data collection; ii) advanced middleware technology for data integration; iii) simulation and virtual visualization; iv) user/social profiling, visualization and feedback; v) energy efficiency and cost analysis engine; vi) web interface and interaction.

### 2.1.1 DESCRIPTION OF PROJECT

The DIMMER project (District Information Modeling and Management for Energy Reduction) is part of FP7 (the seventh Framework program) which is research project funded by the European community. It was started on the 1st October 2013 and it lasted 3 years. Politecnico di Torino participates of this project with other 10 partners from 4 European countries. Figure 2.1

- . Consorzio per il sistema Informativo, Italy
- . ST Polito, Italy
- . DAppolonia, Italy
- . IREN Energia, Italy
- . Clicks and Links, United Kingdom
- . Arup, United Kingdom
- . University of Manchester, United Kingdom
- . Oldham Metropolitan Borough Council, United Kingdom
- . CNet Svwnska Ab, Sweden
- . Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung, Germany

**Third parties:**

- . Istituto superior Mario Borlls; Italy
- . Universita degli studi di Torini, Italy :



Figure 2.1: Dimmer and its world wide partners  
<http://www.dimmerproject.eu/>

### 2.1.2 GOAL AND METHODOLOGY OF WORK

The goals of project are:

- . INTEGRATE Building Information Modeling (BIM) with real-time data and their extensions at the district level (DIM);
- . USE the web-based interface to provide feedback about energy impact of user behaviors;
- . VERIFY the interoperability of district energy production/consumption, environmental;

. CREATE new business models for energy traders and presumes (producer/consumer) exploiting user energy profiling. The project focuses on the interaction of ICT, Information Communication Technologies. Thanks to ICT it is possible to access real-time information about building environmental characteristics and energy consumption. At district level, information about district heating and cooling and the electricity grid can be accessed. Middleware technologies enable a coming interface to monitor and control devices such that these heterogeneous sources of information can be put together in a centralized decision system. Furthermore, advancements in 3D modeling, visualization and interaction technologies enable user profiling and real-time feedback to promote energy efficient behaviors. In order to exploit the full potential of these technologies, the DIMMER project concentrate on:

- . Modeling: Integration of Building Information Models (BIM) with real time data and their extension at the district level (DIM).
- . Middleware: Able to integrate different data sources: Building information model (BIM), system Information Model (SIM) and Geographic Information System (GIS).
- . Interoperability: optimizing information exchanged on ICT new platform and Dbs.
- . Awareness: Visualizing in Real-time Energy related information in the building and district environment, using virtual and c. :

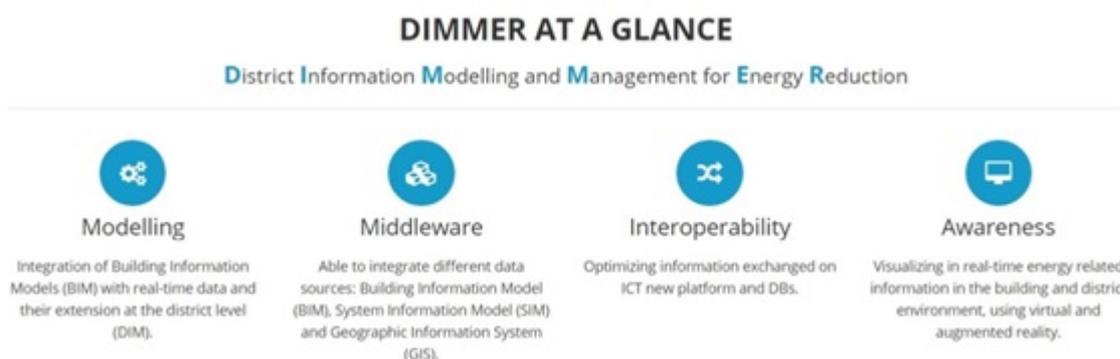


Figure 2.2: Dimmer summary <http://www.dimmerproject.eu/>

### 2.1.3 CASES STUDIES

For validate the DIMMER system were chosen two urban districts from two different cities, in the North and South Europe, Torino (IT) and Manchester (UK). These districts are more different features because they are characterized by heterogeneous buildings (age, materials and sources pf energies) and users.

#### 2.1.3.1 Turin case studies

The Turins district is not far from the city center and is characterized by a reasonably balanced presence of public and private buildings. Conversely, the Manchesters district is the home to the University of Manchester, the Manchester metropolitan University and the Central Manchester University Hospitals NHS Foundation Trust (CMFT)

**T01. POLITECNICO DI TORINO** Corsa Duca degli Abruzzi 24 Technological University Good preservation state 315,000 cubic meter. The buildings are connected to the district heating system and are provided with both BAS and BMS systems.

**T02. PRIMARY SCHOOL MICHELE COPPINO** Via Cristoforo Colombo 36 primary school Good preservation state About 5,400 cubic meter.



Figure 2.3: Turin cases

The building is connected to the district heating system, there are no BAS systems.

**T03. NURSARY SCHOOL BRACCINI** Via paolo Braccini 36 School Good preservation state About 1,305 cubic meter. The building is connected to the district heating system, there are no BAS systems.

**T04. COMUNE DI TORINO SMART CITY DIRECTION** Corso Ferrucci 22/ Via Braccini 2 Office Good preservation state, recently renovated About 5,700 cubic meter. The building is provided with an air conditioning system; there are BAS systems.

**T05. COLLEGIO R. EINAUDI SEZIONE SAN PAOLO** Via Norberto bobbio3/ Corso Lione 44 Hall of residence Good preservation state About 6,270 cubic meter. The building is not connected to the district heating system, there are BAS systems. Figure

**T06. RESIDENTIAL BUILDING** Via Antonion pigafetta 52 Residential building Good preservation state 2,185 cubic meter. The building is connected to the district heating system, there are no BAS systems.

**T07. RESIDENTIAL BUILDING** Corso mediterraneo 130 Residential building Good preservation state 5,863 cubic meter. The building is connected to the district heating system, there are no BAS systems.

### 2.1.3.2 Manchester case studies

**M01. Ferranti Building** (1969) University teaching facilities and labs, was built in 1969 and has a total of 6 floors.

**M02. The Mill** ((1868) Was built in 1868 and has a total of 9 floors. In 1960s the original mill was converted and extended to provide facilities for the university engineering departments.

**M03. Paper Science** (1950) Engineering and science departmental offices. Teaching rooms and research facilities are based in the 7 floors of the paper science building, first incorporated into the campus in 1950.



Figure 2.4: Manchester case studies

**M04. MBS East** (2000) Is the newest building of the Manchester Business School Campus which was built in 2000 and has 5 floors.

**M05. MBS West** (1971) The older part of the Manchester Business School campus was built in 1971 and consists of 12 floors.

**M06. James Chadwick Building** (2012) The James Chadwick building was built in 2011 and has 5 floors.

**M07. Precinct** (1970) Built between 1970 and 1972, has 11 floors.

**M08. Crawford House** (1973) Forms the extension of Precinct 1, across Oxford Road and was built in 19783 and has 6 floors.

**M09. Alan Gilbert Building** (2012) The Alan Gilbert Learning Commons is a state of art study and learning centre that was built in the heart of Oxford Road campus in 2012. It has 4 floors.

**M10. Stopford Building** (2012) The Alan Gilbert Learning Commons is a state of art study and learning centre that was built in the heart of Oxford Road campus in 2012. It has 4 floors.

**M11. John Rylands University Library** (1936) The main building was built in 1937. On its 7 floors holds principal collections for teaching and research in humanities, education, law, medicine, science and social sciences.

## 2.2 DIMMER AND ENERGY

The District Information Modelling and Management for Energy Reduction (DIMMER) project is set to be one of the first to provide insights on our energy future.

In Dimmer project the data on energy use in districts and cities is gathered by Using sensors, researchers are building sophisticated computer models in order to provide the most complete view of smarter energy use in the future. Moreover, Dimmer is trying to capture the true diversity of energy demand

in cities and project how this will change when smarter technologies will be available. The group monitors energy use by individual consumers at the local level. Then the researchers collate the gathered data to create district information models that represent energy use across entire areas.

The models also take account of future advances in technology and possible changes in consumer behavior. The hierarchy of the data of the DIMMER project based on six main domains (Urban/District, Building, Energy Analysis Model, Building Automation System, End users awareness, Visualization and simulation) has been defined as well as a set of tools to be used during the project. Several tests are under test. This project is developing interactive devices which tell consumers about any energy they may be wasting in their homes by real time interacting, helping them to take responsibility for their energy habits. The consumers are Classified depending on their energy and building usage. This general main goal of project objective is achieved under 4 main groups of activities as follow:

1. Visualize in real-time energy related information in the building and district environment; By Energy auditing of selected building as a whole and their surrounding and measurements in real time of thermal and lighting data at district level. and also, Development of a context framework for district level energy awareness
2. Creation of tools for involving users into energy related decisions and collecting their feedback and Correlate user profiling and feedback information with building and district utilization to opportunities for energy distribution optimization;
3. Optimize policies based on more fine information real-time energy production/consumption) and environmental conditions;
4. Perform cost and energy analysis that would enable the offer of personalized tariff plans and their evaluation on the basis of profiled use of energy. In addition, in concept of Energy efficiency and cost analysis engine the researchers Exploit real-time information from buildings and from smart district heating/cooling and grid (including distributed generators DG), building models and user behavior models the optimal energy distribution can be computed and be Compared by simulation results between a standard

reference consumption and an ICT-equipped district use of energy. Depending on the type of buildings and the possible actuation, the output of this analysis can be used to suggest more efficient behaviors for private users, or to actuate optimized distribution policies in public buildings. The analysis engine will be able to suggest more convenient behaviors by accounting for variable tariffs. The key for user acceptance of these suggestions is to enable application suggesting actions in real-time on their personal devices through an innovative interface (see web-oriented interactive interface item). There are three main parties involved in this project; energy supplier, facility managers and users of buildings:

1. The energy supplier (especially in Turin) is primarily interested in optimizing and rationalizing the use of the current infrastructure of production and distribution, for example through peak reduction measures.
2. Facility managers and energy managers are interested in saving money, and preserving a state of thermal comfort, in order to avoid complaints; they have responsibility for energy budget and reducing energy use, and are proactive and interested in energy saving issues.
3. The users of the buildings are mainly interested in comfort but, in the case of private buildings, the monetary aspects acquire a higher degree of prominence.



Figure 2.5: Location of My thesis case study

## 2.3 Turin Case Study, Corso Mediterraneo 130

The case study of my thesis, which is located between the Corso Mediterraneo No. 130 and Christoph Columbus Street No. 50 and No. 52, and Jovani Street, No. 20, which is a fully residential building, except for a commercial ground floor. Figure 2.5 The building is located in the Crocetta neighborhood of the city of Turin, which consists of two distinct regions with a distinct identity, San Secondo and Santa Teresina. The streets of the Corso Mediterraneo, Pigafetta and Giovanni da Verrazzano, which restrict the building, began to appear between 1906 and 1911, according to official documents (for example, the Paravia guide).

According to the study building, the first works on the remains of these

streets date back to the 1930s, the year in which the Santa Teresina region reaches a compound and structure that is responsive to the situation. The first archival documents related to the building date back to 1965. The same year the project was introduced to the municipality of Turin, designed by architect Luigi Buffa, adopted in 1966. The architect Buffa, with other engineers Paverelli and Maschio, has been the designer of the early buildings in the area. More specifically, the project of the buildings of the Corso Peschiera in the first half of 1920, the plaque 22 of 1923 and the number plate 20 (two years later). These designers have made the most recent buildings of the field much simpler and Tuscan, such as the Maschio House on Govone No. 6. This building is in a complex with three main sections, overlooking the streets of Verrazzano, Colombo and Corso Mediterraneo from each side of the main view. Although each section has a different height, they are the same in terms of construction technology.

structure of the building is a skeleton of a beam and column type that is executed with traditional concrete ceilings. According to the year of construction of the structure, there is certainly no pre-fabricated or semi-prefabricated method for the use of this building. It can be referred to as a hybrid structure system. When the overall presence of the building is interrupted in dealing with vertical elements of the building, such as stairs and elevator. For the transfer of vertical forces to the earth, it has been used superficial or direct foundations. Columns, beams are all single-purpose structural therefore the internal and external walls are not.

The walls of this building are in fact of two types of exterior and interior walls. The external wall is Cavity masonry wall consisting of an outer and inner with bricks full and perforated, and separated by a continuous air space, the dead air space provides improved thermal insulation. The exterior wall has one layer stone in basement floor and view of the bricks in upper floors. Separation of the wall surface in the openings for the windows. Figure 2.6

The ceiling is the combined of concrete and brick, which is usually blocked. Considering the construction period, it is assumed that the ceiling of the building is also built in its own place that it first runs the joists and tension

DESCRIZIONE	IMMAGINE	PERIODO DI MAGGIORE DIFFUSIONE		$U$ [W/(m <sup>2</sup> K)]
Muratura a cassa-vuota con mattoni pieni (paramano) e forati		1930	1975	1,26

Figure 2.6: description from Tabula project

arrays and then enter the concreting phase. Vertical blocks mean a total of vertical systems such as stairs and a mechanical system such as elevators and elevators. There are six vertical blocks of both traditional and mechanical elements in this building. Two stairs in the exterior, three stairs in the interior view from the yard side and one in the building. In all cases, each vertical block is arranged with an external elevator. The elevators are of electrical type at normal speed. The doors are semi-automatic. The electric section and towers made for lifting are visible in the high section of the building. The frame of the external windows are basically two kinds: wood, for windows and metal for commercial entrance doors and vertical blocks associated with upper floors. In general, the dominant glass is transparent and single-glazed for doors and windows. For upper windows, external shades are used. Doors of commercial units are all of a kind of metal. The garage door, interior of the courtyard, is a metal. The roof covering is Flat, so that its slope does not exceed 8 percent from the horizon. Using the project designs, the position of the insulation layer is not recognizable as to the insulation layers. However, due to the construction period of the building, it is assumed that this layer is located on all insulation layers, which is also referred to as warm ceilings they say. Figure 2.7



Figure 2.7: Turin Case Study, Corso Mediterraneo 130

## **Chapter 3**

# **PRODUCTION LINE**

In this chapter I am going to qualify the methodology I used for success of energy saving and give an explanation of the work flow I did. In figure 3.1 you can see the method that I flowed during this project.

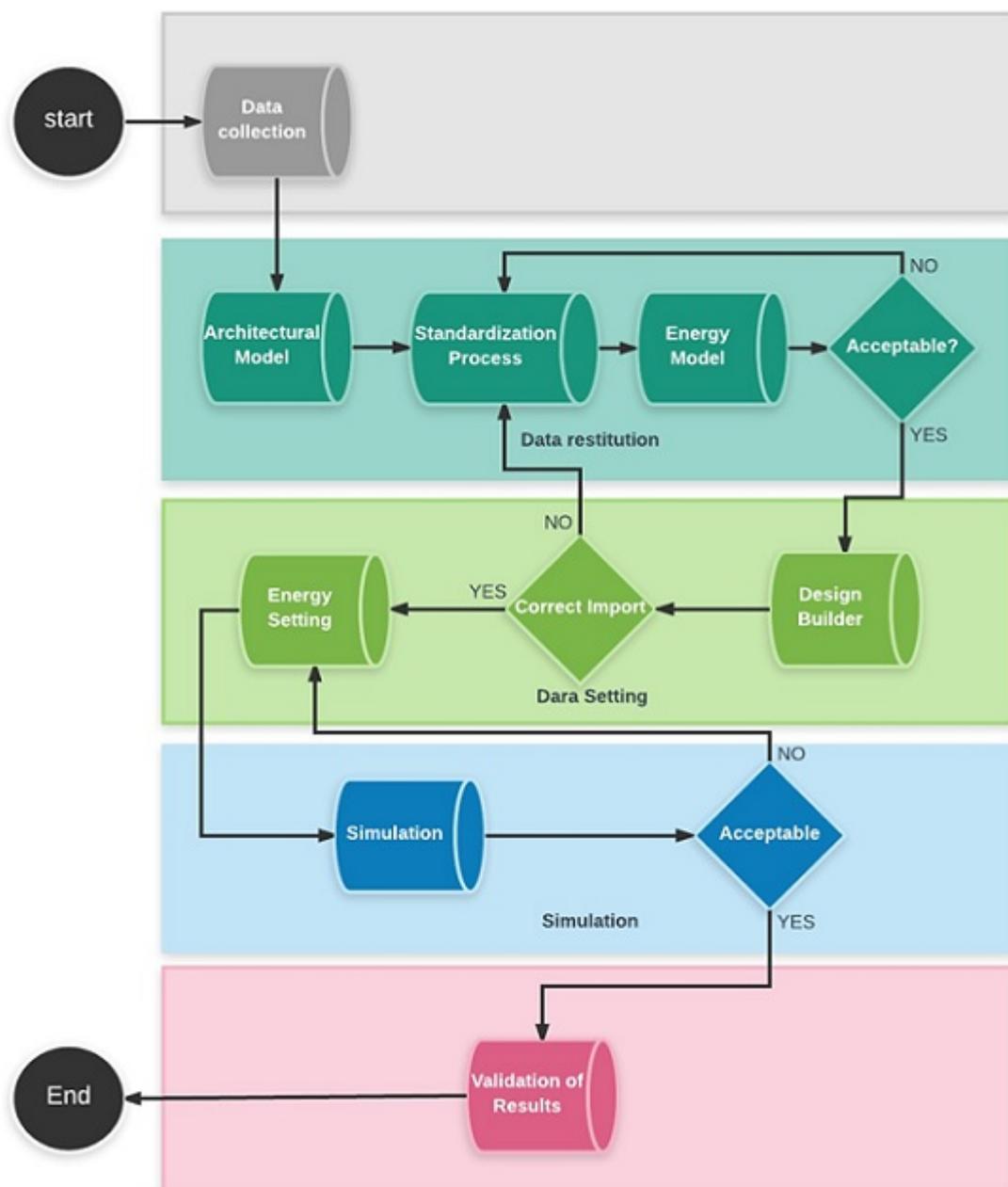


Figure 3.1: Methodology Composition

## 3.1 DATA COLLECTION

First, before starting to the 3D modeling I went to Archivio Storico Torino in order to understanding of the whole information about my case study. I found floor plans and construction documents. next, I got some materials from DIMMER project. in the means of understanding type of wall, I searched in Tabula project. in the case of having cleare calculation I used Piedmont price list.figure 3.2

## 3.2 Modeling

### 3.2.1 ARCHITECTURAL MODEL

On the whole, for parametric modeling different software can be used, but within the DIMMER project was mainly tasted interoperability between the various energy programs and the Autodesk Revit 2017. Once I have collected all the indispensable data, I able to start project: First I drew floor planes (exterior wall, stairs and some interior partitions) of building with Auto Cad software in DWG file from photos which I got from Archivio Storico, after that I defined levels to be used, they are imported into the Revit software the floor plans in DWG format and after we cleaned and faired from irrelevant details to 3D modelling.Figure 3.3

#### 3.2.1.1 STANDARDIZATION

My model was too complicated to be performed later. So I decided to simplify it and make it easier. To achieve this goal the building was modeled with a single type of floor, exterior wall, interior wall, windows, and roof. If you had a building with various walls, both internal and external.an other simplification was considering same thickness while in reality they had different thickness. All elements where be used as benchmarking of DIMMER

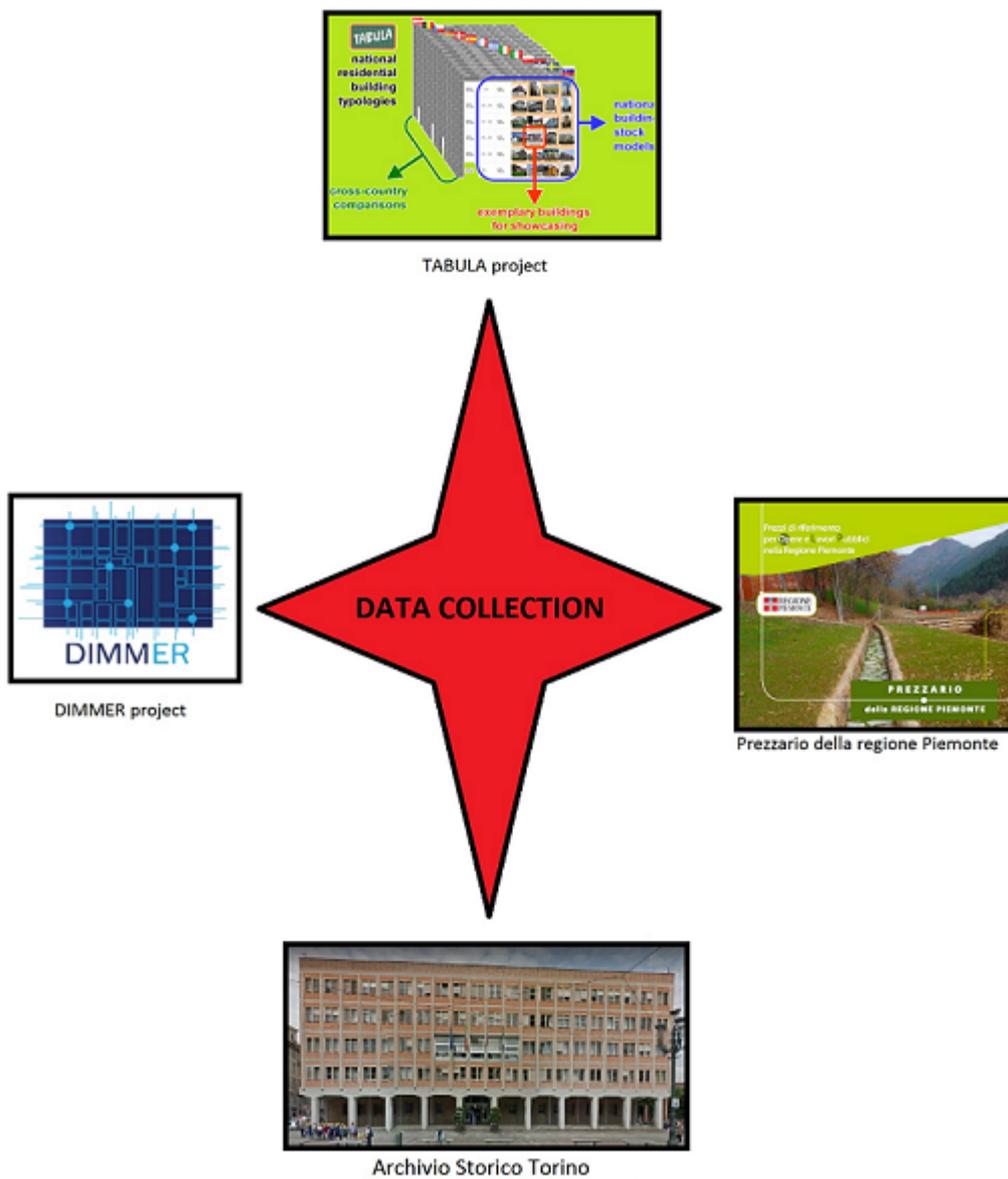


Figure 3.2: Data collection

project which was previously established. The elements are named as: **Txx name yy** Where T indicates that the building belongs to the district of Turin. xx indicates the number of the case study. name is the name of the element of stratigraphy that you are considering, for example, int part (intern partitions), ext wall (outer wall), roof (roof), and so on. yy indicates



Figure 3.3: CAD plan of building

the number of the scenario for the state of affairs worth 01. The elements that I used in very beginning of realization of model, did not contain any specific properties. They are assigned to general type of element considering technological parameters of the model. Inserting the stratigraphy of the different elements and then for each one of them considering the physical and thermal confidants of the material used both for the items and even materials a specific nomenclature was drawn:

**Txx...Name of material...yy** Where

T indicates that the building belongs to the district of Turin. xx indicates the number of the case study.

Name of the material is the name of the material used that is being considered. For example, brick (brick), concrete (concrete), and so on. yy indicates the number of the scenario for the state of affairs worth 01. The same encoding was used for the development of libraries that contain all the constructive

elements and the materials of all cases study of Turin and Manchester. Even at the levels, it is a harmonic coding standardization was adopted.

**XPTE** is the code reported to everything that is on the ground floor;

**XPXX** is the code that refers to all floors above ground, where XX indicates the floor number;

As regards the premises, the nomenclature assigned to them is mainly linked to the floor level.

**PT..yy** is the code refers to all the premises located on the ground floor.

Where yy indicates the local number is the numerical order on the floor;

**Pxx..yy** is the code that refers to all the premises located in the floors above ground. Where xx indicates the floor number and

yy indicates the local number in numerical order on the floor;

**Sxx...yy** is the code that refers to all the premises located in the basement.

Where xx indicates the floor number and yy indicates the local number in numerical order on the floor. The local has also been assigned a real sticker

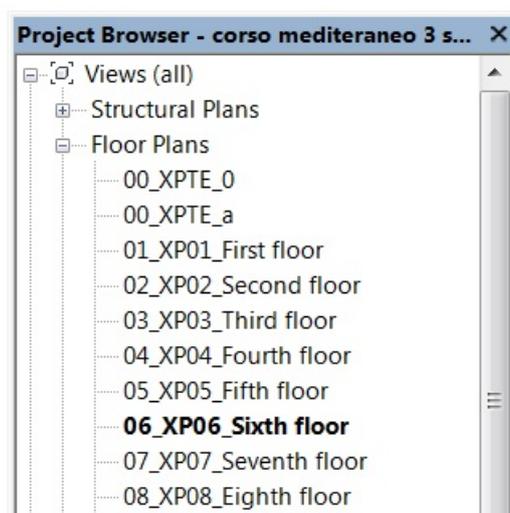


Figure 3.4: Name of floor plans

show, listed below by name. Even the intended use of the local, area and volume. One of the local specifications is precisely the return of the automatic measurement of area and volume that the software provides each time a new venue is inserted. On the contrary, the intended use is a parameter that must be completed by the modeler.

The renaming process of elements needs for proceeding to a parametric models standardization, because this, in order to, creates a code that can be read by all software used in the whole process and for the subsequent link of the individual BIM models of case studies in the district level DIM model. Furthermore, it was also helpful for the creation different libraries of building element and materials of all the Turin cases studied. Even for the windows a simplification was carried out during in the creation of the architectural model since it was decided to shape them with only the glass and then without all the frame structures. It has been made this choice for a reason of data reading. Energy software, since it is not able to recognize all the details.

Once the overall modeling of the building is finished, you have to pay more attention to architectural details, going to model specifically the several necessary families in place.

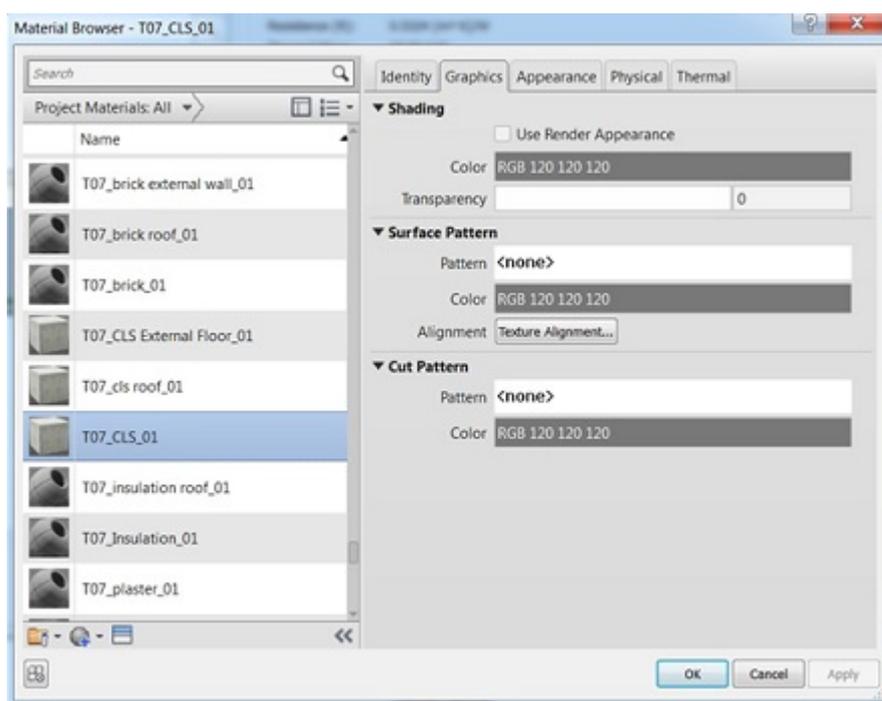


Figure 3.5: Materials of project

### 3.2.1.2 BIM Technology Library

The DIMMER library of Revit components has been created in order to give professionals the chance to use the DIMMER standard within their projects. The starting point for the creation of the library was the TABULA project; for each case study, a construction typology was identified. The components were created in order to be useful in performing energy simulation; for this reason, details on the look of the material were not well finished. The DIMMER library is available on the DIMMER website, from which several components can be downloaded (fig 3.6).

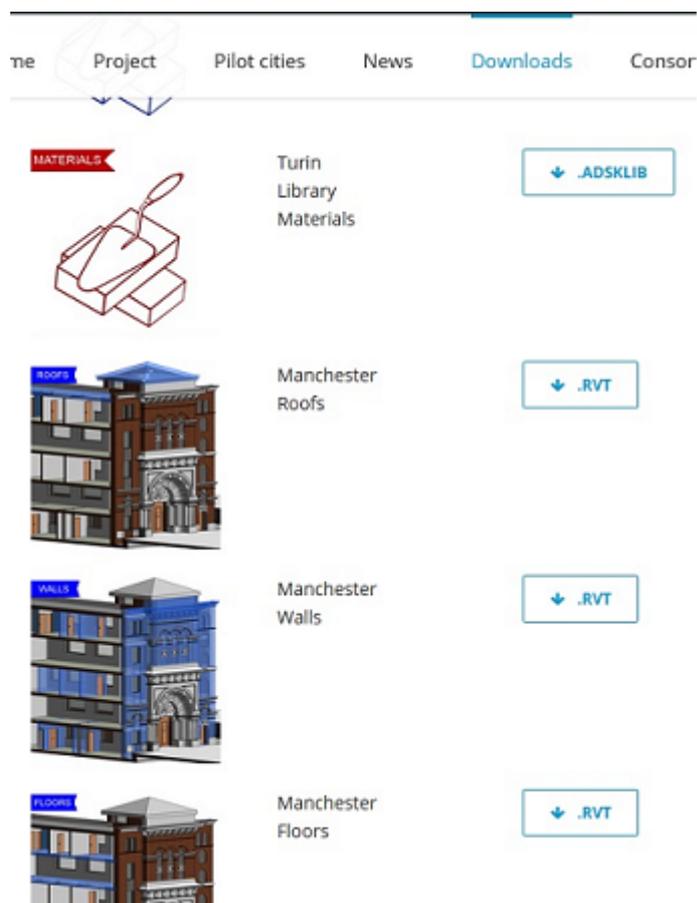


Figure 3.6: Materials of DIMMER

### 3.2.2 ENERGETIC MODEL

One of the areas now better interested in the potential of the BIM methodology is energy. In the last years, the attention of professionals and clients is focused on the sustainability of projects. BIM provides users with the capability to search various energy-saving alternatives in the design phase. There are in fact many useful programs to energy simulation, usable thanks to imports and exports from architectural modeling programs. The more known and used formats are the IFC and gbXML. Before exporting, is anyway needful to simplify the model, since all the items included in an architectural model are functional to energy analysis. The model that gets from the simplification of the architectural model is defined as Building Energy Analytical Modelling (BEM).

#### 3.2.2.1 EAM MODEL

in the Revit 2017 version, it is possible to carry out energy simulation within the program. Starting from the simplified model BEM, launching energy simulations automatically creates the EAM model, Energy Analytical Model. This model is composed of rooms and analytical surfaces. Before the activation of the energetic model, the energy settings be defined. The energy model can achieve both with the use of locals and with the use of rooms. The test has been carried out in both ways and was not found any considerable difference in the energy analysis results. To process the energy analysis, the room had to be placed in the project so that the Energy Analysis Model (EAM) could be created showing all the analytical surfaces useful for the analysis. Moreover, after placing the rooms, a heating schedule could be draft calculating the flow rate and the nominal capacity of the radiators for each space. Finally, the room was given a color: in this case, we give the color as shown in Figure 3.7 and Figure 3.8

One the rooms have been settled, all the envelope components and partition have been defined and renamed. As it regards the external walls and interior partition, the original project had multiples walls with different thickness; as

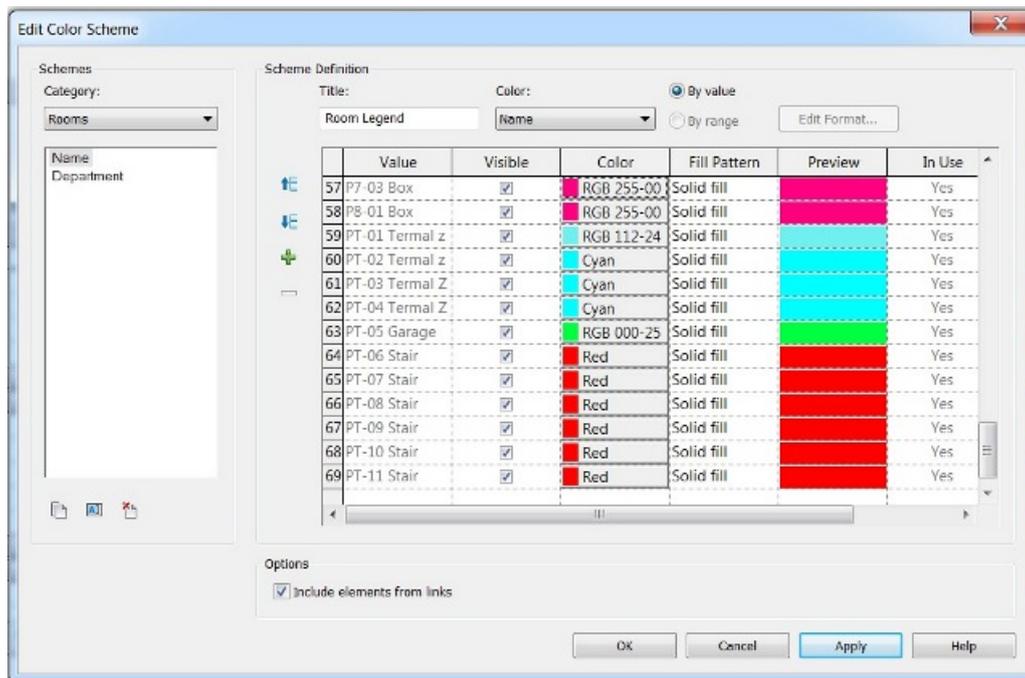


Figure 3.7: Table of rooms' color

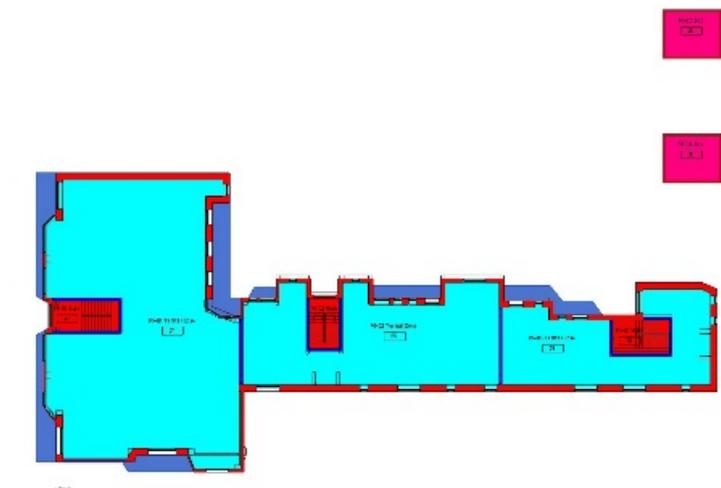


Figure 3.8: colors of rooms

just one typology of the wall had to be used, a mean value of the thickness has been calculated and the external walls had been set with a thickness of 50 cm and the internal partition at 20 cm. For the layers of the components, a schedule in which the heat transition coefficient and the composition were

specified has been followed. All the materials used for different components have been added to a DIMMER library with their own code so that they are easily available to anyone who demands them. Figure 3.9

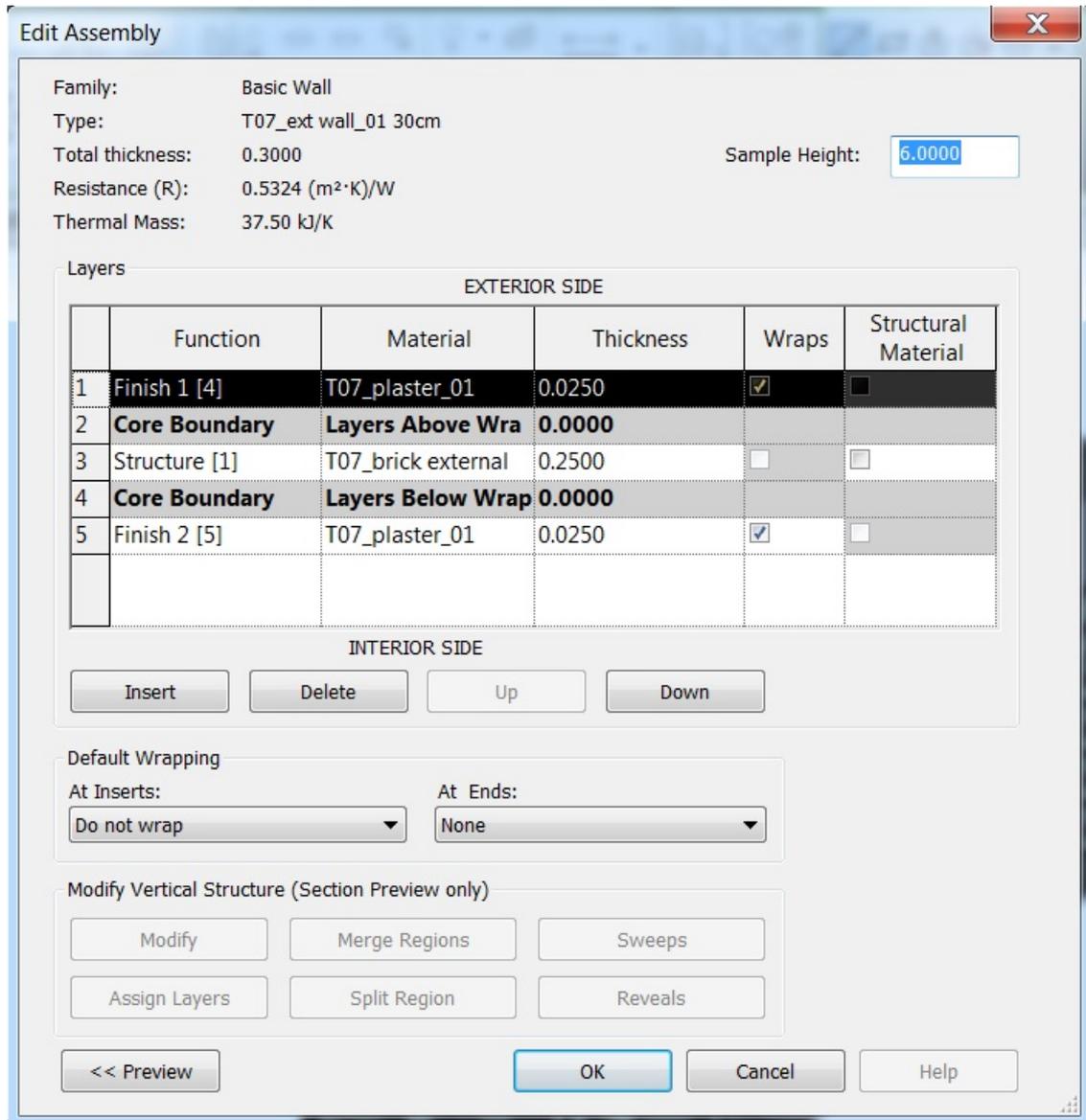


Figure 3.9: example of component layers for external wall

### 3.2.2.2 Data energy setting for EAM

Obtained the simplified model BEM you can launch the energy simulation that returns automatically an EAM model. Energy Analytical Model, including of rooms and analytical surfaces. However, before activating the energy model it is necessary to define the power settings. Among the various information found in the setting tab of energy settings fall entries resolution analytical compartment and analytical surface resolution. Which provide important information for energy analysis of the model. Analytical compartment Resolution: This is the main parameter that affects precision and energy model processing time. This parameter defines the minimum distance between the Revit elements which must be ignored during the identification of model compartments.

Default value = 18 inches (457.2 mm)

Minimum value = 6 inches (152.4 mm)

Maximum value = 10 feet (3048 mm)

Analytical surface Resolution: The parameter determines the algorithm volume to know single, surfaces and it must be less than the minimum share of any surface you want to include in the energy model. Even in this case are limit values inserted, equivalent to a minimum of as a maximum. The added value of default Revit is.

Default value = 12 inches (304.8 mm)

Minimum value = 3 inches (76.2 mm)

Maximum value = 10 feet (3048 mm)

Activating the energy model, it produce a three-dimensional model, composed by:

- . Analytical rooms, locally defined by the construction model and by the delimitation elements of the local;
- . Analytical surfaces, surfaces created in analytical rooms which identify walls, windows, doors, etc.

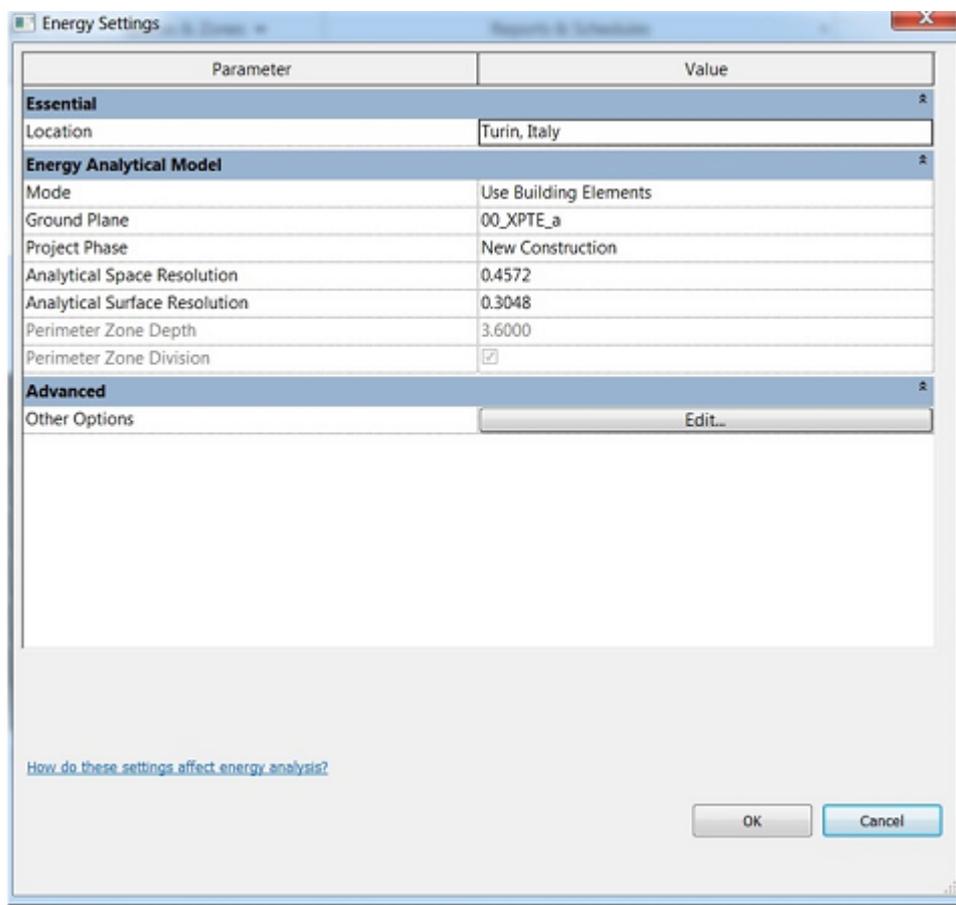


Figure 3.10: Energy setting

### 3.2.3 FROM BIM TO BEM and EAM

FIRST STEP (cleaning)

Formerly I were discussed how to attain an energy model.in order to simulate I require to simplify the model by influential architectural elements.so there are some simplifications which I will clarify in this part.

The first simplification has been made to prospects, with the elimination of architectural details, such as buttresses, decorative frames, these elements are irrelevant for energy simulations and they are not detected by the energy model. the second one that has the same problem is the connecting stairs between the various levels.

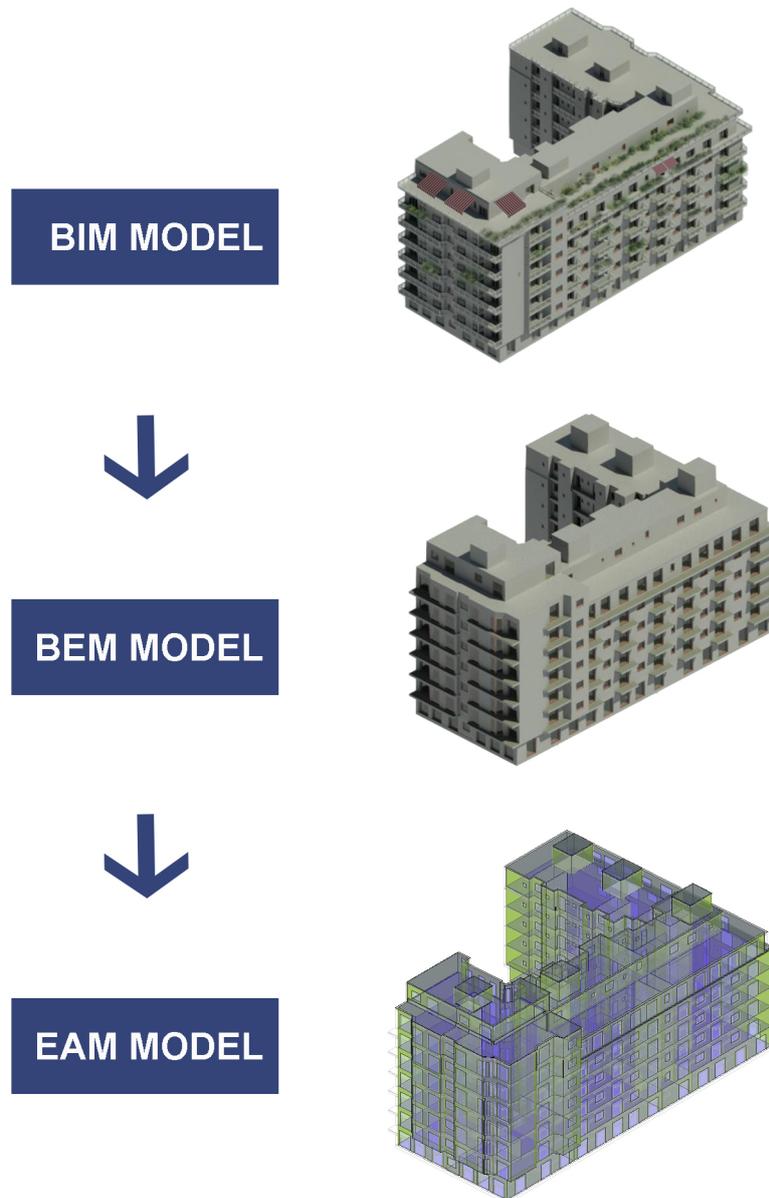


Figure 3.11: FROM BIM TO EAM

The EAM model not recognized trusses, interior stairs, spires and decorative frames. They are not suitable for the energetic part. By looking in Figure3.11

it is clear that the model had the lot of components which could be erased.

once at the simplified model you can launch the energy analysis, with the creation of the EAM energy model.

As it can be seen, each surface has a specific color:

Green for exterior and internal walls

Violet for floors and roofs

Light blue for the fixed windows

Gray for the shading elements

**SECOND STEP (air gaps)** In the second phase, we have examined the items that had a greater discrepancy between BIM and EAM. so, I focused on finding errors or inconsistencies in the construction of the model. In most cases, because of errors the correct construction for the BIM model as attacking the walls to ceilings, are not valid for the EAM mode, therefore I started checking with it then I checked intersection between walls or between walls and floors; For the external walls, it is important to make only the walls that go from the ground floor to the roof. Also for floors I searched intersections with exterior walls and brought the floor up to the center-line of the wall. It is important also verify all roofs, walls and floors are room bounding. For roofs use many types of roof combined with join, make a unique construction give air gap and we must avoid that. presence of these gaps is important because of transferring surfaces three-dimensional plans by energy models which leads to the formation of errors. I searched errors by importing model to SketchUp software as you can see in Figure 3.12 and it was very helpful for me.

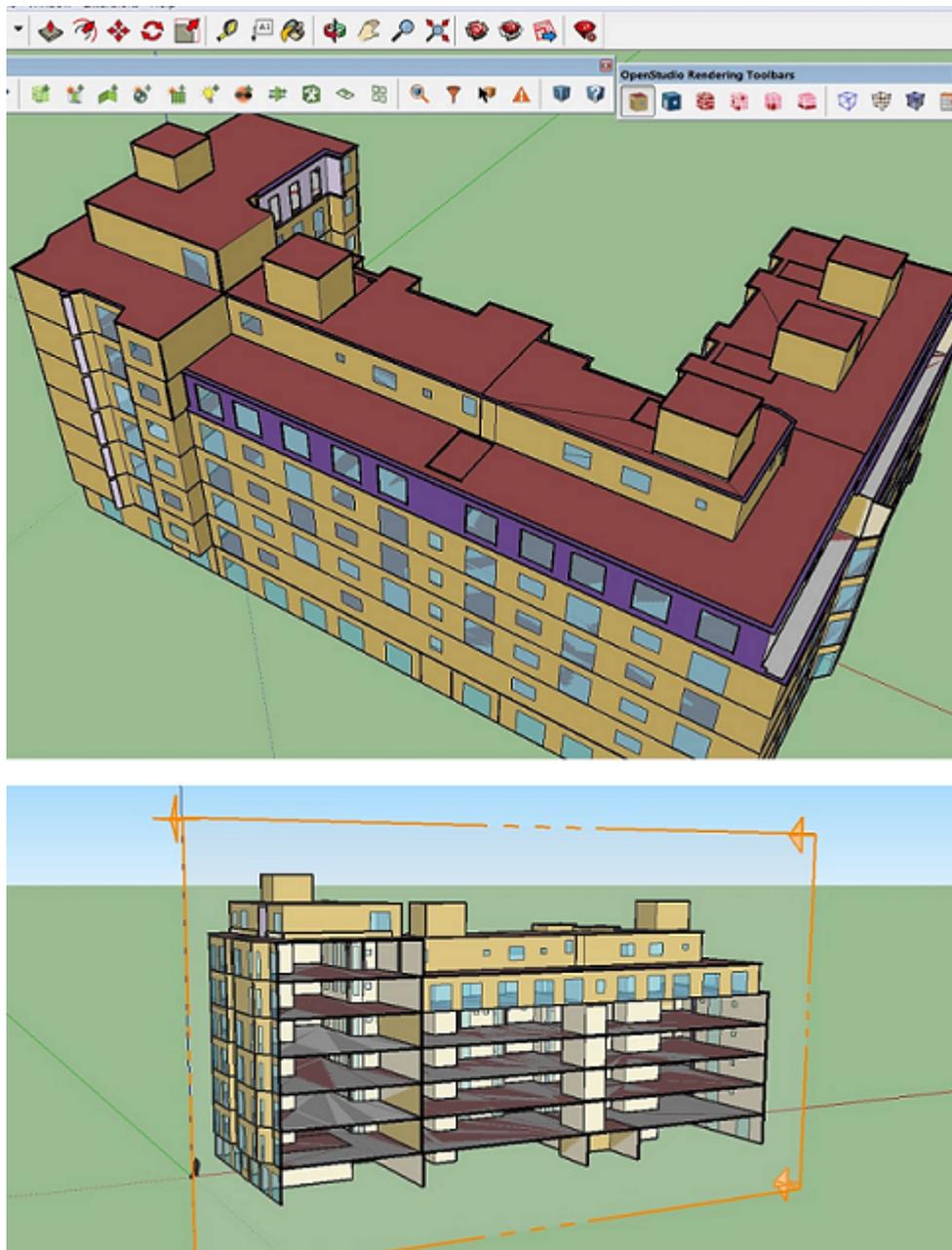


Figure 3.12: SketchUp

### Third Step(compare)

the last simplification is that we can start the energy analysis on the Revit software. To evaluate if the energy model is correct, it is necessary to compare

it with the architectural model to verify the analogies between them and realized the accuracy of the simplifications, the comparison between the two models rooms and analytic surfaces, going to compare the difference in terms of areas. our comparison is through schedules products from Revit, which consists of tables whereas the data collected from the model are presented. we were able to create schedules of any elements of the model BIM while those of the surfaces and the analytic spaces are created automatically at the run of energy simulation. The schedule of the rooms presents an analytic list of the individual room considered in the energy model, with its areas and volumes. if the analytic compartment corresponds to a local, it is reported a name. The schedules of analytic surfaces of the energy model. every surface has the special name for each area, the number of the same type surfaces, the type of opening such as doors or windows and the type of surfaces, including the outer walls, the interior walls, floor, roofs.

whereas the areas of the analytic surfaces used for energy analysis are approximations of the surfaces of model elements, the tolerance between the two models was fixed. the value that identifies the differences between the two models must fit inside of  $-/+ 10$  percent. If the tolerance is outside this range you must check and reshape the BIM model. Furthermore, also the difference between the percentage of BIM and EAM of the same type of surface must return within a range of  $+/- 20$  percent If there are discrepancies between the two models you must proceed checking the items with a greater difference. Figure 3.13

At this point, to evaluate if the model was working in the right way, the EAM has been created that highlights all the components of the model divided into categories starting from the rooms placed in the project.

<b>EAM Components</b>	<b>BIM</b>	<b>EAM</b>	<b>Difference</b>
<b>spaces - Floor Area</b>	7688.94	6580.77	0.144125198
<b>spaces - Volume</b>	20748.18	19407.42	0.064620608
<b>Surfaces - Roof</b>	1214.88	1011.56	0.167358093
<b>Surfaces -Exterior Walls</b>	4698.81	4183.34	0.109702244
<b>Surfaces - interior walls</b>	2214.34	2145.97	0.030876017
<b>Surfaces - interior Floors</b>	5769.7	5527.14	0.042040314
<b>Surfaces - windows</b>	1067.56	1053.34	0.013320094
<b>Surfaces - Basament</b>	1143.45	1042.12	0.08861778
<b>Average Diffrence</b>			<b>0.082582543</b>

Figure 3.13: BIM vs EAM

### 3.3 ENERGY SIMULATION

DIMMER the project bases its research on the possibility of using sample buildings, realize the digital parametric model and define the energy simulations. Energy analyzes are often the comparison or the actual values detected by the sensors on site and the parameters resulting from the simulations. The EAM model that is obtained following the phase of simplification was compared with that BEM. This step is necessary in order to validate the energy model and allows you to evaluate the accuracy of the simplifications. Got the final EAM model you move on to next stage of the simulation.

#### 3.3.1 SOFTWARE DESIGNBUILDER

DesignBuilder is a modeling and energy simulation software. Produced by the U.S Department of Energy Building Technologies Office, it supports open-source calculation Energy plus engine. In DesignBuilder you can draw and



Figure 3.14: DESIGN BUILDER LOGO

model a building starting from null or from auto cad files, or you can import a BIM model in the gbXML form. In the modeling form, you can set all the template on occupation profiles, electrical plant power, lighting, heating, cooling, natural ventilation and domestic hot water (DHW) and the properties of the various construction elements, such as the stratigraphy. DesgnBuilder has a hierarchical structure of the elements, which means that all information that set to the highest level are assigned to those elements start passing from the building to the block, to the zone and finally to the surface. Another important component of the software is the ability to set the heating/cooling system with the HVAC module. The DesignBuilder library provides many solutions for HVAC systems, which can be loaded into the model and modified by the designer. Figure 3.15

This module is important to set for the simulation module. It is based on Energy plus calculation engine to perform dynamic energy analysis and environmental comfort. You can calculate: the heating loads and cooling, the annual plant consumption, the interior temperature profiles, comfort and heat transmission of the building envelope.

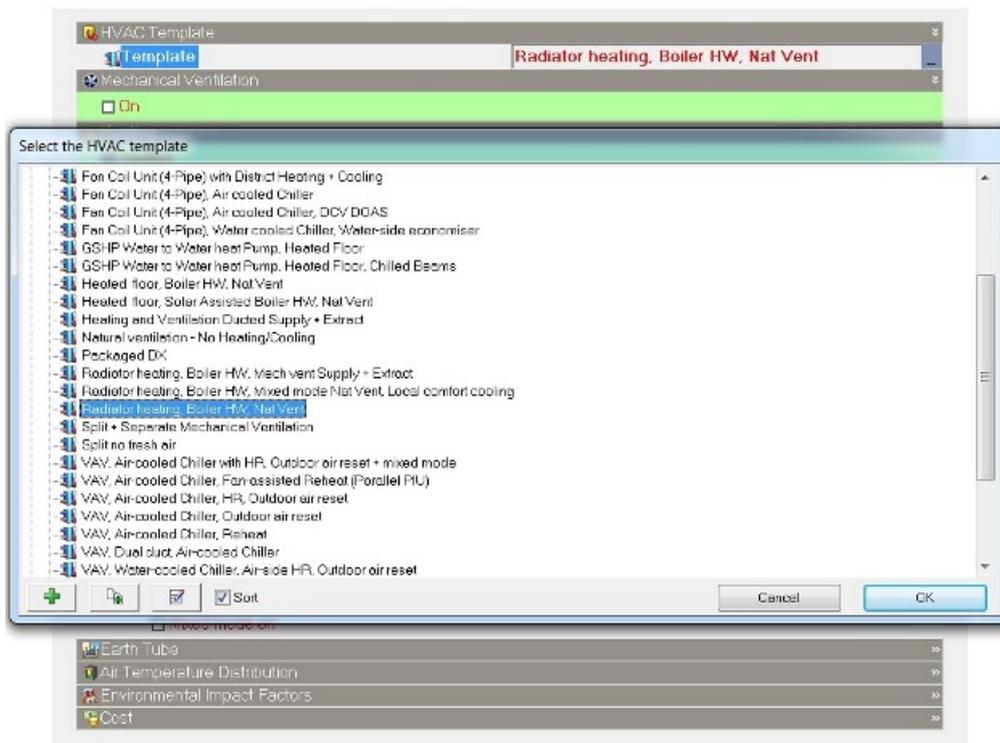


Figure 3.15: HVAC template

### 3.3.2 STANDARD MODEL SETTING

Among the most important steps in the procedure for entry analysis is part of the definition of the geographic location. even before the actual import. it is defined in the template locations. and in this way, the software automatically changes the rest of the setting, such as geographic coordinates, the location of geomorphological data and climate data of the project.

In addition to the locations it is essential to define the Weather reference file, that is used by the program to perform the energy simulations. Given that the building is located in Turin, it was imposed as locations Turin Casele.

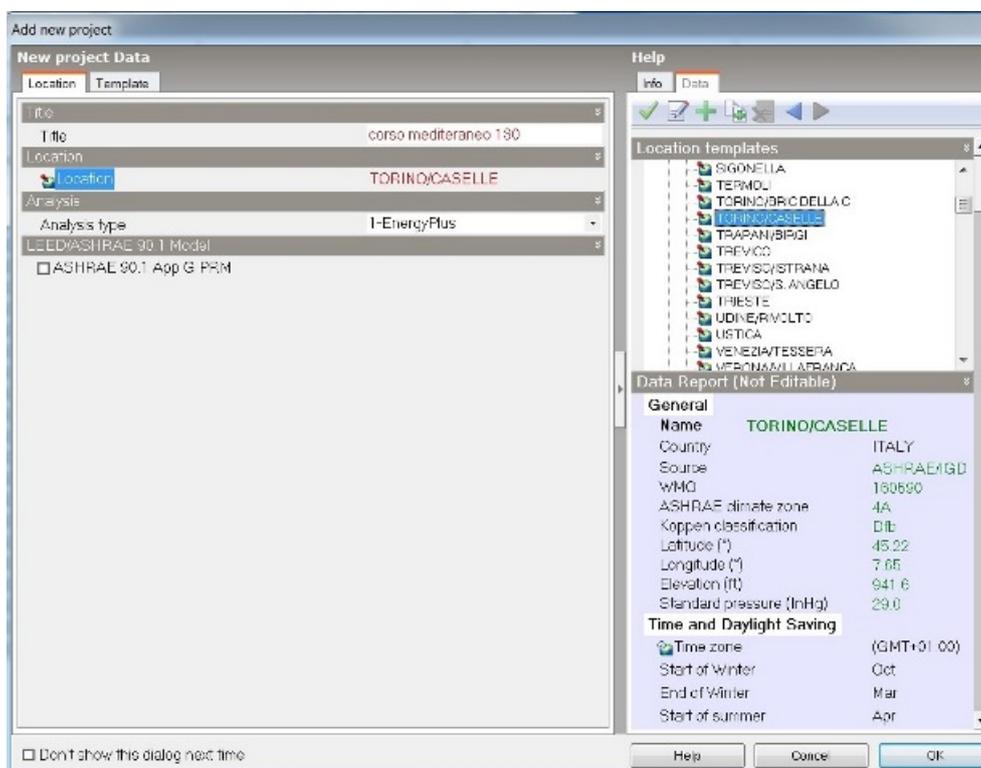


Figure 3.16: Location setting

### 3.3.3 MODEL IMPORTATION

to import into DesignBuilder a parametric model created with another software is required that the model be exported to preliminary gbXML format. Figure 3.17

The task was not simple (there were some errors that I notice in chapter 5) Before proceeding with the export, it is necessary to set some data on the tab General including the Building Type and Location. Shown in Figure 3.18 depicts the building with complete set information. These data will be reported automatically in DesignBuilder model and can be modified for individual heating zones. is written on the card you save your settings and you advance with the export.

To obtain a valid model within the software needs to be done so that when

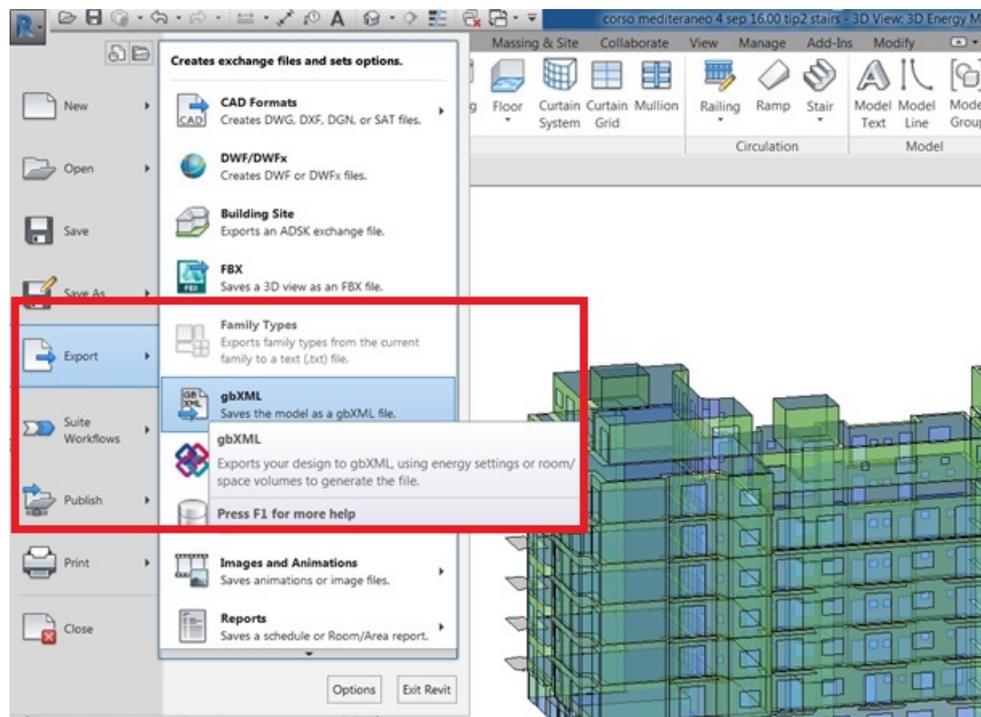


Figure 3.17: Export of gbXML

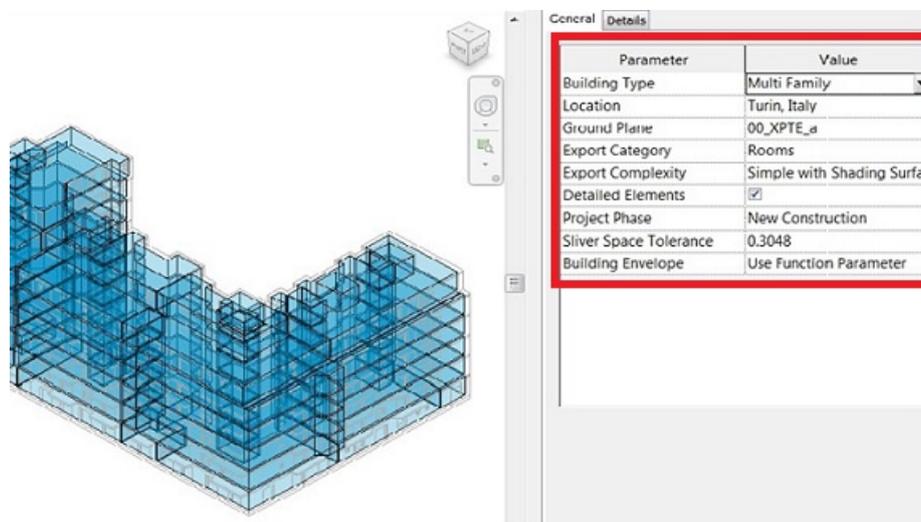


Figure 3.18: Export of gbXML

exporting there are no alerts within the Details tab, or when importing is required to correct them.

The building for the export phase did not bring serious errors in fact in the details tab no messages appear. The only problems affecting certain air gaps that have been resolved before the final export. Figure 3.19

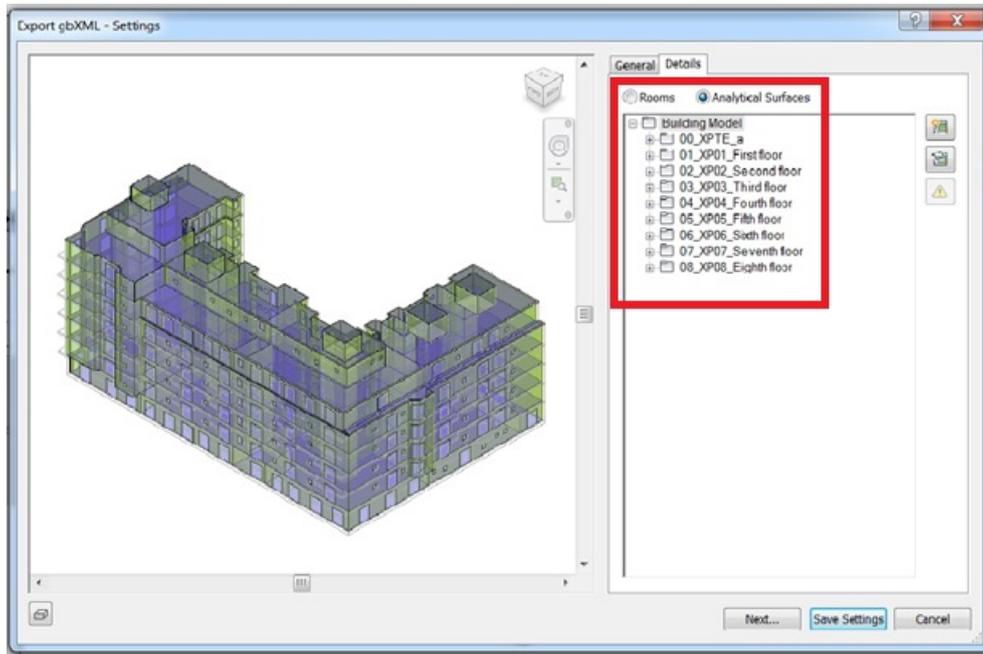


Figure 3.19: Export of gbXML with details

The next step is to proceed with the import model in DesignBuilder. After entering the parametric model of the building in the software you need to verify that there are no import errors, such as local with surfaces not properly closed or unnamed local. It is also essential to check that they have been kept all the thermal and physical properties of various stratigraphy. This task also was not simple, there were some issues that I explain in detail in chapter 5.

In the event that you were to check for these abnormalities during import, you should return to the modelling software Revit and correct errors suggested by DesignBuilder. It is important to remember that every time you make changes to the model of Revit must revive the analysis for EAM model and update the comparison. This is because by making changes to the elements

that make up the model, automatically you change the analytical surfaces associated with them.

DesignBuilder does not allow you to view the interior of the building model, much less if there are any mistakes, which is why you can use the plug-in free of Openstudio Sketch Up software, which allows the import of the model in gbXML format the possibility to display it also inside. Returning to DesignBuilder, after setting the location of the template and you have loaded the weather file was imported. gbXML file.

### 3.3.4 DATA SETTING AND PLANT DEFINITION

Once the import phase of BIM model is passed to the next, or the setting of all cards containing useful data for the simulations. The parameters to be defined are found in the Activity cards, Construction, Openings, HVAC. Figure 3.20

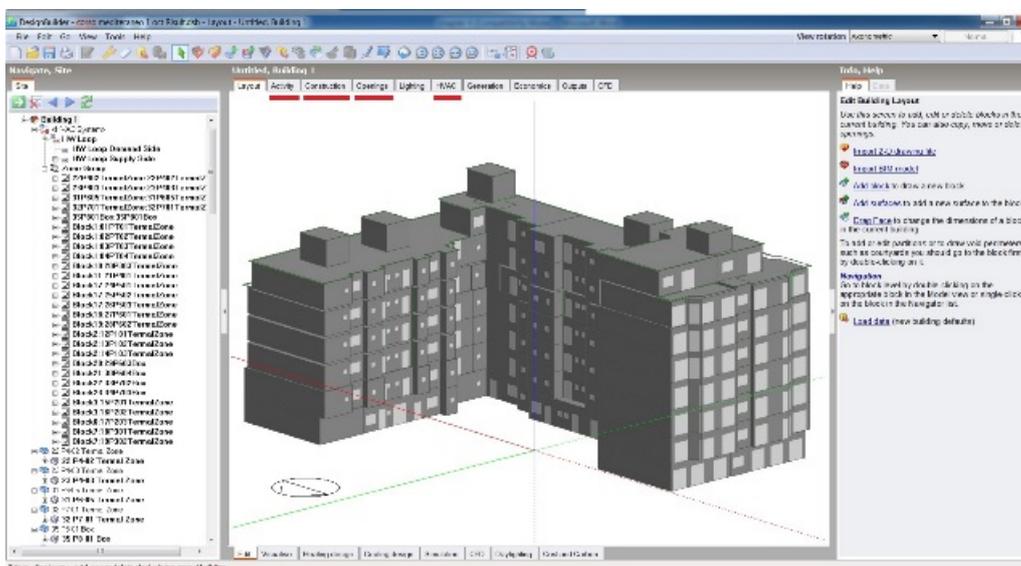


Figure 3.20: Design Builder Layout

### Activity

This is the board that defines the template of the use of the building and that takes account of employment hours (occupancy) and effective hours of use of the electronic equipment (equipment). Choosing the template, change the software automatically all other fields, then manually adjusted according to the actual data received from sensors located on site.(Figure 3.21)

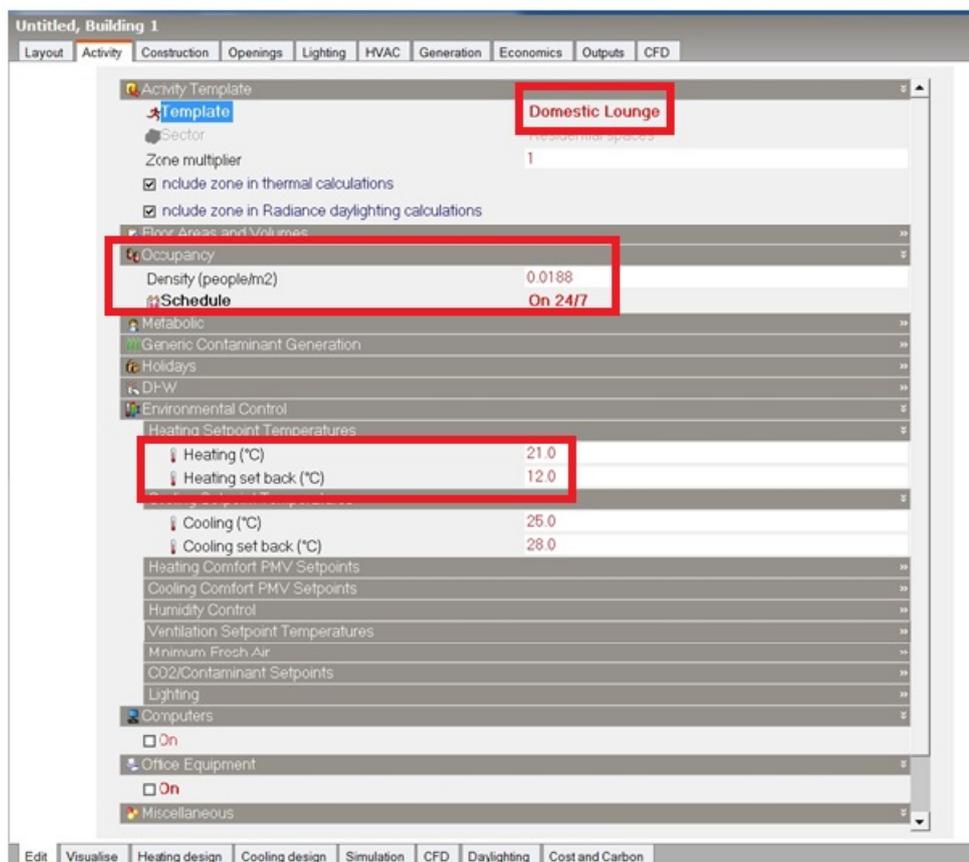


Figure 3.21: Design Builder Activity

As for this case study. It was chosen as the template of the intended use Domestic Lounge For all zones. we chose 'ON 24/7" for schedule of Occupancy and set Setpoint temperature on 21C for Heating and 12C for Heating set back.

### Construction

This is the board that covers the elements that make the model, that is, the vertical partitions (external walls and internal walls) and the horizontal partitions (floors and ceilings). The software provides for each object some stratigraphy default that can be changed manually by the modeler. Figure 3.22

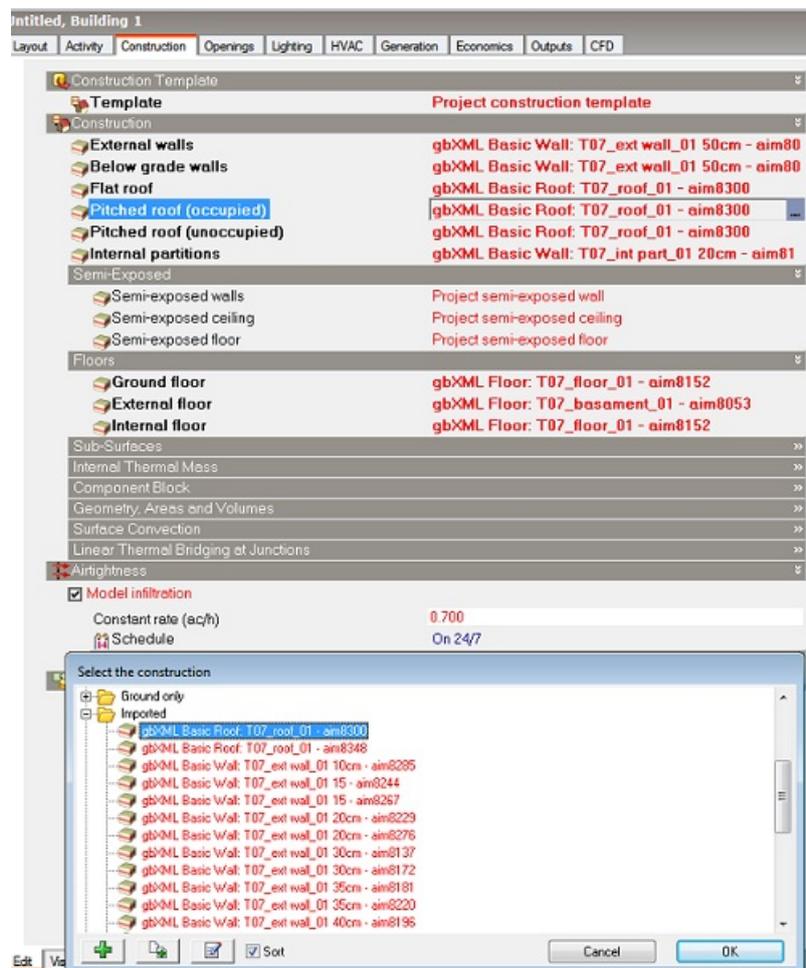


Figure 3.22: Design Builder Construction

In this case, we have chosen stratigraphy that come from the phase of the model import, already equipped with the thermal and physical properties set to Revit. In fact, within DesignBuilder if when importing the materials are

imported as well as set Revit automatically creates a folder called Import, in which are stored the stratigraphy of the model, with the respective materials and physical properties-termiche. it happened some errors when I imported materials in DesignBuilder that I will explain clearly in chapter 5.

### Openings

Its the card that refers to the openings. As a template was confirmed that proposed by the software covering the imported project. While the layout was select No glazing in order not to change the percentage of glass area, which otherwise would exceed abundantly that resulting from BIM model. Figure 3.23

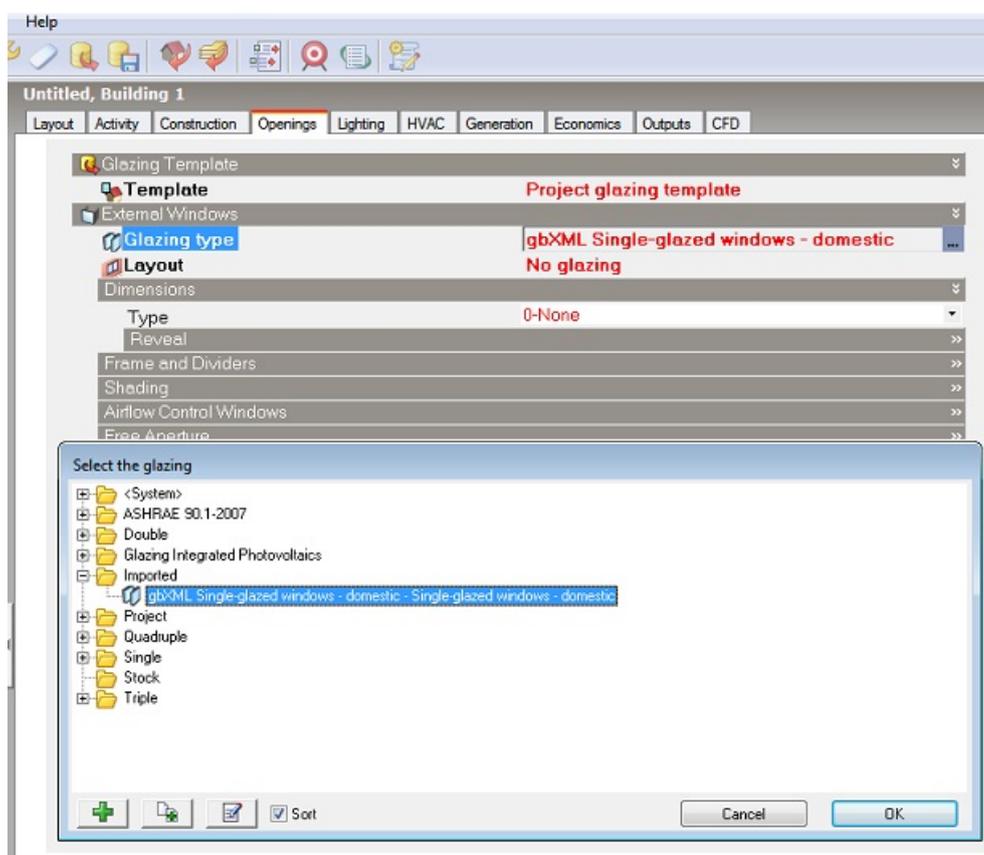


Figure 3.23: Design Builder Opening

In this case also, we have chosen stratigraphy that come from the phase of the model import, already equipped with the thermal and physical properties set to Revit.

## HVAC

It is the card that allows you to set the system parameters. The window for this category shows the items pertaining to the HVAC template. To the heating and cooling program, the humidity control, the DHW system profile and the profile for the natural or mechanical ventilation. Figure 3.24

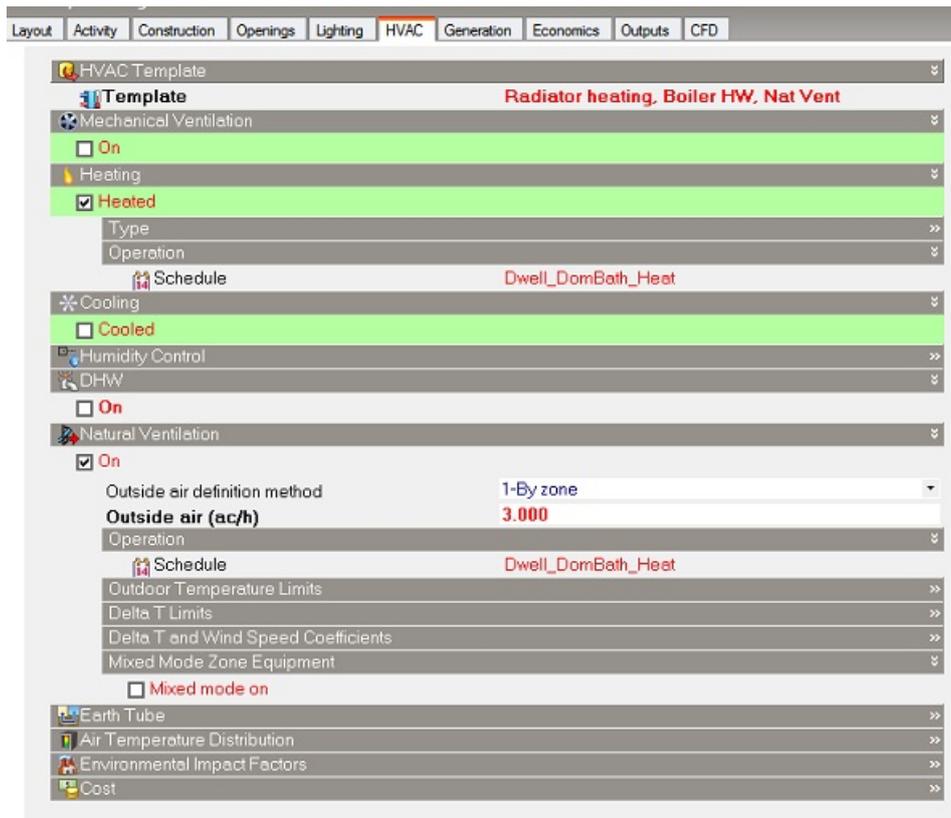


Figure 3.24: Design Builder HVAC

The HVAC template is used to define the type of plant the most similar as possible to that actually exists inside the building. It was possible to set the operating hours of the plant by creating profiles related to the hours of employment. we didnt consider cooling and DHW system.

This case of study has a heating system with radiators. For convenience, I hypothesized model of hot water heater because I didn't know exactly type of the Boiler actually present in the building. The radiators are connected

to the water heater because they are used for heating. Figure 3.25

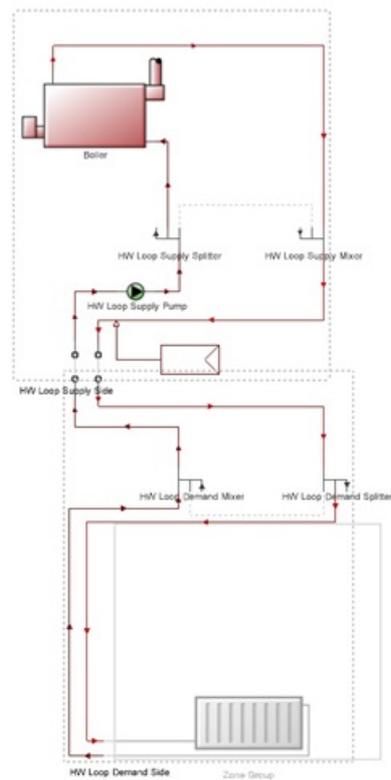


Figure 3.25: Radiator heating system

the stairwells, which are connecting unheated spaces does not requiring heating. In the HVAC tab it was set the template that specifies the operation along with detailed profile on and off. Figure 3.26

It was initially set to a power profile that covered the occupation times, this estimate has not brought convincing result as very credible and very different from the real ones.

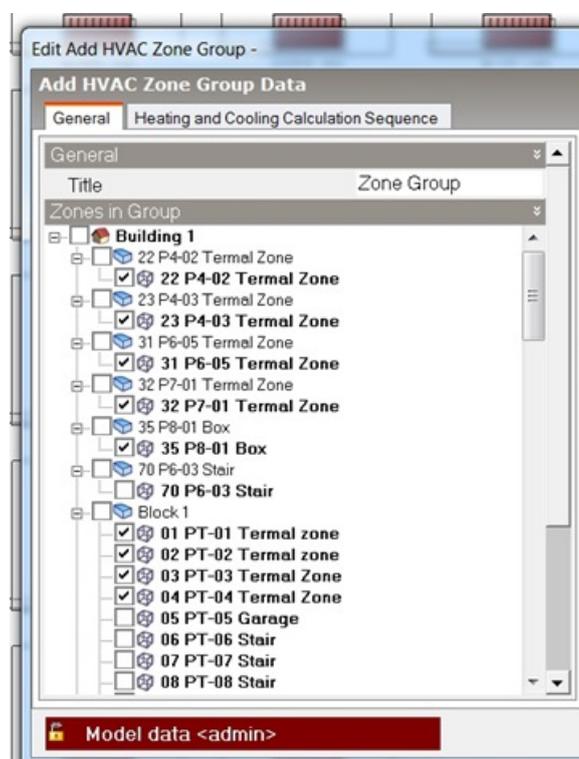


Figure 3.26: Edit HVAC zone group data

### 3.3.5 SIMULATION WITH DESIGNBIULDER

Setting of information on simulation is another very important card to energy analysis purposes, it called Simulation. In this tab, you can fill the input data with respect to the period to be analyzed. In this case of study energy simulations of the model were made from 15th October to 15 April when the plant is scheduled to start heating in particular, it analyzed the week including November 23 to 30, we can decide which output data must return the software, specifically the internal temperatures of the premises, the relative percentage of humidity and the PMV index Fanger.

### 3.4 VALIDATION OF SIMULATION RESULTS

The simulation was launched for energy winter season, from 15 October to 15 April and we compared the behavior of simulated temperature with those measured in the real case for 20 and 21 of March.

real time data came from sensors that positioned inside the building and recorded the variations of the internal temperature and relative humidity.

as you can see the results obtained are valid and similar to those monitored by the sensors. If the two graphs show excessive inconsistency, you must return to the simulation software and change the data entered previously, this until the results are not satisfactory. Almost 15 simulations have been run to obtain the best trend possible which is the one showed on this page. Figure 3.27, Figure 3.28 But they cannot be exactly the same because the

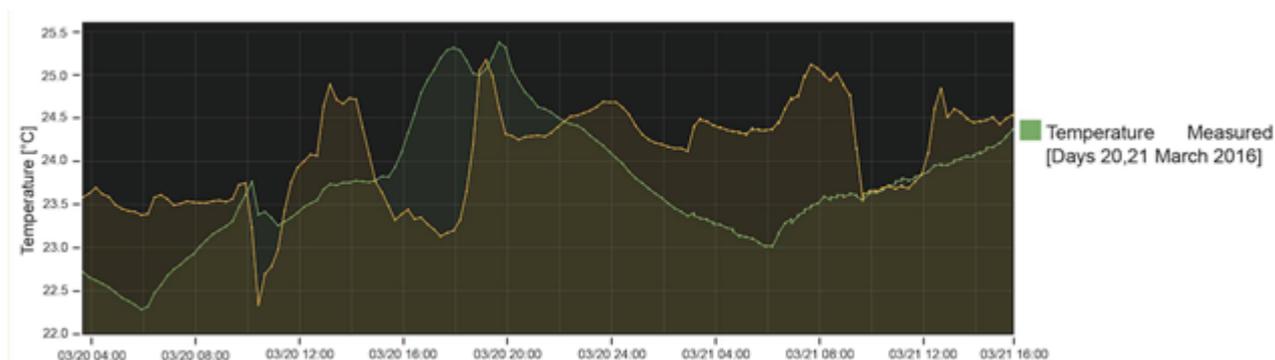


Figure 3.27: Measured Temperature

base year weather information used for the DesignBuilder are different from those of the year which real data refer. The first thing that stands out is 4-degree temperature difference between simulated and real case and it happened because the Set point temperatures that we chose is different from real one. Moreover, occupancy schedule and HVAC schedule were not entirely correct. Figure 3.29



Figure 3.28: Simulated Temperature

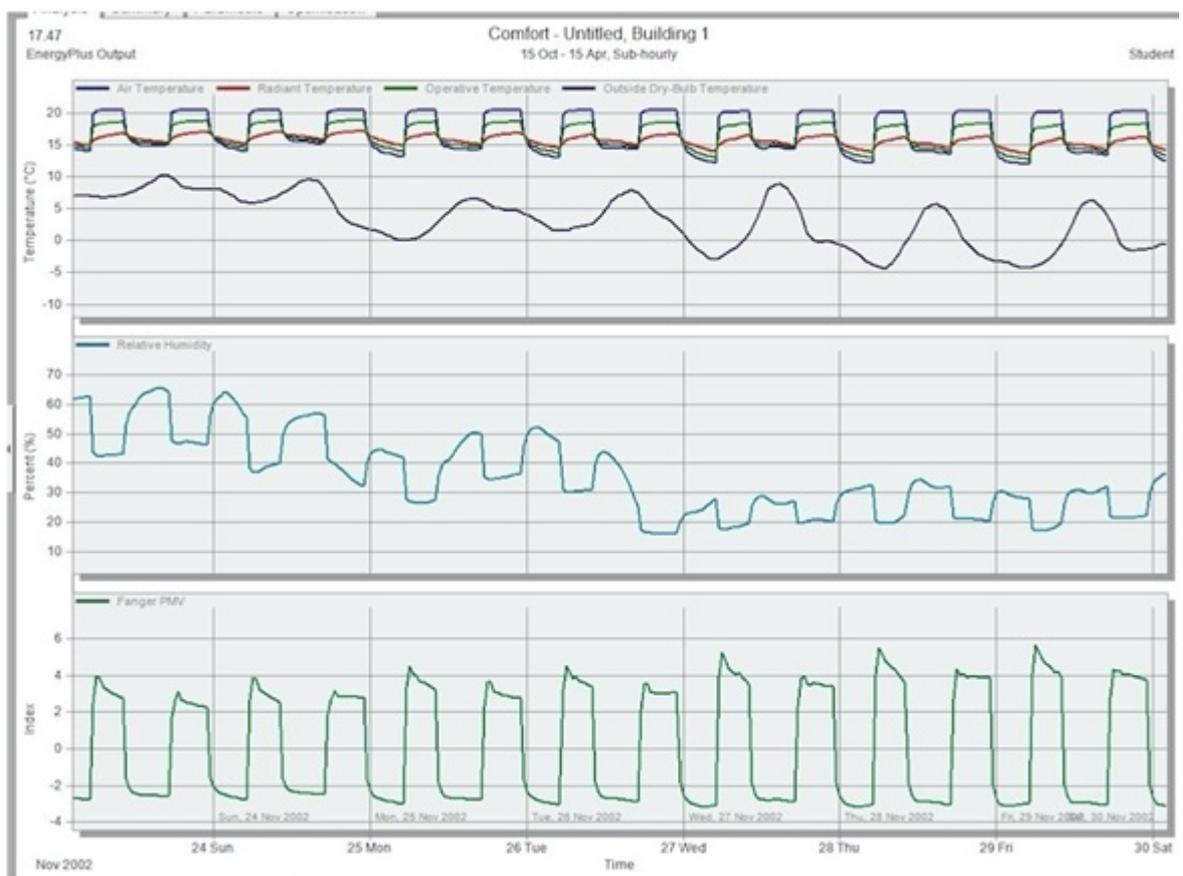


Figure 3.29: Design Builder Simulated Result

# Chapter 4

## Results

In this chapter, I will explain the restructuring of hypothetical scenarios that improve the building in saving energy point of view and could lead to the reduction of cost , energy consumption and consequently of pollutants such as co2.

## 4.1 ENERGY IMPROVEMENT INTERVENTION

After validation the model, I have passed to hypothesize restructuring possible scenarios that can lead to save energy and improve temperature conditions and heat comfort inside the building. The scenarios focus on the components transparent and on opaque components. I changed the stratigraphy of opaque components and the type of windows and then launched the simulation again throughout the all energy winter season (from 15 October until 15 April) next I compare the totals of consumption before and after the restructuring to see how much saving energy is applied with this choice and after that I calculate How much carbon dioxide is preserved and how much is the investment and its economic return.

### 4.1.1 First scenario

The first scenario assumed is the installation of a new window, made of a double low emission glass, in addition to existing one.

Low emissivity glass:

One type of energy-efficient glass is Low emissivity glass (low-e glass) that designed to prevent heat escaping through windows to the cold outdoors. Low-e glass has an invisible coating which substantially decreases heat transfer and reflects interior heat back into room. Figure4.1

By replacing existing window glass with low-e glazing, we can improve the energy efficiency of building, reduce fuel costs and decrease the size of carbon distribution. Low-e glass is more useful for buildings with a high proportion of windows or glass doors. The use of low-e glazing helps to retain heat even in winter, allowing to comfortably use these rooms for more months of the year. During the summer, it also works to reflect the summer sunlight. It specifically reflects long-wave infrared energy. Some low-e windows on the market also reflect short-wave solar infrared energy.



Figure 4.1: Double glazing unit with one Low-E coating

Infect, low-e glazing acts like a thermos. A thermos silver lining helps maintain the current temperature of the drink that its containing. The constant temperature is achieved by the linings reflection, which increases the insulation of the thermos.

In the figure 4.2 you can see how low-e glazing works in the summer and winter

In the spring months, the contributions released by the sun's rays are high, so the heating system helps and disappears. By adding a new window, solar radiation gets smaller through it, and thus loses a significant share of free participation: to do this, the machine works hard in the simulated scenario, and the difference in consumption is lower.

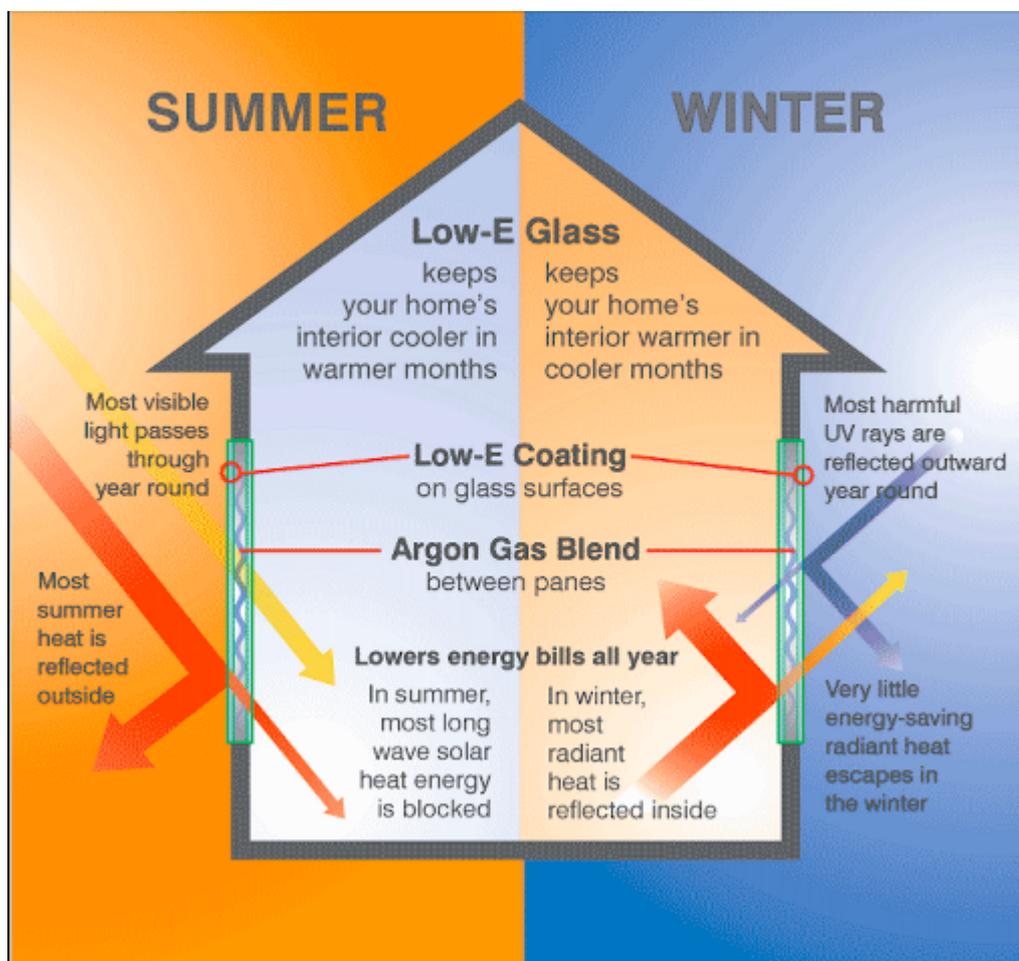


Figure 4.2: Double glazing unit with one Low-E coating (<https://mycoastalwindows.com>)

The thermal transmittance ( $U$ ) of the original window is given and it is equal to  $5,52 \text{ W/m}^2 \text{ K}$  the transmittance of the new composed windows that we chose is equal to  $1,98 \text{ W/m}^2 \text{ K}$  The simulation has given the following results shown in figure 4.3

In total, from 15 October until 15 April its estimated for  $608871.54 \text{ kWh/year}$  it there was a reduction in consumption of 21,47 percent or  $118614,27 \text{ kWh/year}$  figure 4.4

At this point I calculate the total manufacturing operations cost for sce-

Month	VALIDATED MWh/ month	SCENARIO 1 MWh/ month
OCTOBER	35761,73	25274,52
NOVEMBRE	119241,1	90272,23
DECEMBER	171812,3	136732,8
JANUARY	186839,8	151307,7
FEBRUARY	147764,5	118556,1
MARCH	90593,98	69419,59
APRIL	23360,3	17308,6

Figure 4.3: Results

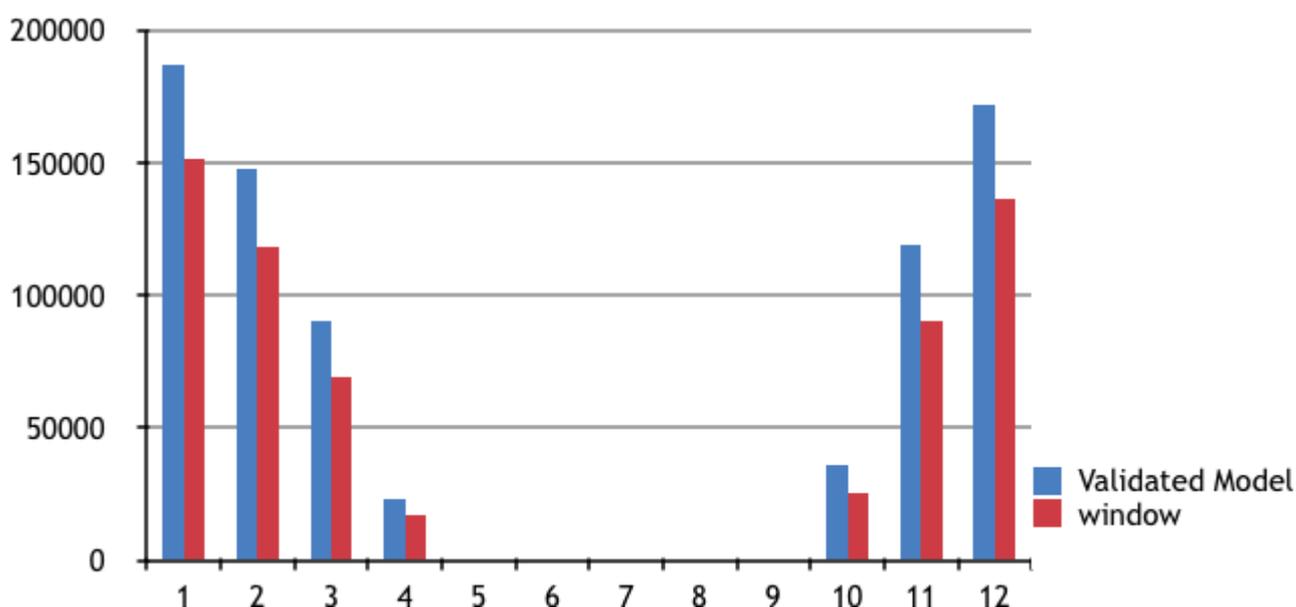


Figure 4.4: Results

nario1. The total transparent area of the building amounts to 1067,56 m<sup>2</sup>; the average cost of the installation of new windows that take it from Piedmont price list is about 300 euro/m<sup>2</sup> that multiplied for the total window area makes 320268 which is Total Manufacturing Operations Cost.

Then it is calculated the fuel expense during the energy winter season, before and after installation new windows. The saved energy amount is 166502,17 kWh/year that costs 16650 euro When The certain fuel price MWh, equiv-

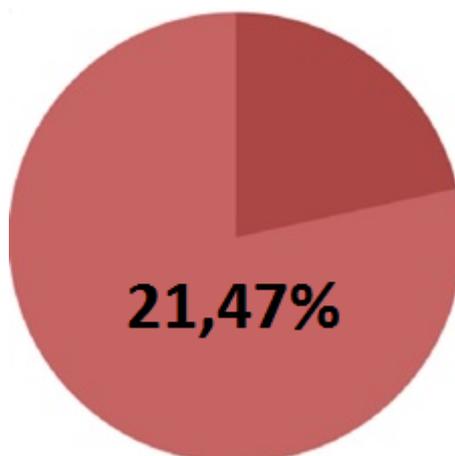


Figure 4.5: Saved energy (scenario1)

alent to 0,10 euro/kWh The Total Fuel Price and the Total Refurbishment Cost will serve to evaluate the fuel economy in monetary terms and then to derive a value of what I can save in a year thanks to the intervention. Concerning the environment impact, I also calculate how much CO<sub>2</sub> emissions are reduced by restructuring, this evaluation was done multiplying to seasonal consumption before and after the intervention of a value equal to 120 kg/MWh. Making the difference between the two-values id evaluated as the decrease of the environmental impact of the building. With scenario1 we can reduce 19980 kg CO<sub>2</sub>. Finally, I determined the indicate which really value the investment convenience ROI and NPV calculated over a period of 15 years, with a rate of interest of 3,5 percent. The return of the investment, which marks the beginning of earning, is in 19,23 years while the NPV (Net Present Value, the measurement of the profitability of an investment) at 15 years is -123327 Euro.

### 4.1.2 Second scenario

The second scenario assumed is the renovation of wall with Cellulose flake in addition to existing one.

Cellulose flakes are a bio-based material for insulation that produced from recycled journal. There are two principal sources that it can be recycled from these: The waste of cellulose refining in the paper mills, which is free and Selected recycled journals which contain a very small amount of pollutant components Figure 4.1.2

Recycling waste paper with a significant amount of pollutant substances



(even if way cheaper) would mean treat it by using a wide range of chemical compounds, which leads to a final product which could contain many other potential harmful compounds. Therefore, the manufactories are supposed to control all the paper collection sources in order to guarantee a safe material for installers and building occupants. This is a very important aspect for this material. Figure 4.6

The installation of **Cellulose flakes** is very simple and needs just a particular pump (provided by the manufacturers) which blows the flakes into the wall cavities through a hole previously created. make them be a suitable insulating material for both new constructions and retrofitting, with the only exception of building elements subjected to high stresses.

As the European standard (UNI EN 13501-1-2009) imposes, all the building



Figure 4.6: Cellulose flakes

elements must be classified with a fire reaction value (A1, A2, B... F, in increasing order of flammability). According to this standard, the reaction to fire of cellulose fiber is classified as E( Gellert, R.2010): principally boron salts or  $Al(OH)_3$  are added to reach at least this standard. It is a quite low value since the cellulose is used in combination with other materials of the building envelope which ensure a lower fire reaction and provide the fire resistance. the reaction to fire was an important aspect to be fulfilled by the cellulose fibers.

The simulation has given the following result:Figure 4.7 , 4.8

Month	VALIDATED MWh/ month	SCENARIO 2 MWh/ month
<b>OCTOBER</b>	<b>35761,73</b>	<b>23267,27</b>
<b>NOVEMBRE</b>	<b>119241,1</b>	<b>84701,75</b>
<b>DECEMBER</b>	<b>171812,3</b>	<b>126802,8</b>
<b>JANUARY</b>	<b>186839,8</b>	<b>139829,4</b>
<b>FEBRUARY</b>	<b>147764,5</b>	<b>108389,3</b>
<b>MARCH</b>	<b>90593,98</b>	<b>62082,1</b>
<b>APRIL</b>	<b>23360,3</b>	<b>14126,71</b>

Figure 4.7: Simulation Results

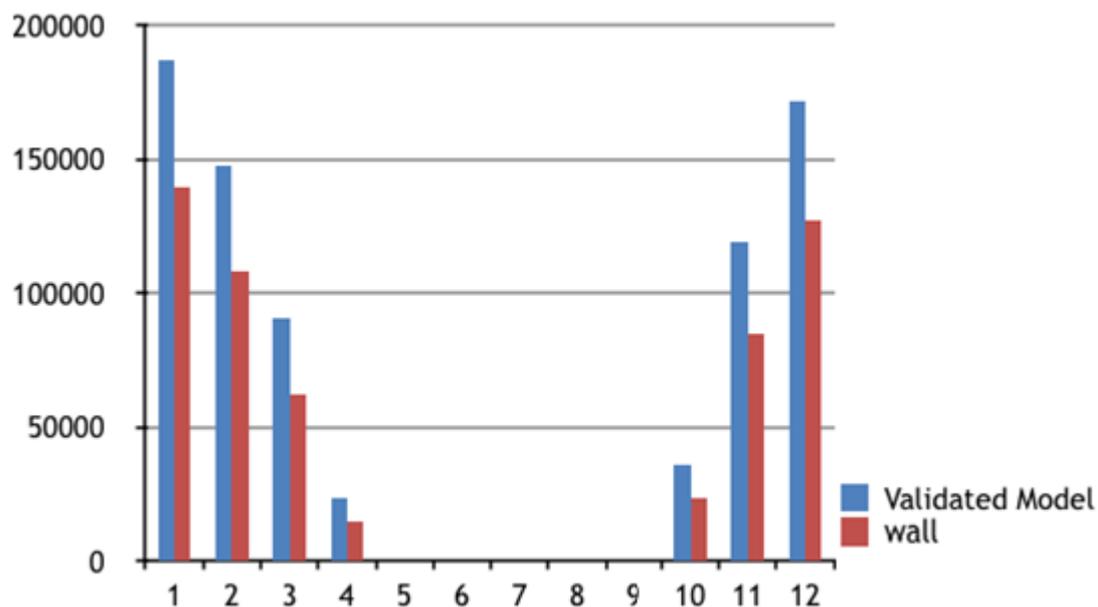


Figure 4.8: consumption chart

In total, from 15 October until 15 April its estimated for 559199,33 kWh/year

it there was a reduction in consumption of 27,88 percent or 168286,48 kWh/year.  
Figure 4.9

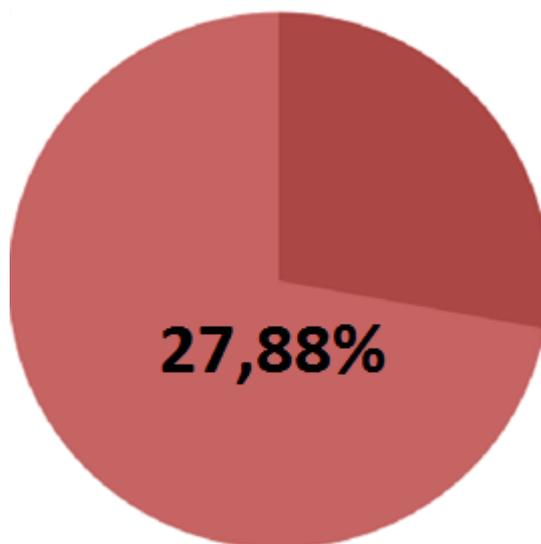


Figure 4.9: saved energy (scenario 2)

At this point I calculate total manufacturing operations cost, fuel expense, CO<sub>2</sub> emissions, ROI and NPV calculated over a period of 15 years like previous part.

I start with calculating the Total Manufacturing Operations Cost for scenario2. The total opaque area of the building is equal to 4698,81 ; the average cost of the renovation of wall with Cellulose flake that take it from Piedmont price list is about 60 /that multiplied for the total Wall area makes 281928,6 euro which is Total Manufacturing Operations Cost. We have to add a portion linked to the administrative cost (1500,00 euro), scaffold cost (13,00 euro/m<sup>2</sup>) and a design cost (+0,09) linked to the project amount. therefore total costs of refurbishment is 368486,70 euro.

Than I calculate in the same previous way the annual savings, in monetary terms as it regards Fuel consumption, and in terms of environmental impact as regards emissions. The saved energy amount at 216174,58 kWh/year which corresponds to 25940,94 kg of carbon dioxide and to 21617,45 Euro/year

saved.

Finally, we determine the indicate which really value the investment convenience ROI and NPV calculated over a period of 15 years, with a rate of interest of 3,5The return of the investment, which marks the beginning of earning, is in 17 years while the NPV (Net Present Value, the measurement of the profitability of an investment) at 15 years is -112793 Euro.

# Chapter 5

## Critical issues

The steps of all this study were not so fluent, in fact there were some issues. I divided this issues in 3 categories (modeling issues, Interoperability issues and simulation issues), in this chapter I am going to explain some critical issues that I experienced and other two issues that I found by serching. Figure 5.1

<b>Modeling issues</b>	<ol style="list-style-type: none"> <li>1. Lack of data</li> <li>2. The room errors</li> <li>3. Air gaps</li> </ol>
<b>Interoperability issues</b>	<ol style="list-style-type: none"> <li>1. Imported model</li> <li>2. Imported materials</li> <li>3. Updating file</li> </ol>
<b>simulation issues</b>	<ol style="list-style-type: none"> <li>1. Weather file</li> <li>2. Hot water Radiator data</li> <li>3. Reference week</li> </ol>

Figure 5.1: issues

## 5.1 Modeling issues

### 5.1.1 Lack of data

The first problem which I encountered was the lack of data. As I mentioned in chapter 3, the project was modeled with photographs that taken from the history archive office of Turin, and they were not enough alone, so I had to use some assumptions in some places. Or get help from the project "Tabula" or "Google Map". For example, there was no precise information about the door, so we use the window into the door in means of calculating the energy.

### 5.1.2 The room errors

As you see in the Figure5.2, the rooms which are not completely closed Leads to this error; for solving this problem it is necessary to control the joints, for instance, the walls with a roof and a floor, or wall with the wall. The other things that must be controlled are: Verify all walls and floors are room bounding; Do not get rooms inside rooms Do not use room separator Not having overlapping rooms in other rooms Air gaps

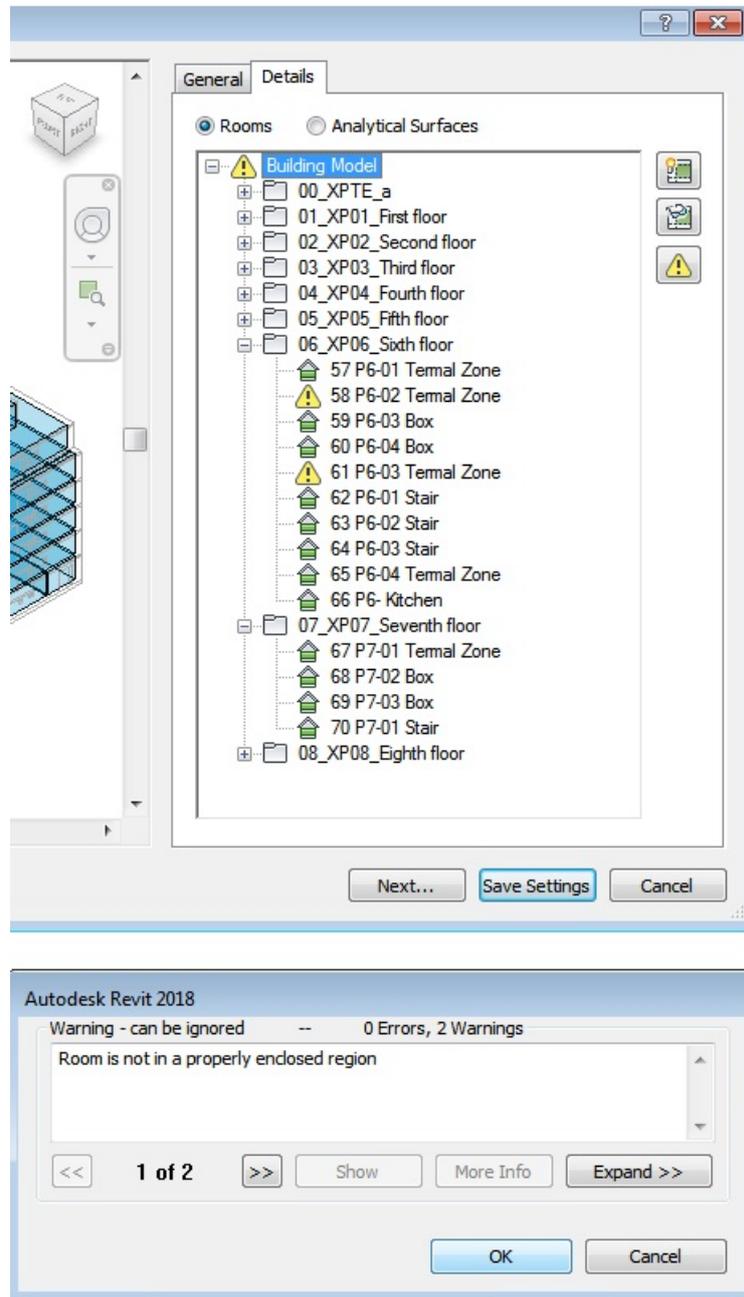


Figure 5.2: The room errors

air GAP.jpg

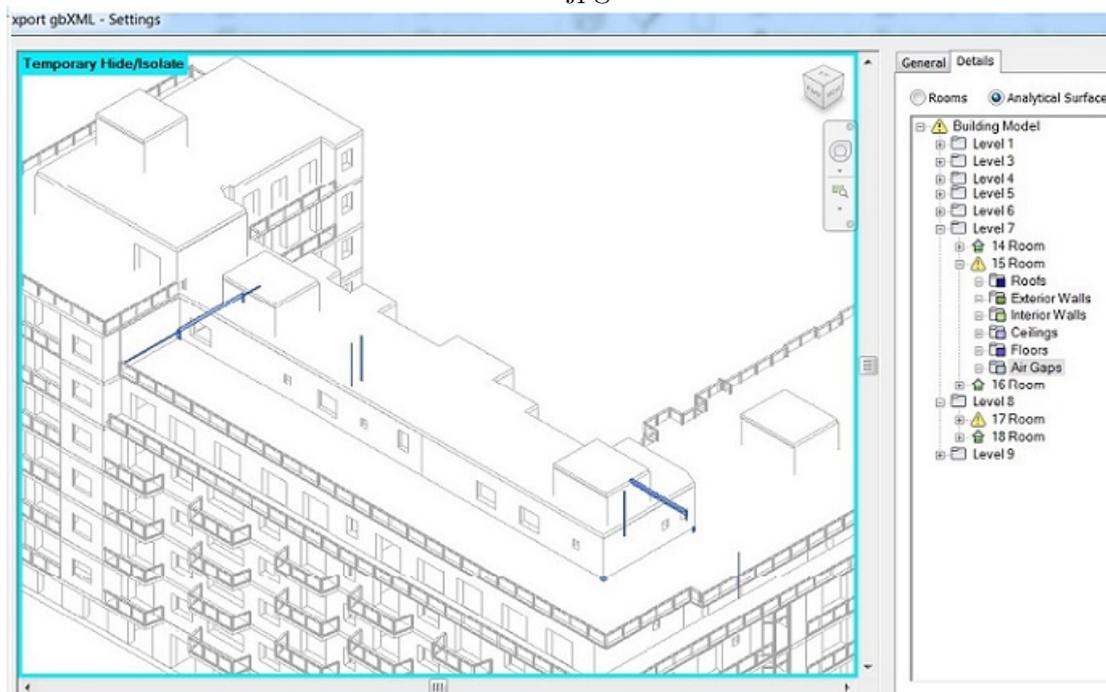


Figure 5.3: Air gaps

### 3. Air gaps

The Air gaps happened if space not completely close and lead to making difference between the BIM and the EAM to increase Figure5.3. As described in chapter 3, for finding air gaps in addition to use the "Revit" software we can use SketchUp ". this problem can be solved by reworking on the model.

## 5.2 interoperability issues

### 5.2.1 Imported model

After entering the parametric model of the building in the software you need to verify that there are no import errors, such as local with surfaces not properly closed or unnamed local or if there are some green or light blue surfaces. Figure 5.4. For example, when I imported gbXML file to Design-Builder, software gave an error which some rooms are not completely closed. At this time, we must turn back to Revit and check again the airgaps and export gbXML file again. We must do this sickly and re-exporting model and re-importing in the design-builder until the problem is solved.

### 5.2.2 Imported materials

We must use imported material from Revit but sometimes you see the folder imports is empty there were problem with the importing the materials inside DesignBuilder and this problem was solved with try for importing several times the model with materials .

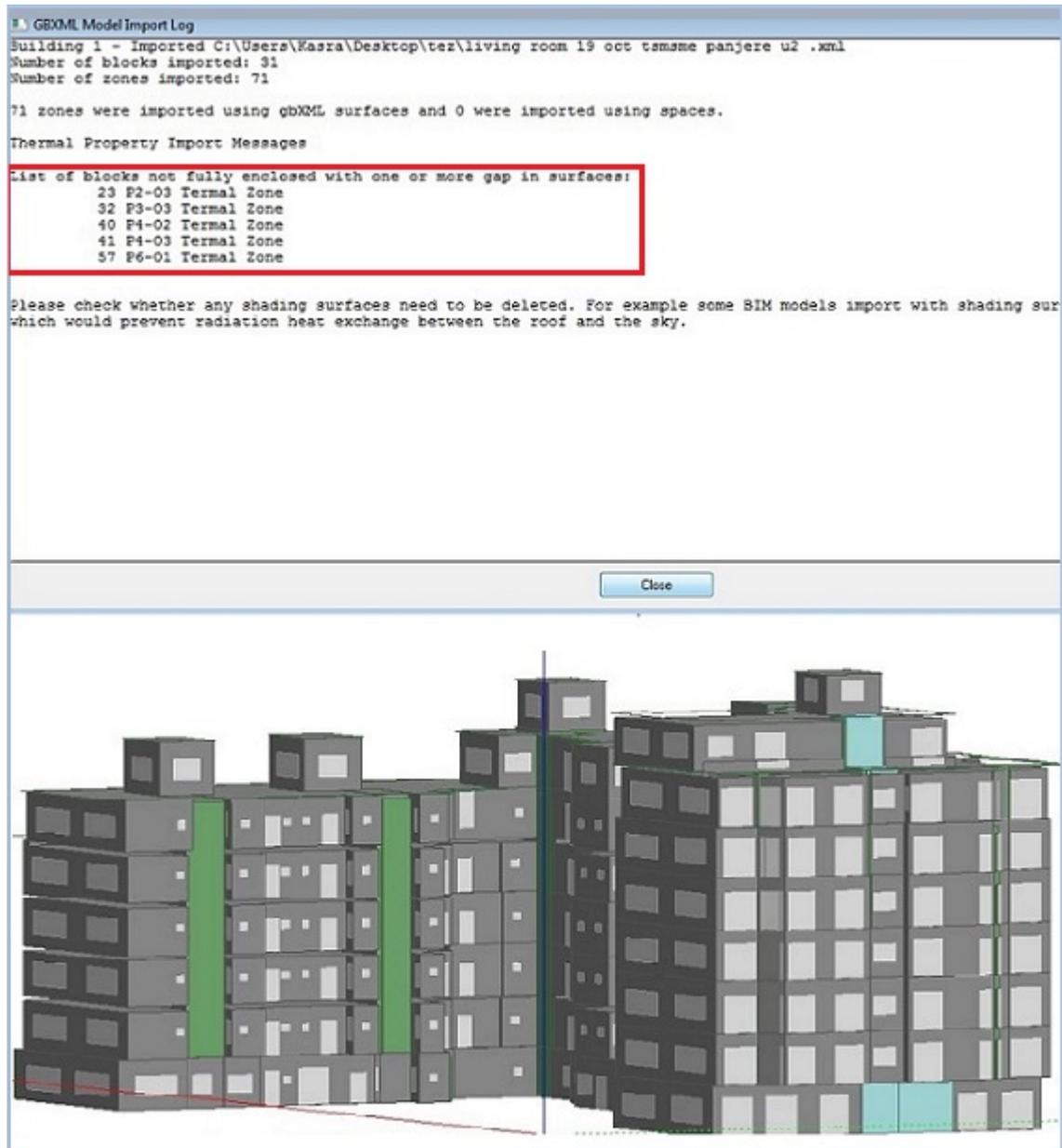


Figure 5.4: Importing to DesignBuilder

## 5.3 simulation issues

### 5.3.1 Weather file:

One of the challenges is the air conditioning simulation section, because of the file available in the software for 2002 and 2003, due to climate change, makes it clear that there is a difference between the results of simulation and the observation of sensors that this inevitable is.

### 5.3.2 Hot water Radiator data:

As I mention before we don't have clear information about the boiler for this reason I hypothesis boiler information and after that for getting better result, I calculated some data like Flow rate and Capacity of each room depends on their volume. Figure 5.3.2

## 5.4 The other two issues

I want to explain other two issues that I found by searching.

1.Updating file (interoperability issues): when you open an older version file with a new version of the software, the file is updated. Maybe during this transition, some information was lost or read in a different way by the new version and this created those gaps and surfaces problem to solve the problem new model was created in a new file and once it was finished, the EAM created worked in the right way.

2.Reference week (simulation issues):

In reality, the heating system is working all the days, but having indicated a single week of reference, the software is not able to understand that the one week before the plant was already turned on. And then the building already

boiler issues simulation.jpg

Edit Water radiator -

**Hot water radiator Data**

Water Radiator Target

General

Name: 22P402TermalZone:22P402Termal

Heating design capacity method: 1-Heating design capacity

**Heating design capacity (W): 41828.10**

Maximum water flow rate (m3/s): Autosize

Rated average water temperature (°C): 75.000

**Rated water mass flow rate (kg/s): 0.999220**

Fraction radiant: 0.300

Fraction of radiant energy incident on people: 0.100

Operation

Availability schedule: On 24/7

Advanced

	H	I	J	K	L	M	N	O	P
name	volume		<b>capacita w</b>		k.cal/ore		litr/ore		<b>FLOW RATE kg/s</b>
PT-01	599.46		17983.8		15466.1		1546.61		0.42961
PT-02	651.07		19532.1		16797.6		1679.76		0.4666
PT-03	692.62		20778.6		17869.6		1786.96		0.49638
PT-04	595.24		17857.2		15357.2		1535.72		0.42659
P1-01	788.78		23663.4		20350.5		2035.05		0.56529
P1-02	1392.42		41772.6		35924.4		3592.44		0.9979
P1-03	769.83		23094.9		19861.6		1986.16		0.55171
P2-01	793.32		23799.6		20467.7		2046.77		0.56855
P2-02	1392.42		41772.6		35924.4		3592.44		0.9979
P2-03	769.83		23094.9		19861.6		1986.16		0.55171
P3-01	793.3		23799		20467.1		2046.71		0.56853
P3-02	1392.42		41772.6		35924.4		3592.44		0.9979
P3-03	769.83		23094.9		19861.6		1986.16		0.55171
P4-01	793.29		23798.7		20466.9		2046.69		0.56852

warmed. For this reason. The analysis resulting invalidated and the graphs show the slightly lower values than those that have in reality. To overcome these problems they moved on to the analysis of energy simulation on Energy plus.

# Chapter 6

## Conclusion

The goal of the conclusion is to summarize the main points of the assignment, and answering the problem statement, which will be done by first giving answers to the research questions. In this part of thesis considering the research and the result data plus all the reviewed related literature, I am going to answer my research question. And then by addressing them to my case study as an empirical research confirm my issues.

now days smart city is an important concept and attracts many attentions and in order to improve smart cities applying a kind of meted of innovation technology would be helpful. Among different existing methods BIM is one of the best solutions. how BIM Method can be applied in order to amend energy and cost saving in urban scale?

The expansion of population and consequently the increase in need of energy has raised the interesting topic of energy management. Moreover the 50 percent of the global population now live in cities and urban population is estimated to reach 70 percent of the total population in the world by 2050. This fact brings attentions to citys energy consumption. On the other hand, in Europe Buildings are responsible for 40 percent of the energy consumption and 36 percent of CO2 emissions, so controlling the buildings would have a huge effect on controlling the general aspect of energy consumption.

This fact has pushed many scientists to work on this topic for instance I mentioned three of European projects in this thesis that are OPTIMUS, INDICATE and DIMMER. concentrating and comparing of 3 projects helped me to understand the solution they suggest to reduce the energy consumption and CO2 emissions with the adoption of ICT measures in district level. As it is clear in detailed explanation of these projects, observations of these processes are to create the prerequisites to help in the realization of a sustainable and Smart City. moreover, the Outstanding goal of mentioned projects is to influence an important social affection by using the awareness of the possibility to check their energy consumption in real time, this aspect is one of the most interesting things which can be a big improvement in the energy efficiency point of view and the reduction consumption. Inspiring this consequence, I made my own example project.

For my project, I used the BIM methodology to achieve energy saving in district level. in the line procedure I applied this methodology to a specific case study but it is possible to use it for all the case studies of the DIMMER project. For urban scale model of DIM, we can use integration of real and simulated data which are received via SIM. we can also run integration of BIM, GIS and SIM in order to achieve the goals of DIMMER project like maintenance and monitoring of energy consumption and user awareness. in order to reach at a working district model while keeps all placed objectives of the project, I have developed one building of the whole procedure. After that I set standards for the model and with interoperability between different software, I simulated and analyzed the energy consumption from the case study examined.

I did not have so fluent steps but there were some critical issues which I divided this in 3 categories: modeling, Interoperability and simulation issues, and found solution for each one and explained before in detail but generally I can say for good model and simulation, we need sufficient data, precise working and good controlling to check airgaps. And for interoperability problems one main problem was between the different software, (in particular Design-Builder) like importing model and importing material from gbXML file.

The solution for this problem could be standardization of the BIM model and cleaning BIM from irrelevant objects that lead to have better EAM model and it allows to avoid further issues related to interoperability

I changed some component of existing building and got the results bellow: Using simulation, I got 21.47 percent of reduction in energy consumption after applying new window and 27.88 percent by applying new wall.

This analysis and its results is very helpful for many purposes such as using a parametric model and creating its relative energy simulations to consider restoration for energy saving. With such an analysis it is also possible to study the actual saving from economical point of view and the improvement of internal conditions. Therefore, analyzing the real data of energy consumption and standardization of the individual building are beneficial for subsequent joining of many parametric models, which are then merged into a single model that will make the real district model. The model I had was a unique building, but it is obvious that the same method could be applied for many buildings in a district or even urban level and in this way, make the effect more huge.

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## Abbreviation

BIM	Building Information Modeling
GIS	Geographic Information System
EAM	Energy Analysis Model
SIM	System Information Model
BAS	Building Automation System
DIM	District Information Modeling
BEM	Building Energy Model
AR	Augmented Reality
HVAC	Heating, Ventilation, and Air Conditioning
CHP	Combined Heat and Power
RET	Renewable Energy Technologies
AEC	Architect, Engineering and Construction
CAD	Computer Aided Design
UNEP	United Nations Environment Programme
ACE	Architects Council of Europe
RET	Renewable Energy Technologies
AR	Augmented Reality
ICT	Information Communication Technologies
CAM	Computer-Aided Machining
EC	European Commission
VCM	Virtual City Model
SEAP	Sustainable Energy Action Plans
DWG	Drawing database (vector) (AutoCAD - Drafix)
IFC	Industry Foundation Classes
IAI	International Alliance for Interoperability
XML	Extensible Mark-up Language
CDE	Common Data Environment
NBMS-US	National BIM Standard United States
DXF	DATA exchange Format

XML      Extensible Markup Language  
DHW      domestic hot water

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