POLITECNICO DI MILANO

School of Architecture
Urban Planning and Construction Engineering

Degree course in Architecture

Project -
Energy Audit and Energy Management in BIM Environment

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PREFACE

Architecture and buildings are identified as being of major importance in reducing the intensity of global warming and ameliorating the impacts on humanity.

Existing research shows that the most important decisions occur at the earlier stages of design, having the greatest impact on the Life Cycle Cost (LCC) of the building.

Architecture firms are required to produce more energy efficient buildings.
The three emerging concepts of Building Information Modeling (BIM), Building Energy Simulation (BES) and Integrated Design Process (IDP) provide a new opportunity to address the challenges of achieving
sustainable communities and ameliorating the impacts of global warming.

DEFINITIONS

Sustainable design: Eco designers tend to analyze the impact of a building using a holistic approach including LCCand Life Cycle Analysis (LCA) evaluations and ecological principles.

Integrated Design Process (IDP): IDP is a collaborative process with a multidisciplinary design team that focuses on the design, construction, operation and occupancy of a building over its complete life-cycle, with a clear definition of environmental and economic goals and objectives.

BIM: Building Information Modeling is a digital representation of physical and functional characteristics of a facility and serves as a shared source for information for it.
BIM software provides objects that represent architectonic elements, parametric 3Dmodeling, rendering functions, automated drafting, rich graphic and non-graphic information stores, and interoperability to analysis programs.

BES: Building Energy Simulation Sustainable design processes usually rely upon BES software to establish expected energy consumption of building designs.
BES tools are best suited for examination of risk and to test design alternatives.

1. Green Energy Audit

1.1 Building energy and environmental enhancement strategies

1.1.1 Defining the operational plan

It is possible, and almost unfailingly cost effective, to reduce the amount of resources (not limited to energy) that an existing building consumes.
However, starting the process of change is not easy if the owner/user client has little technical knowledge, and little or no awareness about the building's energy quality and its actual chances of improvement.

Difficulties are not limited to the evaluation of possible strategies to improve energy performance. Defining an appropriate plan to implement such strategies is also necessary, tackling in a rational way not only all the technical, but also the economic, and sometimes the legal limitations that might apply.
The process is even more complicated when there is more than one decision-maker, as in the case of a large block of flats or housing complex or a timeshare property, because any final decision will have to be agreed upon between all the parties involved. Before starting any project to enhance a building's energy and environmental quality, we need to conceive an operational plan that allows us for rational and coherent consideration of every aspect of the problem.

The diagram in figure 1.1 outlines a possible operational plan.
Subsequent phases are identified down the middle, with actions detailed on the right and the different participants involved on the left.
Once the need for implementing action to improve energy and environmental performance is defined, we need to make an assessment of the building, from the energy point of view, in the current situation and we define the baseline.

The energy audit, carried out by the auditor, can make an overall assessment of the building in order to understand what are the causes of inefficiency, and to obtain useful elements for developing an energy retrofit plan. In the operational strategies for improving the energy performance of a building, the Energy Audit is a key element.

The next step is the selection of the retrofit measures. These may affect the building envelope (or its core), the systems, or the use of renewable sources. At this point a auditor possesses all the technical and management information necessary in order to decide a strategy and to define the measures, however a "comparing notes" with the owner/user/client, is appropriate.

Proposals must also be evaluated economically:
at this stage of the process, the financing issues must be considered.
If economic resources are not available, it is necessary to consider a bank loan.
Third party financing by mean of a ESCo (Energy Service Company) is a good opportunity to evaluate. The availability of incentives for energy retrofit actions (e.g. low interest loans, tax reductions, etc.) play an important role, as they can render convenient retrofit work that, without incentives would otherwise not be.

If the economic plan is consistent, it is possible to proceed to the next stage which involves the executive design of the works, this may involve the auditor or a competent designer (e.g. architect, engineer).
The construction phase involves the construction company and the project supervisor/construction and engineering manager. If the economic plan is not consistent, a modification of the choices is required.
For the Use Member States, Directive 2002/91 EC [1] makes energy certification of buildings mandatory. When the energy retrofit works have been completed, energy certification is convenient since the energy quality of the building has been enhanced.

Energy retrofit of buildings increases the energy efficiency and reduces emissions of greenhouse gases and pollutant gases, improving the sustainability. Aspects that are often overlooked, however, are the system management and maintenance issues:
maintaining high performance over time is possible only if these aspects are considered.

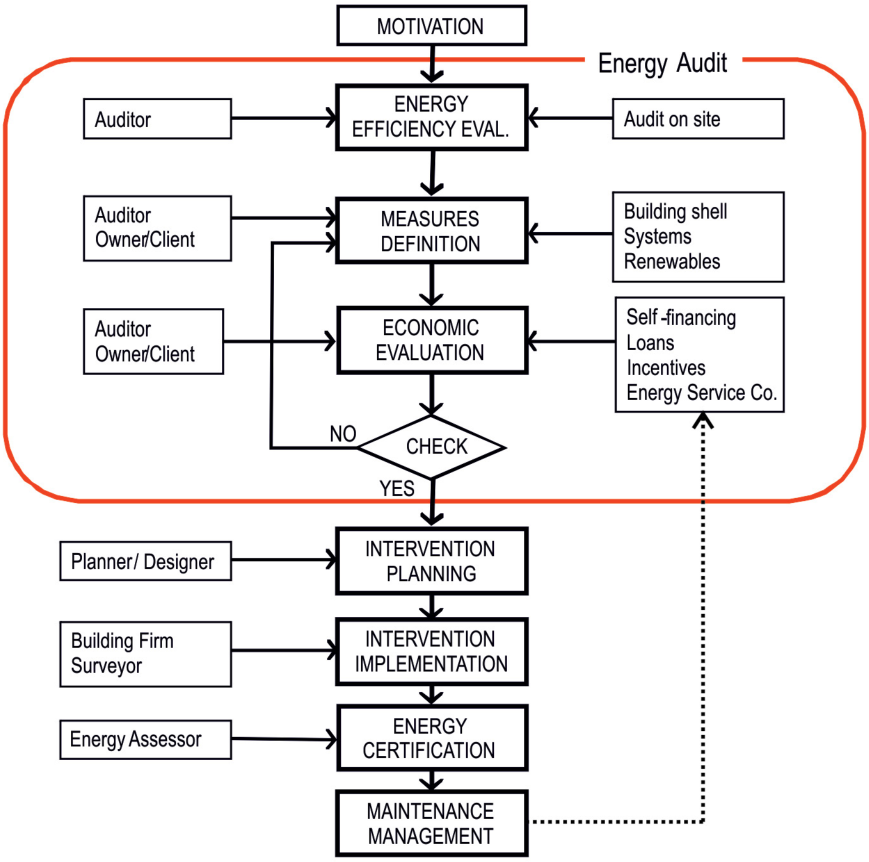

Fig. 1.1 Operational plan to design and implement an energy enhancement project

1.1.2 Reasons that lead to energy and environmental enhancement

Reducing the consumption of resources of an existing building is often possible and convenient. However, initiating the process of implementing the changes is not simple if the owner/user customers have little expertise and little or no awareness of the energy status of their building.

The problem is not only to evaluate strategies for improving performance but also to define a correct path for their rational implementation, considering not only the technical constraints but also the economic and legal aspects.
The decision to start any project stems from the motivation; the stronger the motivation, the easier it will be to realise.
The energy recovery process may be triggered by a number of factors, amongst which are the following:

- there are facilities that fail to provide acceptable environmental comfort;
- need or desire to reduce the consumption of energy and resources (e.g., water);
- the plant must be replaced (because it is malfunctioning, it is inadequate in terms of regulations or safety or because it no longer complies with emission limits);
- major renovations of the building are planned;
- energy certification has demonstrated a lack of energy efficiency.

Facilities that fail to provide acceptable indoor environmental comfort A first reason can be determined by the knowledge that indoor air/environmental conditions are not satisfactory. HVAC (Heating Ventilation Air Conditioning) systems which are not able to control the temperature, for example, can generate indoor conditions which are uncomfortable (e.g. too hot or too cold, too dry or too humid).

During the winter season, an internal air temperature higher than that considered optimal for comfort (e.g. 20 ÷ 21°C), is a clear indicator of energy wastage.

In continental climates, for existing buildings with external walls not properly thermally insulated, for each degree over the optimal temperature the energy consumption, and therefore the energy bill for winter heating,increases by 6÷8% depending on the specific situation (energy efficiency of the building and climate conditions).

A lower temperature, on the other hand, makes the indoor climate uncomfortable and this is also a clear indicator that the system is inadequate.

Similar considerations could be made, of course, for summer air conditioning: in summer seasons the highest energy consumption due to a lower internal air temperature determines an even greater energy consumption.

Sometimes HVAC systems are not able to control the indoor climatic conditions of a building, and in winter, for example, there are simultaneously zones which are too warm, with obvious wastage of energy, and others too cold, with a clear situation of discomfort.
An energy audit, in this case, represents the best technical approach to establish whether the cause is the inefficiency of the building envelope in some parts of the building or on the inefficiency of the plant (unbalanced distribution systems, inefficient control systems, etc.).

High consumption of energy and resources

It is not so easy, for a client who has no terms of reference, to determine whether energy consumption is high, but awareness of what affects the energy bill can be a powerful reason to investigate what might be the causes of any wastage.
Real estate managers or public managers, even if without specific skills in HVAC systems, can produce simple indicators, comparing energy costs with the air-conditioned area or the air-conditioned volume of the building.

Major renovations of the building are planned

Retrofit measures on the building envelope (e.g. thermal insulation of external walls or roofs, window replacement, etc.), normally are the most expensive and economically less convenient if planned only with the goal of increasing energy performance. For these parts of the building, however, major renovation is periodically planned for maintenance purposes.
In these cases the additional cost for improving the energy performance of the components is very low, hence cost-effective.

For example, if the simple renovation of the external plaster of a building facade is planned with a basic budget, the additional cost of additional insulation with ETIC (External Thermal Insulation Composite Systems) is economically acceptable, but the increasing of thermal performance of the facade is very high. Similar examples may include the windows or the roof.
The increasing of the thermal performance of the building, may furthermore suggest a review of the HVAC systems, since the thermal capacity could be significantly reduced.
We can say that when major renovation for the building are planned, an energy audit represents the best technical and economical approach to establish the correct way to plan the redevelopment that could involve not only the building envelope but also the related plant.

Energy certification has demonstrated a lack of energy efficiency

The main scope of the energy certification of buildings is to inform the user, in a simple manner, about the energy performance of the building. A low performance indicator in the certificate, may suggest an energy audit in order to identify in greater detail the causes of inefficiency and also the best solutions to remove it.

1.2 Scope and aims of the Green Energy Audit

1.2.1 The meaning of auditing

The term audit defines evaluation activity of an organization, process, project or product.
The audit activity is aimed at ascertaining the validity and reliability of the information collected and, at the same time, to configure an internal audit control system.

The purpose of auditing is therefore to use the information collected for achieving an improvement that can be defined in several ways, depending upon the application field: better performance, cost reduction, improved security or, more generally, an improvement of the overall quality.

The check and the evaluation, essential and fundamental steps of the whole activity, must then be transformed into concrete suggestions, leading to tangible improvements.
The audit, therefore, must be considered to be a process.

To assess this improvement, the definition of objectives is essential.
The achievement, or not, of these goals depends, of course, on several factors, beginning with economical ones:
the improvement of the organization, of the process, or of the quality of product, remain however key elements of auditing activities.

The figure in charge of performing audit activities, the auditor is usually a person from outside the system: the independence of the auditor is the added value of the whole process.

A useful reference for understanding the logic behind auditing activities in general is the ISO 19011-2002[1] [2] standard, which is applicable to all organizations needing to conduct internal or external audits of quality and/or environmental management systems or to manage an audit programme.

According to the above mentioned standard, audit activity is based on a number of principles, which refer to the auditor, and with which compliance is a prerequisite.
This is to provide sufficient and relevant conclusions of the audit and auditors to ensure that different auditors, operating independently of each other, come to similar conclusions in similar circumstances:

- Ethical conduct: the foundation of professionalism.
  Trust, integrity, confidentiality and discretion are essential to the audit
- Impartial presentation: the obligation to report faithfully and accurately.
  The findings, conclusions and audit reports must reflect faithfully and accurately the audit activities.
- Adequate professionalism: the application of accuracy and discernment in the audit.
  The Auditor pays the appropriate level of attention to the importance of the task they per form and the confidence reposed in them by their audit clients and other stakeholders.
  It is essential that they have the necessary skills.

Additional principles refer to the audit process which is by definition independent and systematic:

- Independence: the basis for the impartiality of the audit and objectivity of its conclusions.
  The auditors are independent of the activity being audited and are free from preconceptions and conflicts of interest. The auditors maintain a state of objectivity of thought during the audit process to ensure that the findings and conclusions are based only on evidence of the audit.
- Evidence-based approach: the rational method for reaching reliable and reproducible audit conclusions in a systematic audit process.
  Audit evidence is verifiable. It is based on samples of the available information, since an audit is performed in a limited time and limited resources. The appropriate use of sampling is closely related to the level of confidence that can be placed on the conclusions of the audit.

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1 The Standard provides guidance on the principles of auditing, managing audit programmes, conducting quality management system audits and environmental management system audits, as well as guidance on the competence of quality and environmental management system auditors.

The general principles set out in this paragraph may be applied to the activities of green energy audits or energy audits discussed below.

1.2.2 Energy auditing

When the subject of audit are buildings, equipment connected to them or production infrastructure, and the purpose is to reduce the consumption of primary energy from fossil fuels, then the audit is referred to as an energy audit.
The definition provided in the Standard EN 16247-1:2012[2] [3], defines the energy audit as "a systematic procedure to obtain an adequate knowledge of the profiles of energy consumption of an existing building or group of buildings, an industrial and service private or public, in order to identify and quantify in terms of cost effectiveness of energy saving opportunities and the relationship of what is revealed".

This definition highlights the three elements that characterize an energy audit regardless the operational mode adopted:

- knowledge of the energy consumption profiles of the investigated system;
- identification of possible energy retrofit measures to reduce energy consumption;
- cost-effective evaluation of the retrofit measures;
- reporting activity (the return of the analytical work done).

Once these points are fixed, the energy audit can be articulated in different ways, with its complexity dependent upon the technical and economical effort that is required.

We must firstly make a distinction between building audit (considering however the building envelope and related plant) and industrial audit.

In the building audit, issues regarding thermal comfort, air quality, lighting comfort, and acoustic comfort of the internal spaces, but also of the external spaces pertaining the building are mainly investigated. The energy audit normally concerns the building envelope but also the facilities such as HVAC systems and lighting systems using an integrated approach, and generally all the systems which are energy consumers e.g. lifts (elevators), safety and security, DWH (Domestic Hot Water), etc..

Building energy audits concern not only residential buildings but also those with other uses such as commercial buildings, offices, schools, hospitals, etc..
In the industrial audit the energy used in the production cycle could be relevant, and indeed sometimes more significant, than that used for ensuring comfort and safety to the occupants. Industrial audits may require special skills in the specific production sectors of the industry investigated.
The energy auditor interface may change due to the complexity of the structure: for simple buildings normally the entity to report to is a person (e.g. the owner or the building manager) while for complex buildings the entity to report to may be a managing organisation with many people involved (e.g. facility management, building management, maintenance management).

The object of the energy audit may be different: with a global approach the auditor needs to consider all the facilities. In some cases, however, the requirements of the customer could relate to a specific service (e.g. only lighting system, only electrical facilities, only heating production, etc.).

Understanding how a building works from an energy perspective, is not simple because the building is a complex system, subject to variables not always predictable. The approach usually adopted in the design phase is to consider simplified boundary conditions (usage mode, standard conditions, standard specifications of the building notes) while the actual operating conditions are influenced by climatic variables usually different from the standard.

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2 This European standard specifies the requirements, common methodology and deliverables for energy audits. It applies to all forms of establishments, energy and use of energy, excluding individual private dwellings. This part covers the general requirements common to all energy audits. Specific energy audit requirements will complete the general requirements in separate parts dedicated to energy audits for buildings, industrial processes and transportation.

Additionally management methods are not always related to single reference models.
In other words, normally there is a difference between standard operating conditions and actual operating conditions and the energy audit approach must consider the second condition.

A simplified energy audit process can be structured into four steps:

- acquisition of documentation;
- field surveys and monitoring;
- definition of energy retrofit measures;
- editing of the audit report.

Acquisition of documentation

The basic information to make a proper energy audit address primarily the characteristics of the building (thermo-physical characteristics of the envelope, such as walls, windows, roofs, basements, and characteristics of HVAC systems, DHW systems, lighting, electrical purposes, etc..).
Information on management procedures adopted (occupation schedules of the spaces, days of activation of the plant, operating temperatures, etc.) are very important in order to understand how the building is used by the occupants.

Field surveys and monitoring

Information to understand the energy behavior of the building can be derived from project documents or, failing that, from field surveys and monitoring. So far as the management aspects are concerned, a monitoring campaign, albeit if limited in time of the main environmental parameters (e.g. air temperature, relative humidity, lighting, thermal and electric energy consumption, etc.) can provide important objective information on the actual behavior of the users.
The analysis of energy bills through the actual consumption of energy, heat or electricity, can complete the framework. The optimization of contracts according to actual usage mode can help to reduce energy bills.

Definition of energy retrofit measures definition

The definition of energy retrofit measures, as previously mentioned, does not involve only technical aspects, namely the feasibility to realize the interventions in practice, but also financial issues, because measures not cost-effective will have little chance to be applied.
Normally retrofit measures are not proposed as a list of single independent options, because the evaluation of the global effects, in term of energy saving or reduction in the use of resources, may be influenced by the synergies between the measures.
If an auditor, for example, proposes as retrofit measures the wall insulation and the boiler replacement, it is clear that the evaluation of the independent effects of the two measures is different from the sum of the evaluation of the two measures taken together, since the wall insulation reduces the energy supplied by the new boiler.
Energy retrofit measures should be proposed to the owner/client as groups of consistent measures that we can define as scenarios.

Editing of the audit report

The success of an energy audit cannot be measured only by the quality of the study but in relation to the retrofit action that is actually implemented. The preparation of the report is therefore a strategic step.
The ability to communicate well to the owner/user client, the findings and proposals contained in the report is a clear indicator of professionalism and the key to the success of an energy auditing portfolio.

Defining of operational levels

A energy auditing activity well done could be expensive, dependent upon the skills of the auditors and the cost of instruments and the software used.
For maximum effectiveness at minimum investment different operating levels of energy audit are used: from the cheaper but effective walkthrough audit, also known as one day audit, which involves less than a day for inspections and surveys, to the simulation audit which can require months of investigation**.**

1.2.3 Green Energy Audit

The word green can have many meanings depending upon the circumstances in which it is used. The original reference was to nature, because green is the color of grass, plants and leaves. Over time, however, the meaning of this word has gone far beyond the original meaning, assuming a meaning that leads to a definition, even if symbolically, maintaining, or contribution to the maintenance of ecological balance.
The word green, then, identifies everything that contributes to the improvement of sustainability in its various meanings, not necessarily tied to nature.
Green building, for example, is used to identify buildings designed and constructed to minimize the environment impact. Similarly we define the green economy, as a new development model that contrasts the economic black model based on fuels fossil[3].

Green design

Green and sustainable are words often used as synonyms in order to emphasize an approach aimed at reducing the impact on the environment. Speaking of design processes, the ASHRAE Green Guide [4] states that the difference between green and sustainable design is the degree to which the design helps to maintain ecological equilibrium. IEQ (Indoor environmental quality), for example, is an important issue of green design but it has no impact on the ecological equilibrium of the environment.

In our opinion, however, the boundary between green and sustainable design is very fleeting as all the issues related directly or indirectly to the use of energy are related to ecological balance. Green and/or sustainable building design, but the same considerations apply to existing buildings under renovation, should have an approach, over the full life cycle, in the following areas:

- minimizing natural resources consumption by mean of the valorization of renewable energy and not energy resources;
- minimizing atmosphere emissions, especially those related to the use of HVAC systems (greenhouse gases, pollutants emissions, acid rains, etc.);
- minimizing solid and liquid waste discharge, during construction phase and operational phase;
- maximizing of the quality of the indoor environmental conditions (thermal comfort, air quality, lighting comfort, acoustics/noise, visual aspects, etc.).

Green design is aimed at considering all the aspects in the areas listed above and, generally, to reduce the impact on the site's ecosystems.
The tools to assess the level of sustainability of a building designed with a green approach are the protocols for environmental certification such as LEED® [4]or BREEAM®[5] .

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3 Green Economy is based on knowledge of ecological economies and green economies that face the problem of interdependence between the human economy and the natural ecosystem and taking into account the adverse effects of economic activity on climate change and global warming.

4 LEED®, Leadership in Energy and Environmental Design, is an environmental certification protocol developed by U.S. Green Building Council (USGBC).

5 BREEAM®, BRE Environmental Assessment Method, BREEAM, promoted by BRE (Building Research Establishment) is an environmental

These protocols, promoted on a voluntary basis, have been established as international standards for environmental certification of buildings.

From energy audit to green energy audit

Energy audit has traditionally been aimed at targets of reduction of energy consumption with an approach very much based on economics, emphasizing not so much the reduction in the environmental impact derived from the choices of greater efficiency, but the resultant reduction in operating costs. Energy audit, however, represents an important opportunity to contribute, through the measures proposed and possibly implemented, to reducing the overall environmental impact of the building or structure under investigation.
This consideration has given rise to the idea of giving a different interpretation of the energy audit. It emphasizes those aspects which, in addition to still ensuring the achievement of the results of improved energy performance, lead to a reduced consumption of other resources that have little to do with energy but whose reduced usage generates benefits in terms of the overall sustainability of the building.
Green Energy Audit is thus not limited to providing tools and methods to reduce only energy consumption, but has a much more important goal:

to contribute to an overall improvement in the sustainability of the building.

This new approach to energy audit, consistent with the statements of the green design above discussed, has involved a series of choices that are summarized here:

- the definition of measures that lead to a reduction in the consumptions: conservation of energy becomes conservation of resources.
- criteria for the choice of actions to be taken/works necessary can be addressed from the outset with these indicators; the auditor then must have two objectives (or a mix of the two): to maximise energy performance and to maximise environmental quality;
- measures that use renewable energy are preferred (e.g. solar thermal, PV solar and bio mass);
- when defining measures, the auditor should consider all natural solutions that can help control the climate and illumination in the building, such as green roofs, green facades, natural shading systems, passive solar and day-lighting systems;
- evaluation of sustainability targets according to the LEED® Standards.

1.2.4 The green energy auditor

The term energy auditor (or green energy auditor) does not necessarily identify a person but, more generally, the design team that coordinates and manages the audit.
In the event that several experts are involved in the same audit portfolio, the person who not only takes charge of the coordination but also takes on the responsibility of the entire work is appointed lead-auditor.
The auditor is primarily a professional figure and his minimum requirements and skills can be defined, in different countries, according to the local laws. In some countries a membership a professional body/institution (such as those through which engineers and architects are recognised) is required.

An energy auditor operating with a green approach, should have acquired a solid experience in assessment method and rating system for buildings.

the following areas:

- green/sustainable design of buildings;
- design of energy systems (mechanical and electrical);
- energy management;
- energy accounting;
- international environmental protocols (LEED®, BREEAMS® or others).

  For the auditor other skills should considered:
- the ability to operate in the field;
- a knowledge of current security issues;
- competence in using survey and monitoring instruments;
- the ability to communicate and interact not only with the client but also with his staff;
- the ability to write the audit reports clearly and effectively;
- ensured continuing professional development (CPD), covering all updates in norms and regulations so that there can also be;
- the availability to allow for and handle continuous updating of the technical and legislative requirements;
- confidentiality in handling information.

In some countries there are energy associations of energy with which the auditors may register.
In the U.S., for example, the AEE (Association of Energy's engineers have created as of 1981, the CEM® programme (Certified Energy Manager) (www.aeecenter.org).
Credentials belonging to this association are recognized both in the private and in the public sectors throughout the country. To join the Association it is necessary to have a professional qualification and professional experience of a number of years ranging from 2 to 10.
This depends upon the individuals' qualifications of membership and whether or not they are on the Register of Professional Engineers: they must also pass an examination.
The inscription, moreover, must be renewed every three years.
A recent initiative is promoted by ASHRAE[6] called Building Energy Assessment Professional (BEAP), whose purpose is to enhance the professionalism of the technicians who work in the fields of certification and energy audits.
In this case the access to the list comes from passing an examination, whilst the necessary competence to qualify for remaining on the list of licensed professionals is checked every three years.
A new register for a green energy auditor, on a voluntary basis, was established in Italy from 2012 by SACERT®[7], on the basis of the quality framework of the ISO/IEC 17024 [5] standard:
the access to the register is given after passing of an examination and verification of maintenance of competence takes place every four years.

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6 ASHRAE – American Association of Heating, Refrigerating and Air Conditioning Engineers – www.ashrae.org.

7 SACERT - Sistema per l'Accreditamento dei tecnici certificatori energetici, www.sacert.eu

1.3 Definition of operating levels

1.3.1 Walkthrough audit

The first category describes energy audits which can be realised in the short term.
They are cost-effective because the auditor is a competent technician with considerable experience in the field.
The terms used to define these types of investigation reflect the different dynamics of the procedures; a walkthrough-audit gives the idea of just "passing through" during a field visit, whereas a one-day audit highlights that the time required is limited to approximately one day, and finally, a preliminary audit sets out that this approach is not final but is a first step towards subsequent energy audits at a higher operational level.

The walkthrough audit is used to describe this first operational category.
The field survey is normally limited to one inspection: more inspections are possible but only where the building or its infrastructure is complex.
The prior planning of the survey should analyze the documents containing general information on the site. The inspection then assumes a double scope:

- a comparison of data with the client which serves also for requesting additional documentation;
- check directly features of building and facilities in order to identify areas of inefficiency for which it is possible to propose retrofit measures.

Once the data have been collected, the auditor analyses the situation: the result of the audit is a brief audit report, identifying plant and management inefficiencies, a first list of measures and suggestions on how to take the analysis into further detail.

The knowledge of the information relating to the consumption of both thermal and electrical energy during the last three-five years is essential since, for this type of approach, monitoring activities are not provided and the limited information acquired does not allow one to make a detailed calculation (e.g. calculation of heat losses or the electric loads) or a theoretical energy balance.

In the walkthrough audit, data regarding primary energy consumption are obtained directly from data of fuel or electricity consumption available in energy bills.
Starting from these data it is possible to make energy or resources indicators (e.g. kWh/m^2 per year or kWh/m^3 per year) which are useful for a comparison with benchmark values that the auditor could directly derive from the literature, from reference sites, or on the basis of his experience.

1.3.2 Standard audit

The second category, the standard audit, defines a more challenging energy audit than the previous category.
The term is most often used to mean that the audit standards are those of an energy audit and that no additional reports at this operational level are specified.
The standard audit represents the best compromise between cost and effectiveness and, as we shall see below, it defines a comprehensive technical approach that requires a greater commitment of resources and more skills.

The standard audit is the most common type of energy audit.
In this type of audit much more information will be collected because the auditor needs all this information in order to make a theoretical model of the building.

The comparison between the energy consumption of the theoretical model and the actual energy consumption derived from analysis of the energy bills,
appropriately calibrated considering the actual operating conditions, allows one to build the baseline.

This is a calibrated theoretical model of the building on which to check, by calculation, the effects of different retrofit measures.
The simulations do not necessarily have to cover the entire building.
If for example we decide to propose the replacement of the windows, the estimate of the savings will cover the benefits that this particular action generates. If the project involved the replacement of incandescent light bulbs with energy saving light bulbs then the evaluations to be carried out would focus on corresponding savings in electricity (with possibly a quick estimate of the energy savings for summer air conditioning, since the internal heat loads will be reduced).

The calculation models used for each of the measures are simple models:
for thermal energy balances, for example, a steady-state simulation model is adequate.
In order to execute properly standard audit, a complete instrumentation tool is required

The monitoring activities may involve the evaluation of environmental conditions
(e.g. air temperature, relative humidity, CO_2 concentration, etc.), or physical quantities that help to understand the operation of the equipment, from the energy standpoint,
(e.g. absorption of electrical energy by a piece of equipment) or an entire subsystem.
The measurement, usually limited in time (one or two weeks) helps the auditor to understand the operation of the building-plant system over time.

In the standard audit the auditor will make a report containing:

- a description of the actual state (of the building and equipment);
- identification of structural and plant management inefficiencies;
- definition and description of action/works required;
- economic assessments.

The purpose of the audit report is to provide the information needed for the identification of the most convenient scenario of retrofit measures.
The green energy audit will also provide a preliminary assessment of the improvement of building sustainability on the basis of an international protocol (e.g. LEED®, BREEAM®, etc.).

1.3.3 Simulation audit

The operational level of the Simulation Audit is more complex than that of the standard audit, because simulation audit provides dynamic simulation of a building-plant system in all its complexity.
In this case, a virtual model of the building is created, and based on this model,
the effectiveness of the strategies adopted are verified.
The simulation models used (e.g. Energy Plus, TRNSYS, ESP-r)[8] require high experiences and skills in building simulation, the process of model construction, furthermore, may require a lot of time.

8 for explanations and insights on simulation software refer to Section 1.4.4.

Modeling of buildings with these tools, however, if well done, provides very precise information for predicting accurately the practical effects of the retrofit measures.

Using the latest generation of simulation models it is possible to obtain a building simulation considering all the synergies and all flows of energy between different systems (e.g. it is possible to measure the effects of lighting and air conditioning in the summer or the effects of artificial lighting and shielding management).

For buildings with a complex envelope (e.g. extensive glass surfaces, sophisticated HVAC systems, extensive use of renewable energy sources), the building simulation approach is more reliable.

1.4 Commissioning Authorities and the Green Energy Audit

1.4.1 The conjunction of the two methodologies

Taking on both energy efficiency and sustainability has become the winning combination for any country that aims to become an active partner in combating the ultimate world challenge: climate change.

The connections that exist between the methodologies introduced by the commissioning process and the energy audit process are many and articulated.

The context in which these practices are applied cannot be separated from a parallel discussion that may lead to their synergy in what can be defined as a process of virtuous cultural growth, aimed at both energy efficiency and (primarily) sustainability.

The key conjunction points between the two methodologies (the Green Energy Audit and the Commissioning Process) can be summarised as follows:

- both are practices that apply in the international framework, defined by the requirements on energy efficiency and environmental sustainability applied to construction;
- LEED® certification requires the adoption of both a mandatory commissioning process for new buildings and a mandatory re-commissioning process for existing buildings: the re-commissioning process is based on considerations emerging from the energy audit;
- both practices are aimed at improving the energy and environmental performance of the building from the design process through to its management and maintenance.

1.4.2 Commissioning and Retro commissioning

Here are some definitions that will facilitate comprehension of the next paragraph :

- Commissioning (Cx): a systematic quality assurance process that spans the entire design and construction process, helping to ensure that the new building's performance meets owner expectations. Owner expectations are listed in the Owner Project Requirement (OPR) document.
- Retro commissioning: a systematic method for investigating how and why an existing building's systems are operated and maintained and for identifying ways to improve overall building performance.
- Recommissioning: another type of commissioning that is applied when a building, which has already been the subject of commissioning, is subjected to another commissioning pro cess. Ideally, a recommissioning plan should be part of the original commissioning plan that is drawn up during the construction of the building.
- Commissioning Authority (CxA): an individual hired to lead a retro/commissioning process: the Commissioning Authority is responsible for managing the process to ensure that the owner will obtain the required performance listed in the Owner Project Requirement document.
- Commissioning Team: all persons involved in commissioning activities and that work to gether to complete the commissioning process. It ideally includes all the persons involved in the design, construction and management of the building, such as the client/user, the design team, the contractor, the construction supervision, the Commissioning Authority, the operation and maintenance staff and many others.
- Commissioning Plan: a document containing all the information required to re/commission the facility. The plan may include specific tasks, their descriptions, and their schedules. Other information that may be helpful includes operational requirements for key systems, functional tests and documentation templates.

  Commissioning Report: a document that provides an overview of the commissioning process.

1.4.3 Commissioning and Retro commissioning: from new buildings to existing buildings

The commissioning process was established long before the appearance of LEED® certification, and the benefits that it brings to a building's construction process are so important that it has been used since the first version of the protocol was introduced.
It is part of the Energy & Atmosphere category, and it is a prerequisite
(i.e., it is a mandatory action).

ASHRAE Guidelines 0 and 1, which describe the commissioning process (Cx), refer to a continuum that starts with the definition of the client's requirements for the management and maintenance of the building. Because LEED® provides both a protocol dedicated to the design and construction phase (New Construction, School, Core & Shell, Commercial Interiors and others) and a specific protocol for maintenance and management (Existing Building Operations & Maintenance), the process of commissioning is mentioned in both. For new buildings, it is the commissioning process; when done to a building that has already been commissioned, it is recommissioning, and when a commissioning process is activated on a building that was not commissioned during its construction, it is Retrocommissioning (Figure 1.4).

Since the Commissioning Process aims to ensure that the client's requirements are satisfied, the fundamental documents for an effective and efficient Commissioning Process are the Owner Project Requirement and the Basis of Design.

The Owner Project Requirement contains the boundary conditions (i.e. what the client wants to develop and how) and the requirements in terms of performance, budget and certification.

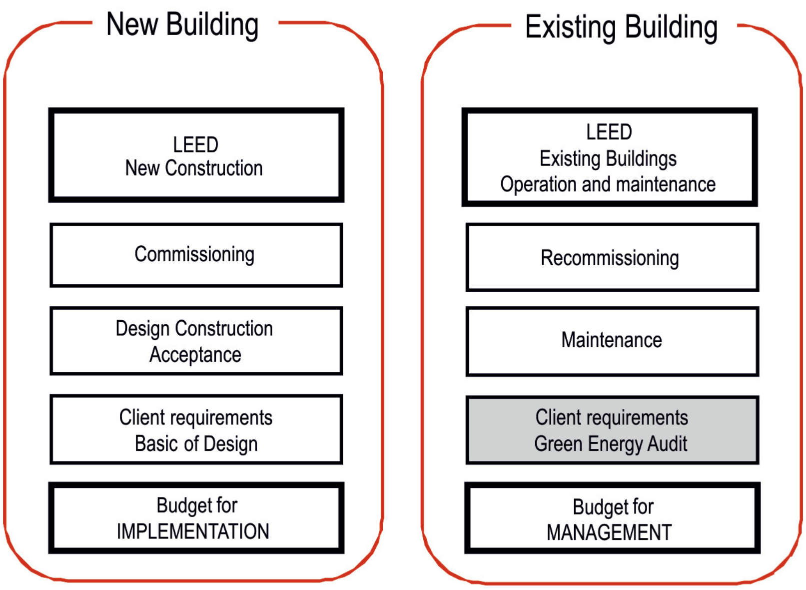


Fig. 1.4 Comparison between Commissioning and Recommissioning process

The Basis of Design explains how a particular technical choice addresses the Owner Project Requirement. It also contains a description of the systems, the reasons for the choices made, the design criteria and the sequences of the control systems. This document is then delivered to the Commissioning Authority, who examines it with the client.

1.4.4 The Re-commissioning Process for existing buildings

The Re-commissioning Process is the natural continuation of the commissioning process in terms of the maintenance and management goals set by the client.
It starts from considerations emerging from an energy audit, and then it develops a plan to achieve the building performance objectives defined in the Owner Project Requirement.

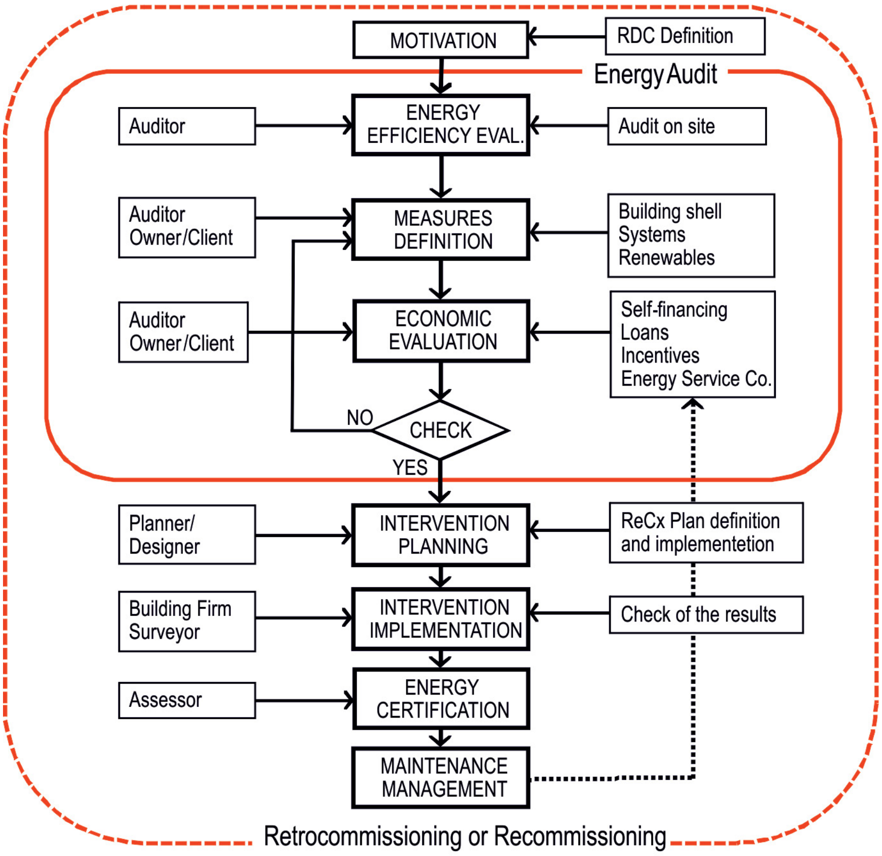


Fig. 1.5 Operational plan to design and implement an energy enhanced project

As defined above, the commissioning process gives the client a detailed report on the design and construction phases, and Green Energy Audits are greatly facilitated when the auditors have access to these documents before and during the analysis.
There is a good chance of achieving very close synergy if the two processes are applied (with different timing) in the same building.

The planned activities in the recommissioning process are structured in the following phases: the Planning Phase, the Investigation Phase (Audit), the Implementation Phase, and the Hands-Off Phase. Further information is available about this subject.

Energy Audits and the energy Retrocommissioning process are very similar and often have large areas of overlap (see Figure 1.5).
Retrocommissioning analyses systems and building management so as to make them as efficient as possible.
Energy audits examine the history of energy consumption and identify strategies to improve energy performance.
The main difference between the approaches is the output produced. Commissioning generates a more efficient building, while energy audits generate a report that contains a series of recommendations to make the building more efficient owing to a series of strategies characterised by different returns on investment.

1.5 Definition of the Green Energy Plan

1.5.1 Clarity in the objectives

The Green Energy Audit is realised with an operational plan, described in the technical report, that defines the strategies and the actions that result in measures for the limitation in the usage of resources.

Whereas the on-site audit phase, with further processing, allows the auditor to define what it is technically possible to achieve, the Green Energy Plan explicitly states what should be done.

In defining and then proposing to the client resource containment measures, the auditor should consider that the objective of the Green Energy Audit is to improve the sustainability of the building.
Since some measures (energy retrofit) result in a cost-effectiveness while others do not, before developing the operational plan of action, or green energy plan, it is important that the auditor understands not only what the goals are,
but also what are the expectations of the owner/client.

In table 1.5.1, there are some questions that the auditor may ask the owner and, depending on the possible responses, some interpretations.
This consultation should be scheduled, obviously, at a meeting preceding the drafting of the Green Energy Plan. With the objectives clarified, the next step concerns the definition of the retrofit measures.

Table 1.5.1 Some questions that the auditor may ask the client and, depending on the possible responses, some interpretations [1].

Possible questions	Interpretations of responses
Is reducing the cost of management the only goal of the audit?	If so, few opportunities remain to suggest other motives and one must understand what financial commitment the customer is ready to sustain and for how long. A negative response provides an opening to other possible reasons; it is for the auditor to define a broader framework.
Is the heightened value of the building as a result of the retrofit work a factor to consider?	A positive response can lead to prediction of the time of return on investment, which may exceed the period of use of the building, since all that is not recovered from the improved performance can be recovered from the consequent increased value of the building when it is sold.
If the client is already planning redevelopment of the opaque building envelope, is it for technological reasons or to improve the image?	The measures applied to improve opaque building envelope performance are those that require larger investments and longer payback times. An affirmative answer to this question gives the auditor the opportunity to offer these remedial actions. The economic evaluation of the investment should reasonably take into account only the value added related to improved energy performance.

Is the client's goal to support domestic economic resources, or is the use of external financing possible?	The availability of external resources allows for more substantial investments, and therefore, for the containment of resources to be amplified. On the other hand, the availability of internal resources can reduce the costs of financing. The auditor must obtain this information in order to properly process the economic evaluation.
Does the client-company usually prepare an environmental sustainability report?	Many companies prepare and publish an annual report on environmental sustainability that highlights the efforts made to reduce the company's impact on the environment. This choice, which is not normally required, shows that the client pays attention to these aspects. If this is the case, the auditor can be more confident in proposing to the client remedial actions that improve the sustainability of the building or its facilities whilst not guaranteeing energy savings and an income that can offset the expenses.

There are 97 retrofit measure sheets describing retrofit measures that can be taken.
Such measures are grouped into five sections:

Building envelope or shell (roofs, basements, walls, transparent envelope, shading, illumination using day lighting, etc.).

1. Mechanical systems (heating, summer cooling, ventilation, DHW, water services, etc.).
2. Electrical systems (generation, distribution and use of energy, lighting);
3. Renewable energy sources (solar thermal, solar photovoltaic, biomass, etc.).
4. Improving management (improving the management, maintenance and energy accounting, etc.).

The list of measures can be integrated as a possible intervention strategies will also take into account particular situations and what the market offers with new technologies.
The measures chosen, however, can cover much of the actions in the civil sector (residences, offices, commercial buildings, schools, etc..).

1.5.2 The retrofit measure sheets

The measure sheets are structured to facilitate both quick reading and a more detailed examination.
The information that allows the reader to understand in a synthetic way the contents of each sheet are shown at the top section as shown in the example of table 1.5.2 which concerns a measure concerning replacement of windows.

Tab. 1.5.2 Example of the top section of a retrofit measure sheet containing the synthetic data of the retrofit measure

Working **C**	Obsolete **A**	New **-**	O&M -
Saving potential □■■■		Payback ■■	
Reliability □■■■		Feasibility ■■■	
Environmental effects		**EC**	

The measure sheets provide the auditor the main parameters for a preliminary conscious choice, but at the same time contain references to general insights.
The measures may include:

- Actions on parts of the building (building envelope or facilities) that although "operative" and not subject to urgent replacement or upgrading, still cannot guarantee the best performance.
- Actions on parts of the building (building envelope or facilities) that are rather obsolete and may be subject to urgent replacement or upgrading;
- Actions concerning new installations in order to improve the sustainability of building.
- Actions to improve the management and maintenance.

Each proposed measure is identified by a 5-character alphanumeric coding:

- the first digit covering the area of interest (1 building envelope, 2 mechanical systems, 3 electrical systems, 4 renewable energy sources, 5 improved management);
- two letters concern the subcategory (e.g. LI lighting, RS renewable energy sources, etc.).
- two progressive numbers for the various subcategories.

Code 3.RS.01, for example, identifies the intervention of installation of a new solar plant for DHW.
Each sheet is structured into three sections:

- the heading;
- the scores section;
- the descriptive part;

The heading includes:

- the identification code;
- the title of the measure;
- the assessments (rating) which show the feasibility of the measure.

Regarding the assessments there are three situations that do not necessarily relate to the building but can refer to a component or system:

- Working/Operative: in this case retrofit actions are not planned (for example, it is proposed a thermal insulation in a facade that, despite being inefficient from the point of view of energy, does not present situations of degradation);
- Obsolete: in this case, the proposed measure is the result of an energy audit which takes into account the fact that there may be synergies with technological redevelopment or regulatory compliance.
- New: in this case the installation of a component or an additional system is provided.
- O&M: in this case the measure does not provide replacements of components or installation of new components, but an improvement of management strategies (considering the real needs of users) or more attention to maintenance.

For these three situations the assessments have the following meanings:

A. The application of the measure is very convenient;
B. The application of the measure is cost-effective;
C. The application of this measure is feasible even if the margins of convenience are not very high;
D. The application of this measure is not very convenient because complex or unprofitable, in the case of maintenance or management measures are required of expertise particularly costly.

The scores section, placed in the upper right part of the sheet, considers a series of indicators, expressed as a rating ranging from 1 to 4 that we describe below: the indicators refer to cases where the application of the measure is very convenient (A) or cost-effective (B).

Savings potential, expressed as annual percentage reduction of primary energy consumption refers to the extent implemented:

? ? ? ?	> 70%
? ? ?	40 to 70%
? ?	20 to 40%
?	<20%)

In the assessment of the energy savings are considered only the benefits obtained by analysing the measure indicated in the sheet (i.e. not the benefits referred to the building as a whole).
In the calculation of the ratings, for each measure, technical and economic evaluations were made considering the maximum achievable for that measure[9].

Payback of the investment expressed as simple payback (SPB):

? ? ? ?	<5 years
? ? ?	5 to 10 years
? ?	10 to 20 years
?	>20 years

Financial returns are always referred to the benefits related to the single retrofit measure.

Reliability of the retrofit measure, indicates how the measure will be effective and reliable over time:

? ? ? ?	high reliability (the measure maintains its performance for a period of time equal to the useful lifetime of the building)
? ? ?	good reliability (the measure guarantees its performance with low maintenance)
? ?	mediocre reliability (measuring its performance guarantees in time but with frequent maintenance)
?	poor reliability (it is very difficult to maintain performance over time because of a considerable commitment and/or need for expensive technical skills).

Feasibility of the remedial action, provides guidance on how is easy or not to implement the measure:

? ? ? ?	maximum ease (the implementation of this measure requires minimal effort and not high expertise)
? ? ?	ease normal (no special efforts are needed since it is routine procedure)
? ?	difficulty (the implementation of the measure requires a special effort and expertise with high levels of qualification)
?	high difficulty (the implementation of this measure is particularly difficult and may have contraindications).

9 In the case of the thermal insulation of a wall, for example, it is obvious that the potential savings depend on the quality of the insulation added (thermo physical characteristics of the insulating material and its thickness)

Improvement of sustainability: the positive effects on the improvement of sustainability (reduction of energy consumption, reducing environmental impact, improving comfort) generated by the implementation of the measure are assessed and summarised:

A	reduction of energy consumption (fuel, electricity, etc.)
E	reduction of resources consumption (non-energy as water, etc.)
I	reduction of the environmental impact (we consider only the direct effects, such as improved thermal insulation certainly reduces fuel consumption but has no direct effect on the environmental impact whereas the replacement of a heat generator reduces emissions and hence has a direct effect on the environmental impact)
C	comfort improvement (thermal comfort, lighting comfort, IAQ).

In assessing the ratings other symbols are used:

□ indicates a possible extension of the rating criteria (□ □ ☐ ☐ means ranging from 2 to 4),
NA indicates that the assessment of the specific evaluation criteria for the specific measure is not applicable.

The descriptive part includes:

- a general description section that describes the measure synthetically from the technical point of view, but mainly focuses on the reasons that can make its implementation very convenient in the overall context as well as any interdependency (or alternatives offered) with other measures that may be cited. In this section, reference is made to issues related to the application of the measure described, as well as the selection criteria;
- a tips and warning section in which we provide tips to increase the effectiveness of the measure, but at the same time highlight possible weaknesses.

1.6 Retrofit measure sheets

1.6.1 Introduction

The definition of the green energy plan for the improvement of the sustainability of a building is brought to fruition mainly with the choice of retrofit measures that should be implemented.
The one hundred measures presented and discussed in this chapter are sufficient to cover most needs for residential, educational and commercial buildings but can also be useful for industrial buildings, excluding obviously the measures aimed at the optimisation of production processes.
The proposed measures relate to:

- parts of the building (building envelope and systems) that whilst "operative" and not subject to urgent redevelopment, still cannot guarantee the best performance in terms of energy, comfort and indoor environment;
- parts of the building which are instead obsolete and are subject to urgent redevelopment or replacement;
- improvement of management and maintenance.
  The different sections, one for each measure, constitute separate sheets organised in the following manner:
- a table containing the main parameters for a preliminary selection (code of the measure, short description, rating assessment);
- a general description of the measure;
- tips and warnings to consider before selecting the measures.
  Retrofit measures have been combined into the following sections:
- Building envelope (shell)
- HVAC Systems
- Plumbing and DHW Systems
- Electrical Systems
- Renewable energy sources
- Management improvement.

The retrofit measures described below are treated independently: the auditor should take into account that, when provided with multiple measures (scenarios) there may be interactions between them, with positive but sometimes negative effects.

1.7 LEED

1.7.1 Definition of LEED

Leadership in Energy and Environmental Design (LEED) is one of the most popular building certification programs used worldwide. Developed by the non-profit U.S. Green Building Council (USGBC) it includes a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighborhoods that aims to help building owners and operators be environmentally responsible and use resources efficiently.

From 1994 to 2015, LEED grew from one standard for new construction to a comprehensive system of interrelated standards covering aspects from the design and construction to the maintenance and operation of buildings.

LEED also has grown from six volunteers on one committee to 119,924 staff, volunteers and professionals.
LEED standards have been applied to approximately 83,452 registered and certified LEED projects worldwide, covering around 13.8 billion square feet (1.28 billion square meters).

USGBC's Green Building Certification Institute (GBCI) offers various accreditation to people who demonstrate knowledge of the LEED rating system, including LEED Accredited Professional (LEED AP), LEED Green Associate, and since 2011, LEED Fellows, the highest designation for LEED professionals. GBCI also certifies projects pursuing LEED.

1.7.2 Rating systems

LEED has evolved since 1998 to more accurately represent and incorporate emerging green building technologies. The pilot version, LEED New Construction (NC) v1.0, led to LEED NCv2.0, LEED NCv2.2 in 2005, and LEED 2009 (previously named LEEDv3) in 2009.
LEEDv4 was introduced in November, 2013. Until October 31, 2016, new projects may choose between LEED 2009 and LEEDv4. New projects registering after October 31, 2016 must use LEEDv4.
LEED 2009 encompasses nine rating systems for the design, construction and operation of buildings, homes and neighborhoods.
Five overarching categories correspond to the specialties available under the LEED Accredited Professional program.

That suite currently consists of:
Green Building Design & Construction

- LEED for New Construction
- LEED for Core & Shell
- LEED for Schools
- LEED for Retail: New Construction and Major Renovations
- LEED for Healthcare

Green Interior Design & Construction

- LEED for Commercial Interiors
- LEED for Retail: Commercial Interiors

Green Building Operations & Maintenance

- LEED for Existing Buildings: Operations & Maintenance

Green Neighborhood Development

- LEED for Neighborhood Development

Green Home Design and Construction

- LEED for Homes

(The LEED for Homes rating system is different from LEED v3, with different point categories and thresholds that reward efficient residential design.)

LEED also forms the basis for other sustainability rating systems such as the Environmental Protection Agency's Labs21.
To make it easier to follow LEED requirements, in 2009 USGBC helped Building Green develop LEEDuser, a guide to the LEED certification process and applying for LEED credits written by professionals in the field.

1.7.3 LEED energy modeling

Design teams have the option of achieving points under the Optimize Energy Performance credit by building an energy model. This energy model must follow the modeling methodologies outlined in Appendix G of the ASHRAE 90.1 building energy standard.

The guidelines in Appendix G require that the team make two energy models: one representing the building as designed, and a second "baseline" building.
The baseline building must be modeled in the same location,
and have the same geometry and occupancy as the design building.

Depending on location (climate) and building size, the standard provides requirements for HVAC system type, and wall and window definitions.
The goal of this methodology is to provide a baseline building to use as a reference point
to compare the design building against.

It is a way to standardize the baseline, while putting weight on important factors that heavily influence building energy consumption (e.g., location, geometry, and occupancy patterns).
The number of points achieved in this credit is correlated with the percent predicted energy savings demonstrated by the difference between the design and baseline energy models.
This method of energy modeling has been criticized for inaccurately predicting actually energy usage of LEED-certified buildings.

1.7.4 Energy performance research

On average, LEED-certified buildings use the same source energy and produce equal greenhouse gas emissions as non-LEED-certified buildings. They use between 11 and 39% less site energy than non-LEED buildings on average, although 28-35% use more energy.

No correlation was found between the number of LEED points achieved and measured energy savings.
In 2009 Newsham et al. analyzed a database of 100 LEED-certified buildings. In this study, each building was paired with a conventional "twin" building within the Commercial Building Energy Consumption Survey (CBECS) database according to building type and occupancy.

On average, LEED buildings consumed 18 to 39% less energy than their conventional "twin" building, although 28 to 35% of LEED-certified buildings used more energy than their "twin."
The paper found no correlation between the number of energy points achieved or LEED certification level and measured building performance.
In 2009 Scofield published an article in response to Newsham et al., analyzing the same database of LEED buildings and arriving at different conclusions.

In his analysis, Scofield considered source energy (accounting for energy losses during generation and transmission) as well as site energy,
and used area-weighted energy use intensities, or EUIs (energy per unit area per year), when comparing LEED and non-LEED buildings to account for the fact that larger buildings tend to have larger EUIs.

Scofield concluded that, collectively, the LEED-certified buildings showed no significant source energy consumption savings or greenhouse gas emission reductions when compared to non-LEED buildings, although they did consume 10-17% less site energy.

Scofield in 2013 analyzed 21 LEED-certified buildings in New York City.
He found that buildings that had achieved LEED Gold used, on average, 20% less source energy than did conventional buildings. Buildings with LEED Silver or LEED Certified ratings actually used 11 to 15% more source energy, on average, than did their conventional counterparts.

Stoppel and Leite developed a study in 2013 to evaluate the predicted and actual energy consumption of two twin buildings using the energy model process documented during the LEED design phase and the utility meter data after 12 months of occupancy.

The authors found that energy model predicted 14% and 25% more energy consumption for each building compared to the actual buildings energy use.
The study's results suggests that mechanical systems turnover and occupancy assumptions significantly differing from predicted to actual values.

In 2014, Fuertes and Schiavon developed the first study that analyzes plug loads using LEED documented data from certified projects.
The study compared plug load assumptions made by 92 energy modeling practitioners against ASHRAE and Title 24 requirements, as well as,
the evaluation of the plug loads calculation methodology used by 660
LEED-CI and 429 LEED-NC certified projects.
In general, energy modelers considered the energy consumption of plug loads of equipment that are constantly running (such as refrigerators) as well as monitors and computes predictable.

Overall the results suggested a disconnection between energy modelers assumptions and the actual performance of buildings.
The study also shows that there was no consistency on the method used by LEED-CI and NC projects, while one is based on the power and percentage of ENERGY STAR equipment installed in the building the other one is based on a whole-building-design energy model.

In conclusion, the study suggests LEED or ASHRAE to develop guidelines for plug loads calculations.

2. BIM

2.1 Preface

Building information modeling (BIM) is a process involving the generation and management of digital representations of physical and functional characteristics of places.
Building information models (BIMs) are files (often but not always in proprietary formats and containing proprietary data) which can be exchanged or networked to support decision-making about a place. Current BIM software is used by individuals, businesses and government agencies who plan, design, construct, operate and maintain diverse physical infrastructures, such as water, wastewater, electricity, gas, refuse and communication utilities, roads, bridges and ports, houses, apartments, schools and shops, offices, factories, warehouses and prisons.

The US National Building Information Model Standard Project Committee has the following definition:

Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.

Traditional building design was largely reliant upon two-dimensional technical drawings (plans, elevations, sections, etc.). Building information modeling extends this beyond 3D, augmenting the three primary spatial dimensions (width, height and depth) with time as the fourth dimension (4D) and cost as the fifth (5D).

BIM therefore covers more than just geometry. It also covers spatial relationships, light analysis, geographic information, and quantities and properties of building components (for example, manufacturers' details).

BIM involves representing a design as combinations of "objects" – vague and undefined, generic or product-specific, solid shapes or void-space oriented (like the shape of a room), that carry their geometry, relations and attributes. BIM design tools allow extraction of different views from a building model for drawing production and other uses.
These different views are automatically consistent, being based on a single definition of each object instance.

BIM software also defines objects parametrically; that is, the objects are defined as parameters and relations to other objects, so that if a related object is amended, dependent ones will automatically also change.
Each model element can carry attributes for selecting and ordering them automatically, providing cost estimates as well as material tracking and ordering.

For the professionals involved in a project, BIM enables a virtual information model to be handed from the design team (architects, landscape architects, surveyors, civil, structure land building services engineers, etc.) to the main contractor and subcontractors and then on to the owner/operator; each professional adds discipline-specific data to the single shared model.

This reduces information losses that traditionally occurred when a new team takes 'ownership' of the project, and provides more extensive information to owners of complex structures.

2.2 BIM ORIGINS AND ELEMENTS

The concept of BIM has existed since the 1970s.
The term 'building model' (in the sense of BIM as used today) was first used in a 1986 paper by Robert Aish - then at GMW Computers Ltd, developer of RUCAPS software - referring to the software's use at London's Heathrow Airport. The term 'Building Information Model' first appeared in a 1992 paper by G.A. van Nederveen and F. P. Tolman.

However, the terms 'Building Information Model' and 'Building Information Modeling' (including the acronym "BIM") did not become popularly used until some 10 years later. In 2002, Autodesk released a white paper entitled "Building Information Modeling," and other software vendors also started to assert their involvement in the field.

By hosting contributions from Autodesk, Bentley Systems and Graphisoft, plus other industry observers, in 2003, Jerry Laiserin helped popularize and standardize the term as a common name for the digital representation of the building process.
Facilitating exchange and interoperability of information in digital format had previously been offered under differing terminology by Graphisoft as "Virtual Building",
Bentley Systems as "Integrated Project Models", and by Autodesk or Vector works as
"Building Information Modeling".

As Graphisoft had been developing such solutions for longer than its competitors,
Laiserin regarded its ArchiCAD as then "one of the most mature BIM solutions on the market" but also highlighted the pioneering role of applications such as RUCAPS, Sonataand Reflex.

Following its launch in 1987, ArchiCAD became regarded by some as the first implementation of BIM, as it was the first CAD product on a personal computer able to create both 2D and 3D geometry, as well as the first commercial BIM product for personal computers.

2.3.1 BIM THROUGHOUT THE PROJECT LIFE-CYCLE

Use of BIM goes beyond the planning and design phase of the project, extending throughout the building life cycle, supporting processes including cost management, construction management, project management and facility operation. Management of building information models.

Use of BIM goes beyond the planning and design phase of the project, extending throughout the building life cycle, supporting processes including cost management, construction management, project management and facility operation.

Management of building information models Edit Building information models span the whole concept-to-occupation time-span.
To ensure efficient management of information processes throughout this span,
a BIM manager (also sometimes defined as a virtual design-to-construction, VDC,
project manager – VDCPM) might be appointed.
The BIM manager is retained by a design build team on the client's behalf from the pre-design phase onwards to develop and to track the object-oriented BIM against predicted and measured performance objectives, supporting multi-disciplinary building information models that drive analysis, schedules, take-off and logistics.

Companies are also now considering developing BIMs in various levels of detail, since depending on the application of BIM, more or less detail is needed, and there is varying modeling effort associated with generating building information models at different levels of detail.

2.3.2 BIM IN CONSTRUCTION MANAGEMENT

Participants in the building process are constantly challenged to deliver successful projects despite tight budgets, limited manpower, accelerated schedules, and limited or conflicting information.

The significant disciplines such as architectural, structural and Mechanical, Electrical, Plumbing, and Fire Protection Systems (MEP) designs should be well coordinated, as two things can’t take place at the same place and time.
Building Information Modeling aids in collision detection at the initial stage, identifying the exact location of discrepancies.

The BIM concept envisages virtual construction of a facility prior to its actual physical construction, in order to reduce uncertainty, improve safety, work out problems, and simulate and analyze potential impacts.
Sub-contractors from every trade can input critical information into the model before beginning construction, with opportunities to pre-fabricate or pre-assemble some systems off-site.
Waste can be minimized on-site and products delivered on a just-in-time basis rather than being stock-piled on-site.

Quantities and shared properties of materials can be extracted easily. Scopes of work can be isolated and defined. Systems, assemblies and sequences can be shown in a relative scale with the entire facility or group of facilities. BIM also prevents errors by enabling conflict or ‘clash detection’ whereby the computer model visually highlights to the team where parts of the building (e.g.: structural frame and building services pipes or ducts) may wrongly intersect.

2.3.3 BIM IN FACILITY OPERATION EDIT

BIM can bridge the information loss associated with handling a project from design team, to construction team and to building owner/operator, by allowing each group to add to and reference back to all information they acquire during their period of contribution to the BIM model. This can yield benefits to the facility owner or operator.

For example, a building owner may find evidence of a leak in his building. Rather than exploring the physical building, he may turn to the model and see that water valve is located in the suspect location. He could also have in the model the specific valve size, manufacturer, part number, and any other information ever researched in the past, pending adequate computing power.

Such problems were initially addressed by Leite and Akinci when developing a vulnerability representation of facility contents and threats for supporting the identification of vulnerabilities in building emergencies.

Dynamic information about the building, such as sensor measurements and control signals from the building systems, can also be incorporated within BIM software to support analysis of building operation and maintenance.

2.3.4 BIM IN LAND ADMINISTRATION AND CADASTER EDIT

BIM can potentially offer some benefits for managing stratified cadastral spaces in urban built environments.
The first benefit would be enhancing visual communication of interweaved, stacked and complex cadastral spaces for non-specialists. The rich amount of spatial and semantic information about physical structures inside models can aid comprehension of cadastral boundaries, providing an unambiguous delineation of ownership, rights, responsibilities and restrictions.

Additionally, using BIM to manage cadastral information could advance current land administration systems from a 2D-based and analogue data environment into a 3D digital, intelligent, interactive and dynamic one.

BIM could also unlock value in the cadastral information by forming a bridge between that information and the interactive lifecycle and management of buildings.
Due to the complexity of gathering all the relevant information when working with BIM on a building project some companies have developed software designed specifically to work in a BIM framework.

These packages (e.g.: Bentley AECOsim Building Designer, ArchiCAD, MagiCAD, Tekla Structures, Autodesk Revit, Synchro PRO, VectorWorks, Trimble SketchUp) differ from architectural drafting tools such as AutoCAD by allowing the addition of further information (time, cost, manufacturers' details, sustainability and maintenance information, etc.) to the building model.

2.3.5 NON-PROPRIETARY OR OPEN BIM STANDARDS EDIT

BIM is often associated with Industry Foundation Classes (IFCs) and aecXML – data structures for representing information. IFCs have been developed by building SMART (the former International Alliance for Interoperability), as a neutral, non-proprietary or open standard for sharing BIM data among different software applications (some proprietary data structures have been developed by CAD vendors incorporating BIM into their software).

Poor software interoperability has long been regarded as an obstacle to industry efficiency in general and to BIM adoption in particular.

An early example of a nationally approved BIM standard is the AISC (American Institute of Steel Construction)-approved CIS/2 standard, a non-proprietary standard with its roots in the UK.

There have been attempts at creating a BIM for older, pre-existing facilities.
They generally reference key metrics such as the Facility Condition Index (FCI).

The validity of these models will need to be monitored over time, because trying to model a building constructed in, say 1927, requires numerous assumptions about design standards, building codes, construction methods, materials, etc., and therefore is far more complex than building a BIM at time of initial design.

2.4 BUILDING INFORMATION MODELING FOR ENERGY EFFICIENCY

Throughout the world goals are in place to try to reverse the negative impacts of climate change, with a focus on energy efficiency and carbon emission reduction to help us save energy and improve our environment.

Experts agree that buildings are the biggest source of emissions and energy consumption around the globe.
Yet, on the positive side, they also represent one of the fastest,
most cost-effective ways to reduce greenhouse gas emission.
As such, retrofitting existing buildings can lead to a significant reduction in building energy consumption.

As the countries across the globe retool in reaction to a challenging year, forward-thinking engineering firms are presented with tremendous opportunity to emerge as leaders in terms of helping to improve the performance and sustainability of existing and new buildings.

Fortunately, new technologies help make this once overwhelming prospect manageable - especially when compared to traditional 2D drafting tools.
For example, building information modeling (BIM) is an integrated process for exploring a project’s key physical and functional characteristics digitally - before it is built.

The coordinated, consistent information used throughout the BIM process helps architects, engineers, contractors, and owners to see, prior to construction, what their design will look like and more importantly, how it will perform.
When applied to existing buildings, purpose-built BIM solutions can help capture the building geometry and characteristics needed to conduct various aspects of energy performance analysis for example,

a basic model can be created through the BIM process that can then be used to support energy and investment-grade audits.

With a building information modeling process, any architecture, engineering, and construction (AEC) firm can leverage BIM for greater energy efficiency in new designs as well as in renovation and retrofit projects.
With BIM at the core, design professionals can quickly and easily provide building owners with energy improvement suggestions and conceptual building energy usage.
With a simple energy model, what-if scenarios can be performed to best determine the optimum energy and water requirements of the building.
BIM can empower design professionals to engineer better buildings.

Conducting analyses on the design model is critical; in fact, some studies show that when a design team uses whole building energy analysis, they can save an average of 20 percent on energy use.

For retrofit projects, the potential for energy savings is even greater because older buildings tend not to have had any tenant or system improvements over the years.
This creates an opportunity for greater reductions in energy consumption - reductions that can be calculated using whole building energy analysis as part of the BIM process.

With BIM, AEC professionals are well positioned to ensure sustainability and energy efficiency throughout the life of the building, whether it is a new design or an existing building.

2.5 BIM IN AUTODESK

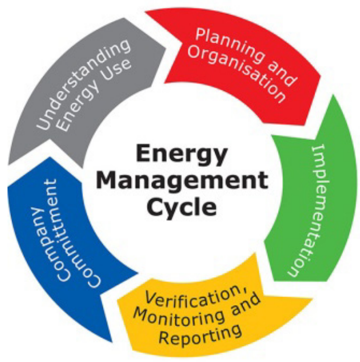
Building Information Modeling (BIM) is an intelligent 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and mange buildings and infrastructure.

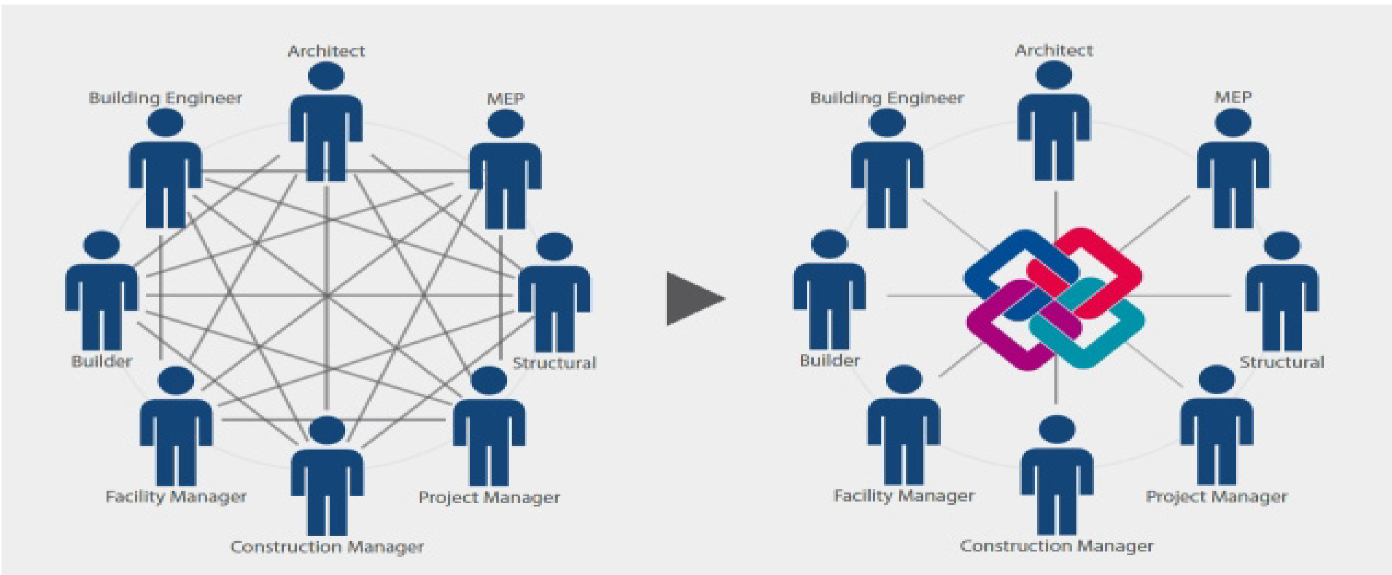
Building Information Modeling processes have helped countless firms in diverse industries operate more productively, produce higher-quality work, attract more talent, and win new business.
With a rising number of government and commercial organizations mandating BIM, now is the time to consider implementing BIM.

2.6 THE FUTURE OF BIM

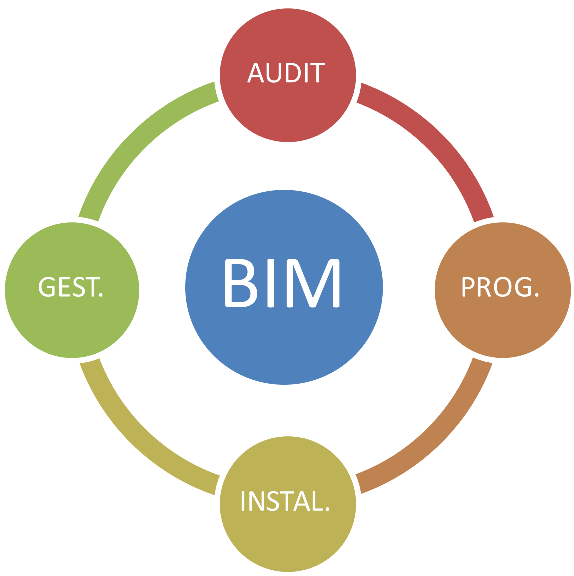
The future of the construction industry is digital, and BIM is the future of design and long term facility management, it is government led and driven by technology and clear processes and it is implementing change across all industries.

Clients, building owners and operators are getting more and more access to BIM models through their mobile devices even without the need to installing a BIM application first.
This shift will put the adoption of BIM onto the next level so you as a professional really cannot afford ignoring BIM.





Exchange between 2D drawings | Execution of an IFC / BIM project



3. Energy analysis with ArchiCAD

Sustainable architecture is the practice of designing, constructing and maintaining buildings in a way that their environmental impact is minimized.
One of the most important aspects of sustainable design is energy efficiency - a drive to reduce the amount of energy a building consumes during its life-span.

As building shape and orientation play a crucial role in determining the structure's future energy consumption, design is central to the building's energy performance.
Therefore architects are hugely responsible for the buildings' environmental impact.

These characteristics are notoriously difficult and expensive to change at the final stages of the design process where, traditionally, energy efficiency calculations take place.

If architects could easily analyze their design for energy efficiency at the earliest possible design phases, they could get invaluable feedback on their building's energy performance and be in a position to react to it. To do this, they need a digital model of the building and an analysis tool that can determine its efficiency.

ArchiCAD® is Graphisoft's purpose-built virtual modeling solution that allows architects to create a 3D model of their design, effectively creating a Virtual Building™.
This White Paper details how ArchiCAD supports key aspects of energy-efficient design and how best to analyze the Virtual Building for energy performance using various purpose-built building energy analysis software tools.

3.1 Standards for sustainable architecture

"To not make the most efficient use of energy in any form of building is an unethical architectural practice."
The gauntlet has been thrown down for the architect to take on a new mantel - that of balancing the aesthetic expectations of our modern lifestyles with a lead role in ensuring building efficiency at the heart of building design.
Now that the tools exist, architects face a commercially sound choice of delivering analysis services and designs, or waiting for governments to enforce new regulations.

All of this aside - building owners themselves are becoming more aware of the ever-increasing maintenance costs of their buildings and the huge long-term expense burden they could incur from energy-inefficient architectural design.

It's no longer simply a question of installing eco-friendly energy-conserving materials.
Building owners and designers alike are making that active commitment to go green throughout the design process, since the Virtual Building's rich data allows for green interventions at the most fundamental, early design phases.

3.2 Energy analysis

Sophisticated energy usage simulation software has been around for more than two decades.
Unfortunately, these programs not only required comprehensive knowledge of how to analyze energy usage patterns but also of the particular program itself.

The result has been that only specialists could do energy simulations, and with the effort and expense required, it generally meant that energy analysis only took place once - at the end of the design process.

At this late stage, the analysis became awoken gesture and helped little in influencing the design in terms of energy efficiency.

It only served as a checking tool to allow the architect and client to justify the results, and it was rarely used as a collaborative design tool among the design team.

Nowadays there are a suite of easy-to-use applications available that can be handled by the architect, delivering energy analysis throughout the design process.
Energy analysis no longer needs to be an expensive specialist-dominated procedure.

It is just another design consideration that helps the architect create energy-efficient buildings using software tools which can interact with the Virtual Building data, requiring little additional effort on the designer's part.
ArchiCAD provides robust design information along with this necessary level of model detail.

This information can be directly accessed and used for energy analysis by Green Building Studio® and ArchiPHYSIK®, or via industry standard formats to otherapplications such as ECOTECT®.

These applications have been designed for architects and can be used from the early design phases to help them make the right environmental - and legal - design decisions concerning the buildings envelop structures and materials.

ArchiCAD's support for IFC provides a link for professional building performance simulation software like EnergyPlus® or RIUSKA®.

These tools are fully integrated building and HVAC simulation programs that dramatically improve the simulation of whole-building approaches in design, planning, and construction, and opens new doors for energy savings, cost savings and indoor environmental quality.

Using ArchiCAD with all the above tools provides great benefits to both architects and energy specialists. Because the energy analysis tool can directly accessArchiCAD Virtual Building models, feedback on the energy consumption of the building can be obtained at any time during the design process.

And ongoing changes to the design do not lead to any laborious reworking on the simulation side– manually adjusting the geometry of the building to keep up with the alterations –because the essence of a 3D model means all the data is up-to-date and immediately usable.
Of course, without a Virtual Building the process will be more painful and inefficient.

However, with ArchiCAD the updated 3D model can be easily analyzed over and over again by the energy simulation tool, no matter how much or often the plan evolves.

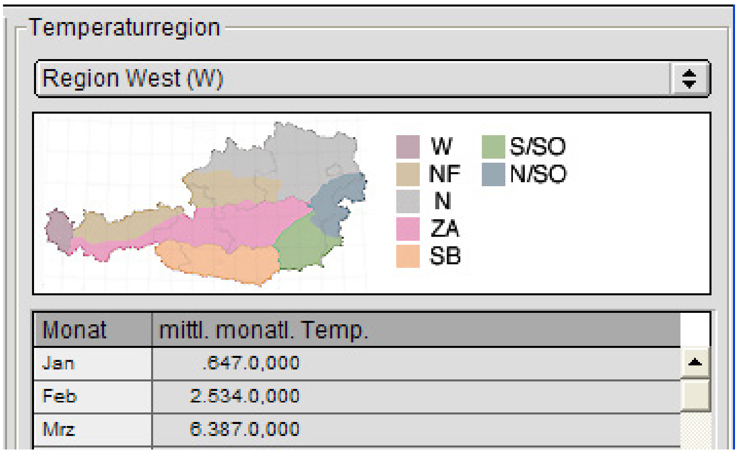
Clearly this saves both the architect and client a great deal of effort and money, and makes earlier design influences based on energy efficiency a realistic, responsible and commercially attractive option for all parties.

3.3 Partner products

ArchiPHYSIK (4.5)

ArchiPHYSIK (APH) is a stand-alone tool with a plug-in to ArchiCAD to estimate, calculate and optimize the physical properties of the building - such as thermal insulation and storage properties, vapor diffusion and acoustic damping.

ArchiPHYSIK has a large "real-life" building elements library which makes the calculation realistic and precise. A built-in "climate generator" simulates the precise weather conditions of the selected location.
Templates of local building regulations help you create the required certificates easily.

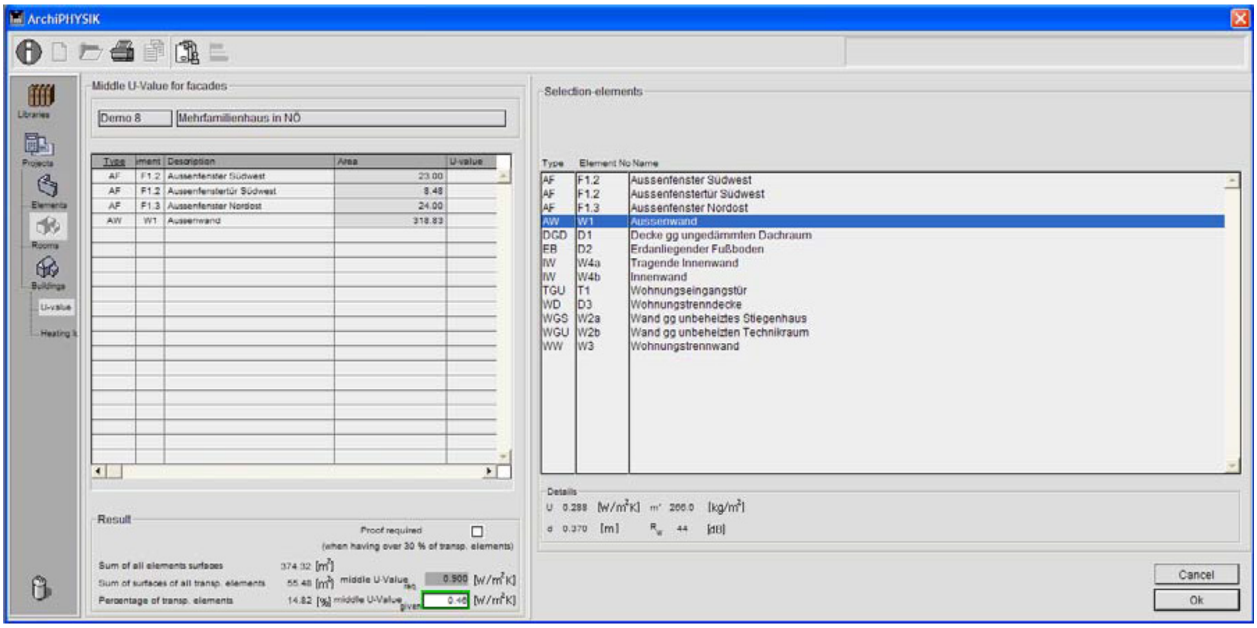


Location selection in APH.

An API link between ArchiCAD and APH allows you to export the model geometry to APH, calculate physical properties and select the best building structures accordingly.

The calculated data can be linked back into ArchiCAD.
This 2-way live link gives immediate feedback on how design changes affect the physics of the building, enabling you to select building materials and design solutions taking into consideration the energy performance of the building from the early design phase.

Instant update of the energy calculation from within ArchiCAD lets you easily monitor the physics of the building during all of the design phases.



Interface of ArchiPHYSIK.

Green Building Studio

Green Building Studio (GBS) is a free Web service that allows architects to create building energy performance and energy cost estimates of their ArchiCAD models at the earliest design phases. GBS has been specifically designed to streamline the integrated design process and greatly reduce the cost of designing green buildings by facilitating team collaboration.

It connects to ArchiCAD via a Plug-in that converts the ArchiCAD model to a GreenBuilding XML format (gbXML, an open XML schema that is quickly being adopted by the HVAC software industry for data exchange) and uploads it to the GBS website directly from ArchiCAD.

The geometry of the ArchiCAD model including zones(ArchiCAD zones either created by the user or automatically placed by the Plug-in based on the geometry),
their bounding surfaces and openings, and exterior shading
surfaces are contained in the gbXML file and are enriched with intelligent baseline defaults relevant to local building codes and a full whole building energy analysis is run using the DOE-2.2 simulation engine (a widely accepted building analysis program).

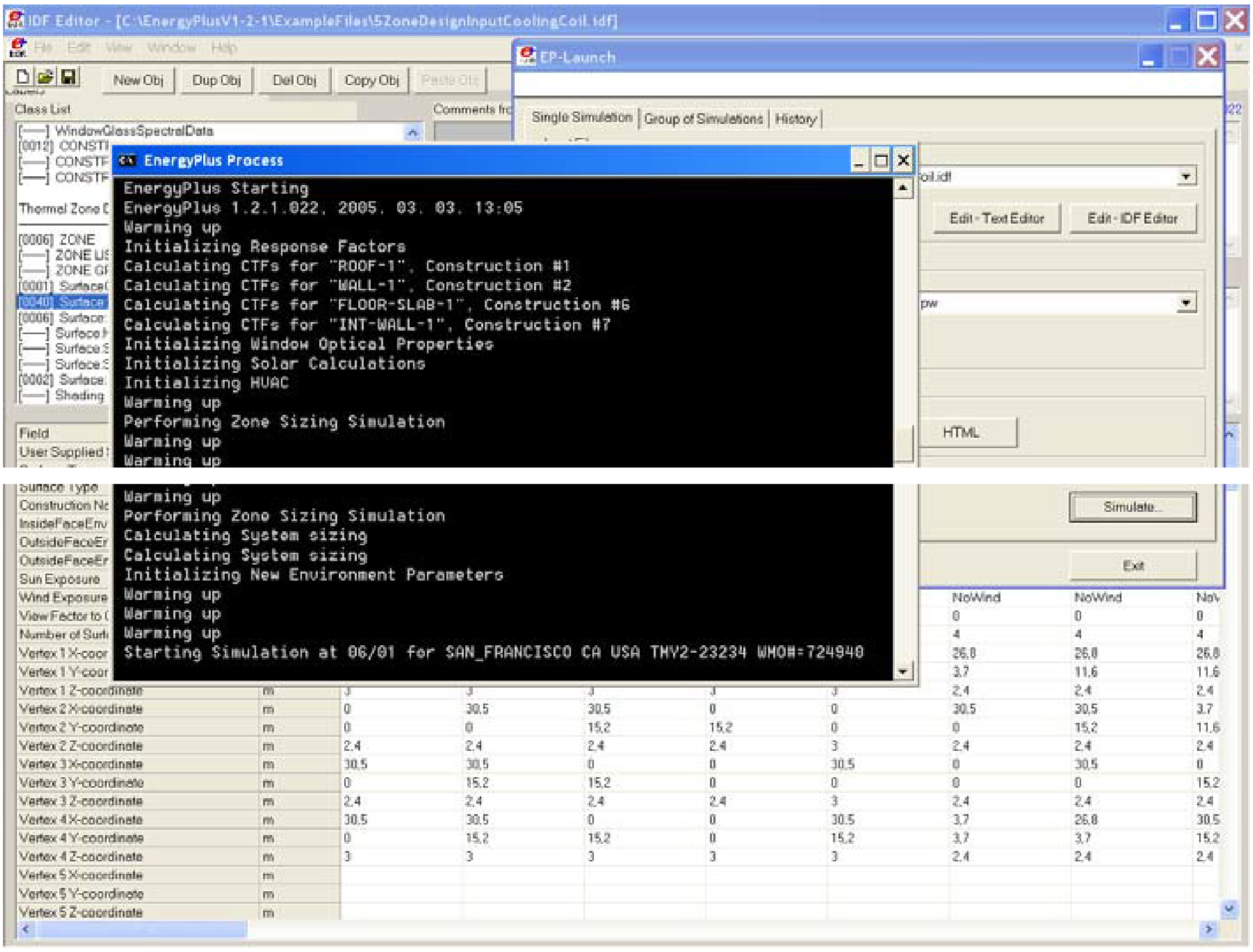
Only the building type and the location have to be entered in Green Building Studio manually. Annual energy consumption costs and a wide range of data on the building heating and cooling loads, spaces, and systems (breakdowns of energy use for major electric and gas components like lighting, HVAC, and space heating) are summarized and presented in ArchiCAD.

EnergyPlus

EnergyPlus is a next generation building energy simulation program that allows architects, engineers, building owners and managers to minimize energy use and cost.

It optimizes building performance by simulating building energy usage: building heating, cooling, lighting, ventilation, and other energy flows. EnergyPlus is a fully integrated building energy performance simulation software, which dramatically improves the simulation of whole-building approaches in design, planning, and construction, and opens new doors for energy savings, cost savings and indoor environmental quality.

EnergyPlus is a stand-alone simulation engine without a graphical interface. It comprises hundreds of sub-routines working together to simulate heat and mass energy flows throughout a building, calculating loads for HVAC equipment sizing and performing energy analysis for evaluating energy consumption.



EnergyPlus simulation process with two helper applications in the background.

Running accurate simulations requires a wide range of data sets including, among others: geometry, construction, location, weather, building usage and HVACdescription data.

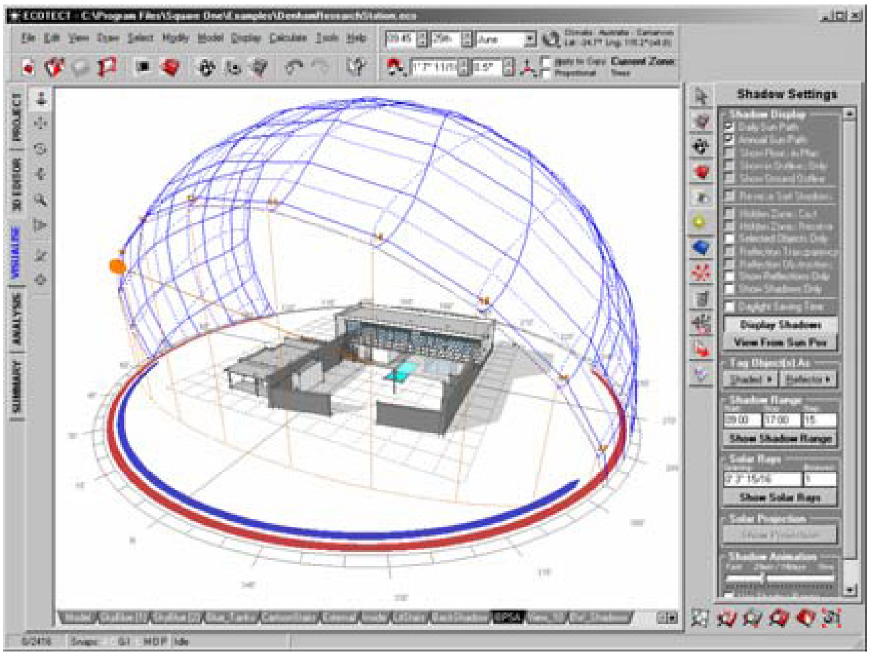
Due to the large quantity of necessary input data and the lack of a"user friendly" interface, this engine is geared towards an audience with a strong technical background.
Although the learning curve is quite steep, it is possible to complete simpler simulations after a few weeks of training with the help of thorough documentation.

The simulation process relies on editing and processing person-legible text files.
The building description data is entered by hand or by using some basic utilities.
The engine can be coupled easily with third party applications like the BSPro Com Server, which helps the process of converting IFC building data to EnergyPlus input data format. EnergyPlus users can take advantage of ArchiCAD's interoperability standards compliance during the building envelope input process: ArchiCAD 6.5, 7,8.0, 8.1, 9 projects can be exported to IFC 1.5, 2.0, 2x and 2x2 interchange formats.
EnergyPlus IDF format can also be obtained through gbXML using the Green Building Studio as discussed earlier.

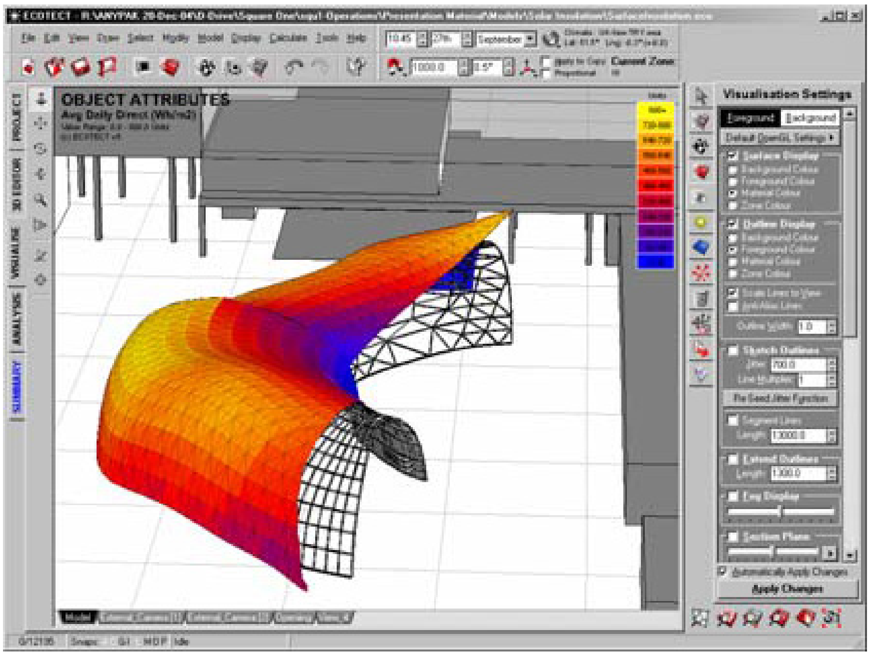
ECOTECT

ECOTECT is a highly visual and interactive building design and analysis tool that linksa comprehensive 3D modeler with a wide range of performance analysis functions covering solar, thermal, energy, lighting, acoustics, resource usage and cost aspects.

Whilst its modeling and analysis capabilities can handle geometry of any size and complexity, its main advantage is a focus on feedback at the earliest stages of the building design process.



OpenGL visualization is combined with a vast range of analysis features - the example above showing interactive sun positioning for viewing real-time shadows and sun penetration.



Analysis information displayed directly within the context of a building model - the example above showing incident solar radiation over a complex 3D form sited within a cityscape.

ECOTECT aims to provide designers with useful performance feedback both interactively and visually.

Thus, in addition to standard graph- and table-based reports, analysis results can be mapped over building surfaces or displayed directly within the spaces that generated them, giving the designer the best chance of understanding and demonstrating exactly how their building is performing.

In addition to the extensive selection of internal calculations that ECOTECT can perform, it also exports to a range of more technical and focused analysis engines such as Radiance, EnergyPlus, ESP-r, among others.

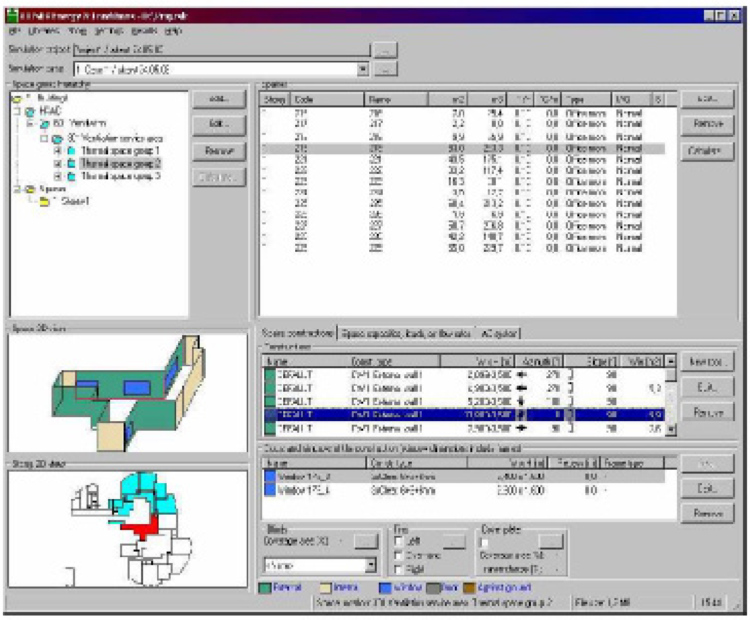
The recent addition of a comprehensive scripting engine that provides direct access to model geometry and calculation results has made performance-based generative design and optimization a very real option for the environmental engineer and designer who uses ECOTECT.

Scripting allows models to be completely interactive and self-generative, automatically controlling and changing any number of parameters, materials, zone settings or even geometry during calculations or as the user specifies. At a more day-to-day level, the scripting functions are excellent for automating the more mundane tasks involved in calculation runs, results comparison and report creation.

ECOTECT is unique within the building analysis industry in that it is entirely designed and written by architects and intended mainly for use by architects - although the software is also quickly gaining popularity with engineers, consultants and building designers, as well as owner-builders and environmental enthusiasts alike.

RIUSKA

RIUSKA is a tool for the dynamic simulation of comfort and energy consumption in building services design and facilities management. It calculates inside temperatures and the heating and cooling of individual spaces, and can be used to compare and dimension HVAC systems as well as for calculating the energy consumption of entire buildings.
It also has a module to calculate the heat loss of a building in a steady state condition.
RIUSKA is based on many years of development work at Greenland, in Finland.
The engine at its heart is the internationally known DOE 2.1 E simulation program.



The RIUSKA interface.

RIUSKA covers all the requirements of thermal performance simulation from
preliminary design to facilities management and renovation.
It has been developed specifically as a design tool for use by engineers in their everyday work.

It is possible to directly transfer and reuse digital building geometry data fromArchiCAD through the IFC interface. RIUSKA has been officially certified by the IAI to
comply with the IFC 2X, IFC 2.0 BLIS (Building Lifecycle Interoperable Software) and the IFC 1.5.1 standards.

ArchiPHYSIK

Value proposition The strong-point of ArchiPHYSIK is its use of realistic building components, realistic climate data and pre-created data templates and its two-way linking of the database to the ArchiCAD model.

Therefore the value propositions are:

- The component database helps you select the appropriate "real-life" building components from the early design phase to control energy performance of the building.

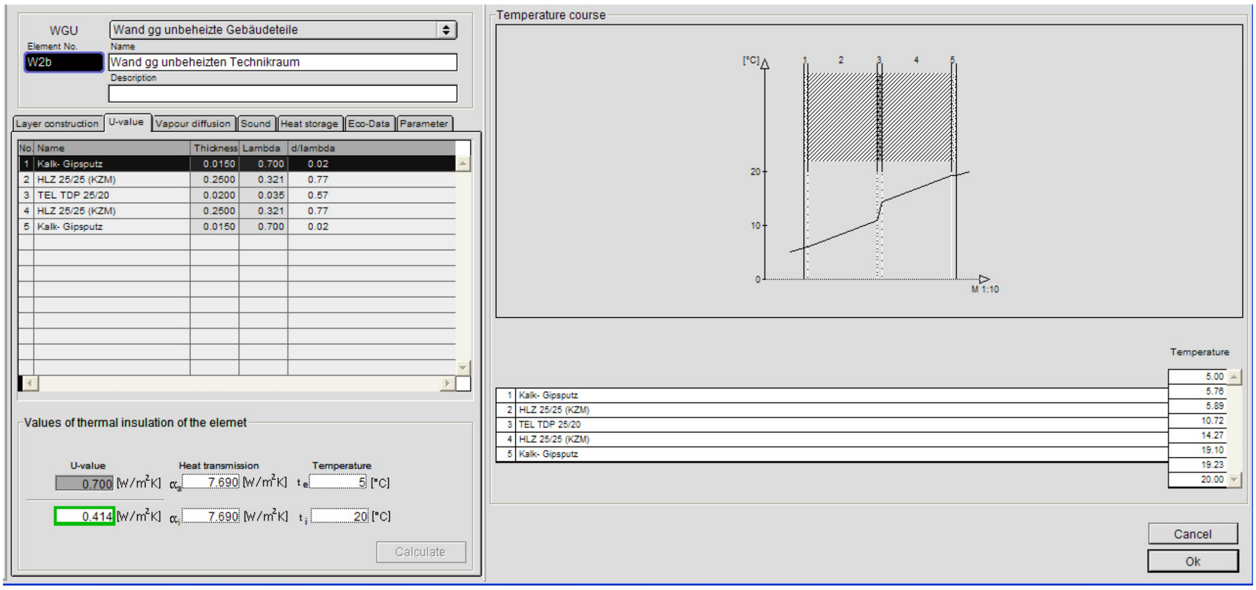
- The bi-directional linking gives feedback on how design changes affect the physical properties of the building. This makes it possible to create rough energy calculation early on, and consider energy performance all along the design process.

- It automates the creation of energy certificates that meet local authority expectations according to EN and ISO standards.

Main features
- Types of calculation:

o Thermal insulation
o Heat storage
o Vapor diffusion
o Acoustic damping
o Heat loss and heating energy calculation
o Ecological impact, CO2 pollution

A graphical interface for calculating heat fall-off and vapor diffusion.
Value and vapor resistance can be calculated and modified for each building element by changing the thickness of layers and changing the material properties.

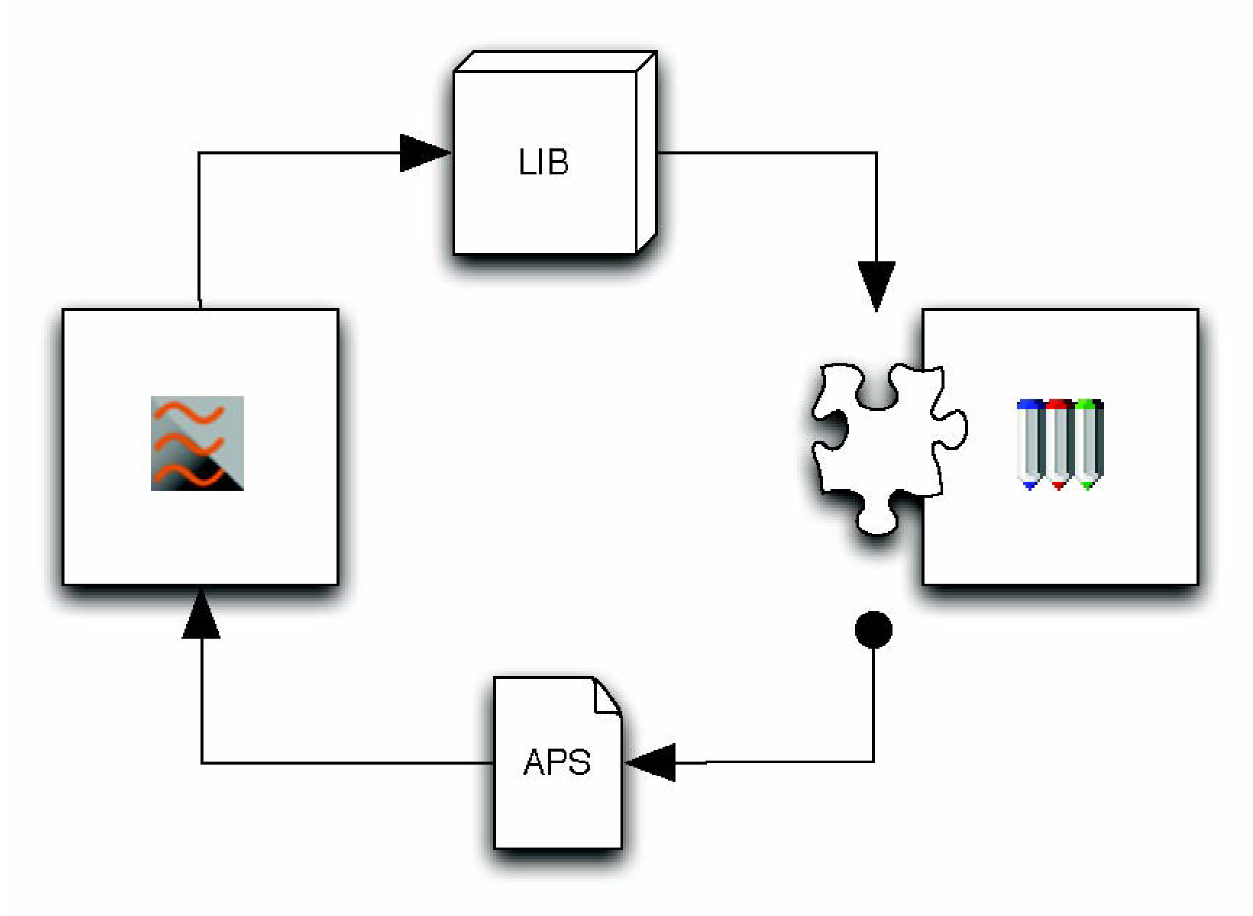


Graphical interface to calculate U-value of a building structure.

• ArchiPHYSIK library contains:

o building materials, elements and composite structures
o their U-values, λ-values, eco-index and validated data for acoustic damping
o thermal bridges
o regional climate data
o regional requirements

• “Energy certificate” creation based on ISO and EN standards.
• Pre-defined forms to easily create printed output.
• Add-on for ArchiCAD to export model into a data file readable for APH.
• Data exported to ArchiCAD that displays main values of the energy calculation.
Live link with APH makes it possible to update these values when design is changed.



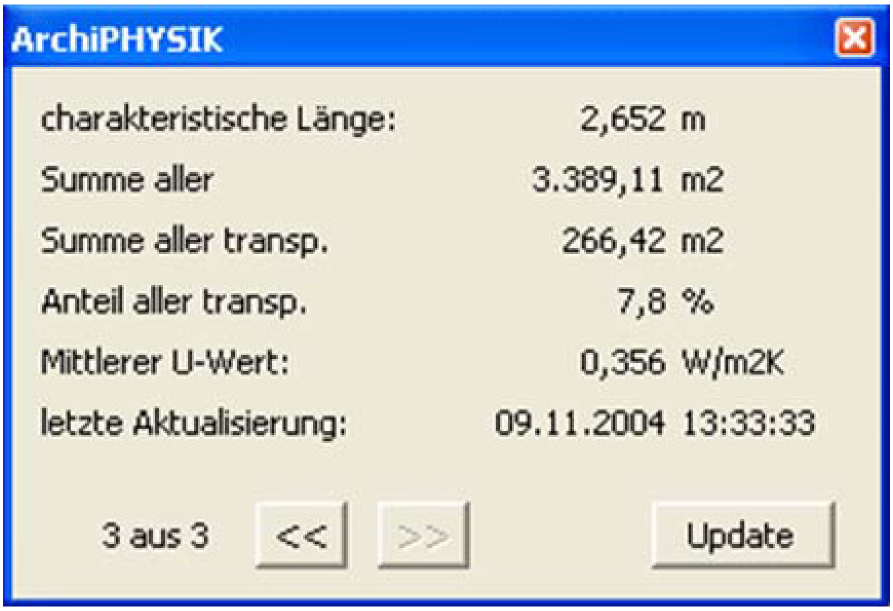
Workflow diagram – connection between ArchiCAD and ArchiPHYSIK.
• Stand-alone or Web-based solution.
• Available for MAC and PC.

Relevant design stages
Using APH at an early design phase will assist in deciding the right materials and building structures to be used.
The two-way linking between APH and ArchiCADensures that the energy consequence of design decisions can be permanently controlled.
APH greatly facilitates the creation of the final papers required by the authorities.

Audience
• Architects who strive to achieve an energy-conscious design process.
  Energy calculation is available from the very beginning, and the final output is also easy to create.
• Authorities who govern the planning process, and create statistics for the region (e.g. CO2 savings to conform the Kyoto-protocol).
• Building material manufacturers and service contractors for energy consultants.

Workflow with ArchiCAD

• With the Add-on provided for ArchiCAD, export the model geometry into an .aps file.
• In ArchiPHYSIK (standalone application) import the .aps file. During the course of import each building element type (different types of walls, slabs, roofs, windows and doors as well as zones) have to be linked to an APH library record (pre-defined “real life” structures).
• Define building location by entering zip code, select the building regulation you need to meet.
• APH automatically publishes the most important data in a text file, which cane displayed and updated in ArchiCAD.



Energy data displayed in ArchiCAD.
• Select the templates you need, and print the energy certification.

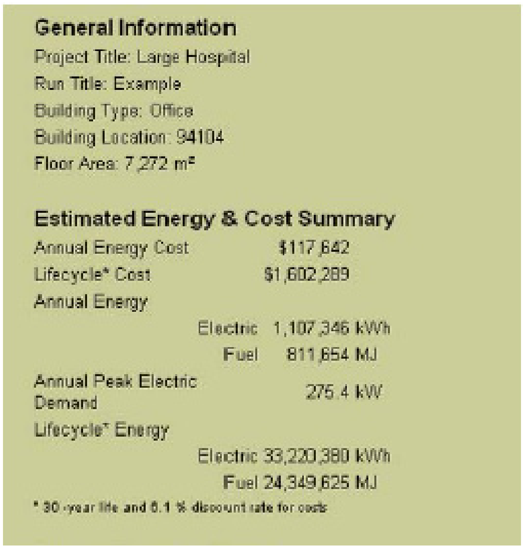
Output
• Energy Data displayed in ArchiCAD that shows the current values of the most important energy parameters.
• APH library elements can be exported as GDL objects to facilitate detail creation in ArchiCAD.
• Printed output based on templates. A well formatted “energy passport” can be created with very little editing work.

Green Building Studio

Value proposition
GBS removes major barriers to energy efficient and sustainable green building design as well as streamlining everyday engineering tasks. It provides whole-building energy analysis using the widely accepted building analysis program, DOE-2.2, at no charge to the design team.

• Drives down the costs of building design and whole-building energy analysis,
• Speeds time to project completion, eliminating time-consuming plan take-offhand analyses,
• Accelerates Green Building LEED compliance
• Improves model accuracy, sharing gbXML files between engineering programs
• Identifies appropriate manufacturers products for the building early in the design cycle.

Main features
• Whole-building energy analysis GBS is accessed from within ArchiCAD and uses the wide range of building design information in the model to create a geometrically correct thermal model of the building, with appropriate zoning and orientation.
This model is developed using regional building standards, and codes for intelligent assumptions for the appropriate space loads, constructions, and typical building systems.
The building is then run through the DOE 2.2 hourly simulation model using typical annual weather data for the building’s location.
Annual energy consumption, costs, and a wide range of data on the building heating and cooling loads, spaces, and systems are summarized and presented within ArchiCAD.

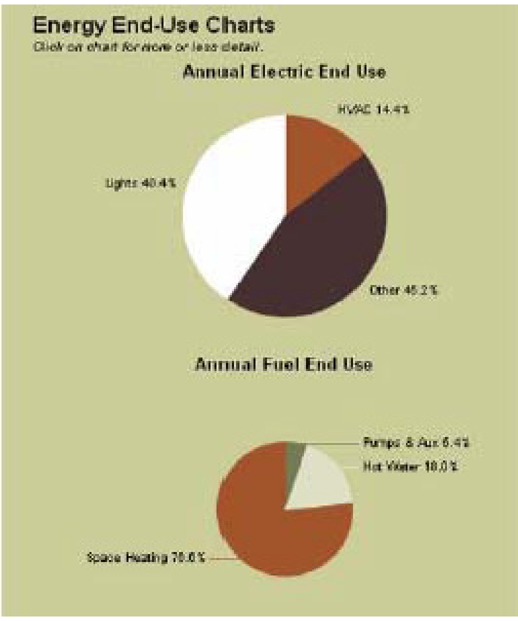


General Information
Project Title: Large Hospital
Run Title: Example
Building Type: Office
Building Location: 94104
Floor Area: 7,272 m²

Estimated Energy & Cost Summary

Annual Energy Cost		$117,642
Lifecycle* Cost		$1,602,289
Annual Energy		
	Electric	1,107,346 kWh
	Fuel	811,654 MJ
Annual Peak Electric Demand		275.4 kW
Lifecycle* Energy		
	Electric	33,220,380 kWh
	Fuel	24,349,625 MJ

* 30 -year life and 6.1 % discount rate for costs



- Project information sharing with design teams and manufacturers
  Every building project is given the ability to "opt in" and share detailed project and building data with other team members and building product manufacturers (BPMs) at the earliest stages of design.
  This means that the architect can share detailed building data directly with their engineers in the format they need for running their analysis programs, and with BPM sale steams and those preparing bids. The information includes detailed data about constructions, geometry, and spaces in the building, and is available at the planning and schematic design stages.
  This data goes well beyond the project summary data currently collected by lead services like Dodge Project Information and can be used to precisely market building products to the right people in the right projects at the right time in the decision cycle, well before plans are finalized and bid packages prepared.

- Design alternative comparisons
  There are two ways to use GBS to compare the estimated energy consumption of alternative building designs.
  Each building design configuration can be submitted to GBS as a separate run within a single project.
  When each run is successfully completed, the results are summarized in a GBS table and can be reviewed.
  This is an excellent way for the architect to quickly and cost effectively share their initial design schemes with their engineer, energy consultant, and LEED consultants prior to their initial Charette.
  Currently detailed result comparisons are not available, but have been designed and are planned for in a future release. However, for buildings in California, GBS have the Savings By Design option, which does make a second model run using high-efficiency design recommendations of the California Utilities, which usually provide about a 30% reduction in energy costs. This can be used to review a relatively standard Title 24 code compliant building and the high efficiency alternative.

Runs	Date	User	Building Type	Floor Area (ft²)	Annual Elec Cost	Annual Fuel Cost	Annual Elec Demand (kw)	Annual Elec Use (kwh)	Annual Fuel Use (MBtu)	EUI (kBtu/ft)
Run 1	Feb 16 05 8:31 AM	Ineda	MultiFamily	1538	$4,064	$599	16.7	51,443	125	114.1
Run 1	Feb 16 05 8:28 AM	Ineda	MultiFamily	1538	$4,760	$700	19.2	60,250	146	133.7
Run 1	Feb 16 05 8:25 AM	Ineda	MultiFamily	1538	$45	$34	0.1	569	7	1.3
Run 1	Feb 16 05 7:26 AM	Ineda	MultiFamily	1538	$4,064	$599	16.7	51,439	125	114.1

- Additional information services

  Using gbXML and GBS, detailed DOE-2 and EnergyPlus, model input files are created in minutes and at no charge to the design team (EnergyPlus requires a scaled fee).

  These highly detailed model files typically take 1-2 weeks to develop using plan take-off services or engineers.

  This service can take $5,000 to $10,000 or more out of the cost of preliminary and downstream building design, and can also significantly reduce the cost of sales for BPMs that run engineering models or sales sizing tools.

- Product Advisor

  In the near future, each building project run through the GBS will place relevant product information in front of the design team as early as during the planning and schematic design stages.

  Using a Google-like bidding and paid placement approach, and a building relevance filter, highly targeted advertisements are placed in front of the building designer in the GBS Product Advisor.

  These advertisements are linked to the Building Product libraries online, providing a high ROI advertising placement for BPMs and appropriate information for the design team.

Relevant design stages
GBS is intended to be used at the earliest design stages to evaluate multiple design proposals for building energy performance.

Audience
Practicing architects, designers, engineers, construction managers, etc.
Also power user energy simulation consultants and researchers can use the Web service to eliminate manual plan take-offs and to build geometrically accurate models.

EnergyPlus

Value proposition
A building's heating, cooling, ventilation, lighting, and equipment systems all interact with each other, the building envelope and the building site in a multitude of complex ways.
Integrating all of the variables into an energy-efficient design can be daunting task without the assistance of design tools, such as EnergyPlus.

It allows users to calculate the impacts of different heating, cooling, and ventilation equipment, and with various types of lighting and windows to maximize building energy efficiency and occupant comfort.

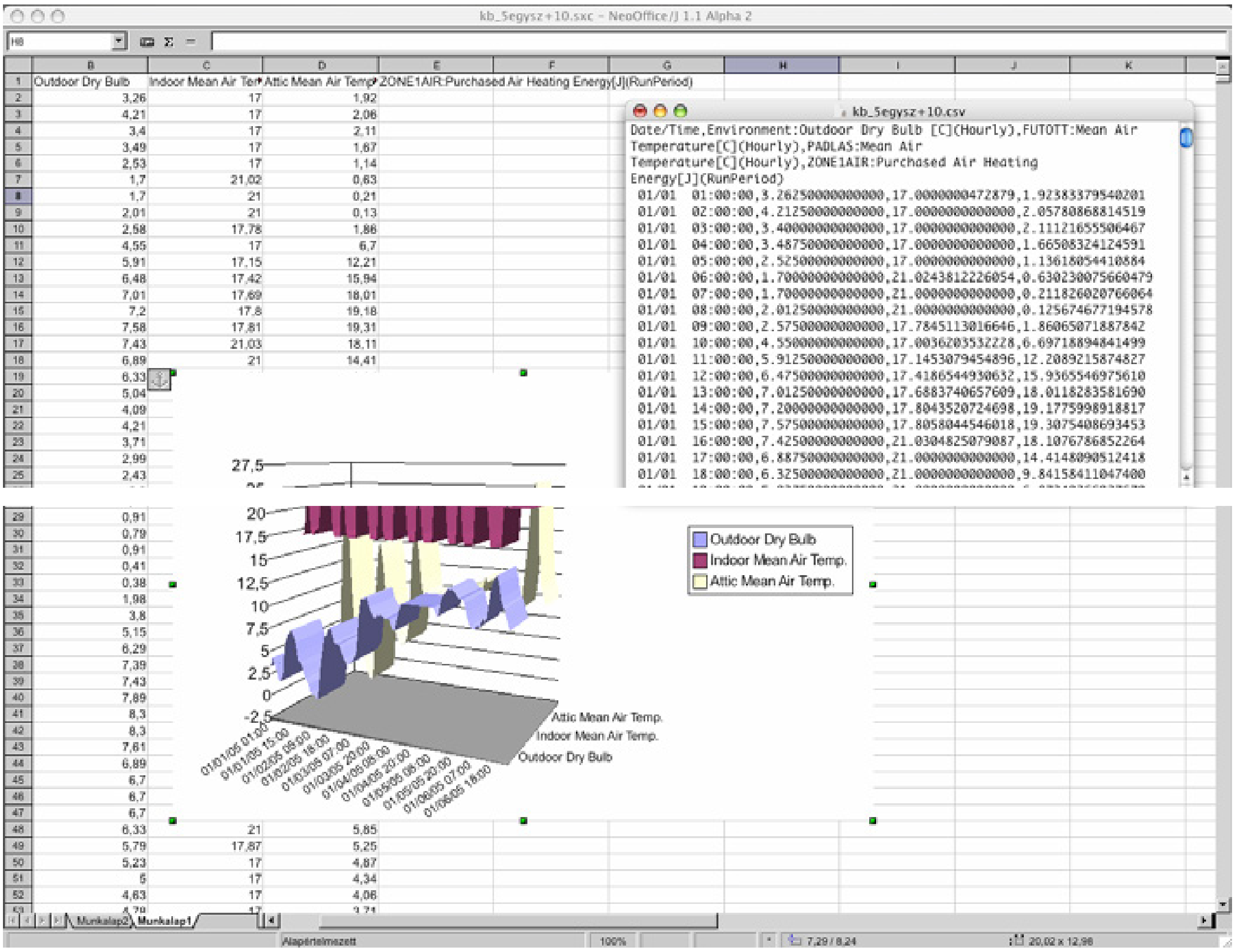
Due to its modular design and simple input/output formats the engine can be coupled easily with third party applications, therefore it can be adapted to the requirements of different domains.
Various tools and interfaces are available for creating, editing, and displaying input files, running multiple parametric simulations, facilitating building geometry input from other applications.

Graphisoft's Virtual Building technology and IFC interoperability compliance makesArchiCAD a useful tool for accurate geometry data input of rather complex building envelopes.
By using ArchiCAD the object-oriented data will be preserved during the whole data conversion process.

Features
EnergyPlus includes many innovative simulation capabilities: time steps of less than one hour, modular systems and plant integrated with heat balance-based zone simulation, multi-zone air-flow, thermal comfort, extensive day lighting and advanced fenestration capabilities, and photovoltaic simulation. EnergyPlus also calculates indirect environmental effects such as atmospheric pollutants, associated with building's energy use.

Strengths
EnergyPlus is state-of-art software under constant development.
It was first released in April, 2001, and at the time of writing the current release is 1.2.1, which is the ninth formal release in four years.

- Users have significant control over almost every detail during the simulation process: the data input can be made using various methods, the output can be flexibly configured and the results can be processed using any spreadsheet application.



Raw output in CSV format and editing data with a spreadsheet application.

Relevant design stages

EnergyPlus is intended for highly accurate analysis. It is a perfect tool for late design stages: for construction plans, HVAC system planning, and performance analysis.

Instead of a detailed model, the actual building can be stripped down to a simplified building envelope and thermal model, thus EnergyPlus can be used efficiently for earlier design stages as well. Below are some possible uses:

Energy conservation studies

- Effect of the thickness, order, type of materials, and orientation of exterior walls and roofs;
- Effect of thermal storage in walls and floors, and in energy storage tanks coupled to HVAC systems;
- Effect of occupant, lighting, and equipment schedules;
- Effect of intermittent operation, such as the shutdown of HVAC systems during the night, on weekends, holidays, or for any hour;
- Effect of reduction in minimum outside air requirements and the scheduled use of outside air for cooling;
- Effect of internal and external shading, tinted and reflective glass, and use of day lighting.

Building design studies
Initial design selection of the basic elements of the building, primary and secondary HVAC systems, and energy source;

- During the design stage, evaluating specific design concepts such as system zoning, control strategies, and systems selection;
- During construction, evaluating contractor proposals for deviations from construction plans and specifications;
- A base of comparison for monitoring the operation and maintenance of the finished building and systems;
- Analysis of existing buildings for cost-effective retrofits.

Audience
The intended audience is a design engineer or architect that wishes to size appropriate HVAC equipment, develop retrofit studies for life-cycle cost analysis, optimize energy performance, etc.

ECOTECT

Value proposition
ECOTECT is a complete building design and analysis tool that covers the broad range of analysis functions that are required to truly understand how a building design will perform.
Wherever possible, simulations are visual and interactive allowing designer to "play" and learn about building performance as they use the software.

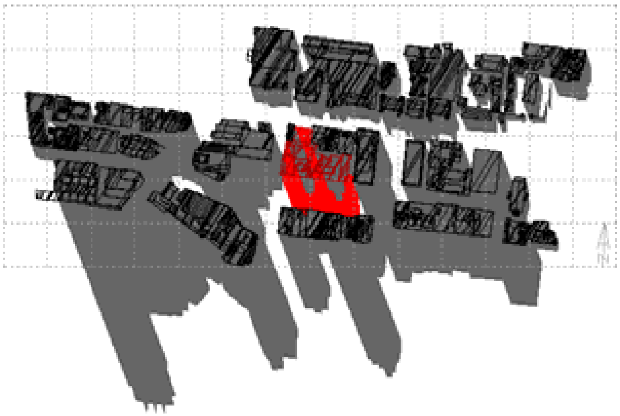
Main features

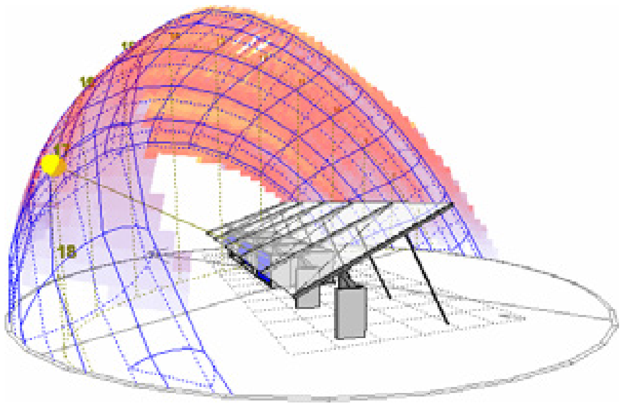
- Modeling & visualization - includes its own interactive 3D modeling interface for creating, importing (and exporting), checking and adjusting building geometry.
  Not limited by complexity or form, the interface also incorporates many useful features for viewing and analyzing a design.

Image below shows an OpenGL view of a model displaying shadows and sun penetration inside the building with the use of the automatic section cut feature (red "cut" lines).

• Shadows, shading & solar analysis –solar analysis is an important aspect of building design. Excessive solar exposure is a major cause of thermal and visual discomfort in buildings, even in relatively cold climates.
However, the sun is also the most effective source of natural energy (and the cheapest) which you have at your disposal.

Being able to design with the sun with certainty inessential for any energy efficient building. There are a vast array of solar analysis and shading features in ECOTECT which will help you with every aspect of this process.

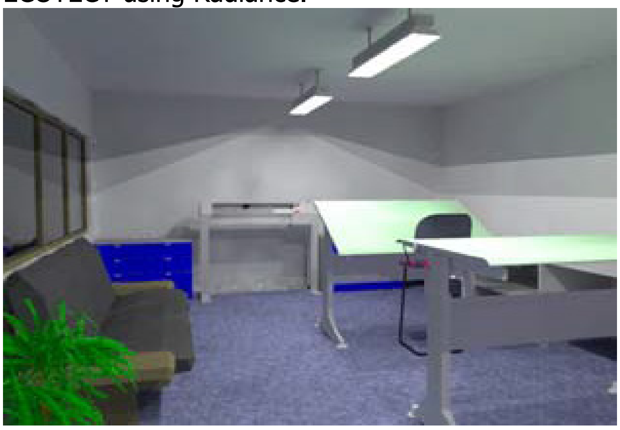




Images above; interactive shadows with numerous display functions – highlighting shadows from particular geometry is one example, shown top. Below, 3D sun-path with solar intensity overlaid – allows for immediate understanding of when and from where solar exposure will be a problem or beneficial.

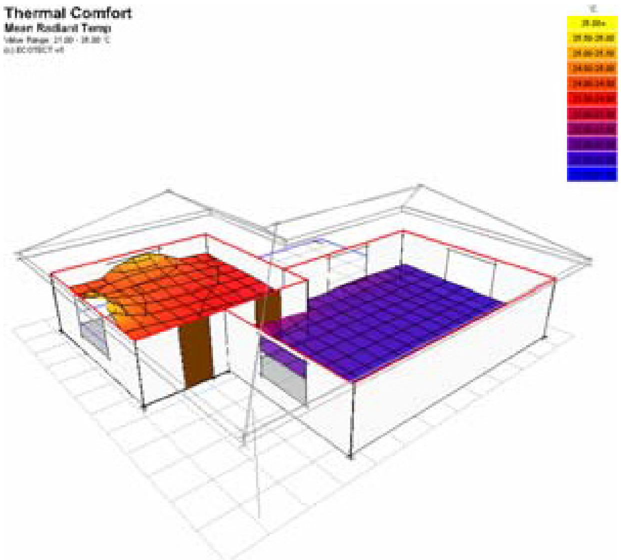
• Lighting design - ECOTECT uses the BRE-daylight Factor method for day lighting calculation and the Point-to-Point method for electric lighting.
For more detailed analysis and photo realistic rendering, it uses the Radiance Lighting Simulation™ engine from Lawrence Berkeley Laboratories.

Image below ; electric lighting simulation rendered from ECOTECT using Radiance.



• Thermal performance - ECOTECT uses the CIBSE Admittance Method to calculate heating and cooling loads for models with any number of zones or type of geometry.
You can assign detailed material properties to all objects as well as operational schedules to occupancy, gains ,infiltration and equipment. For design validation it is also possible to use the Energy Plus or HTB2 engines, as well as export to several others.

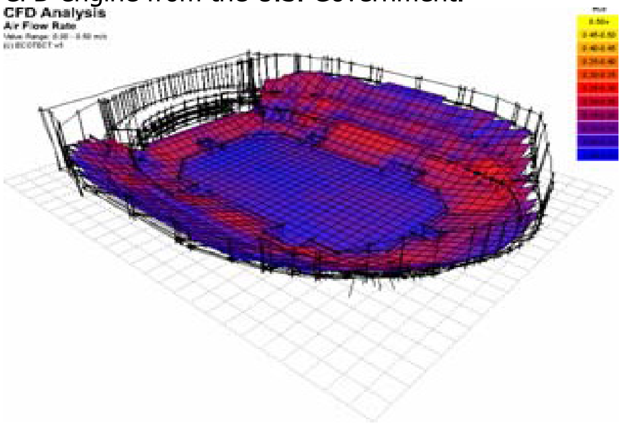
Image below; example comfort analysis showing variation
in mean radiant temperatures inside a small 2-zone building.



• Building regulations - As part of ongoing research into automated compliance testing for building regulations, the Right-to-Light codes and Part-L from the U.K. are the first set to have been fully implemented in ECOTECT - this includes easy to-follow wizards to guide users step-by-step through the process. Work is currently underway to add support for LEED, the Australian BCA, the Italian building regulations and others.

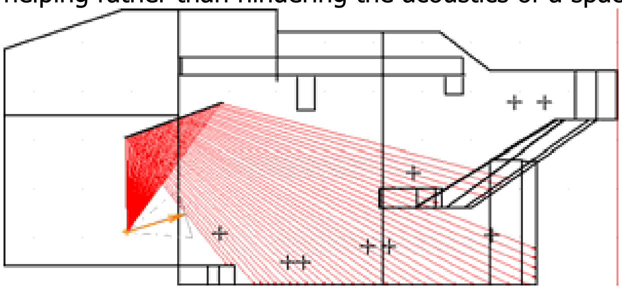
• Ventilation - The thermal analysis routines in ECOTECT do not require detailed air-flow and ventilation information.
However to support ventilation analysis, ECOTECT can be used as a preened post processor for external computational fluid dynamics tools that fully consider air-flows.

Image below; CFD results from WinAir4. v5.50 of ECOTECT will also include support for NIST FDS a free fire and ventilation CFD engine from the U.S. Government.

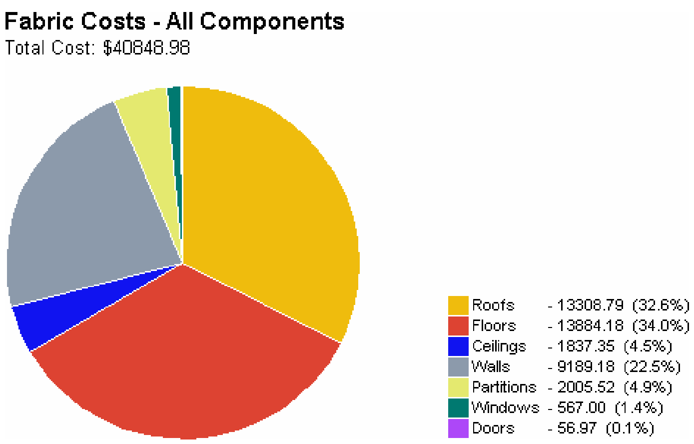


• Acoustic analysis - there are a number of acoustic analysis options in ECOTECT - these range from simple statistical reverberation times through to sophisticated particle analysis and ray tracing.

Image below; side view showing acoustic rays linked to are flex or – excellent for ensuring that internal geometry is helping rather than hindering the acoustics of a space.

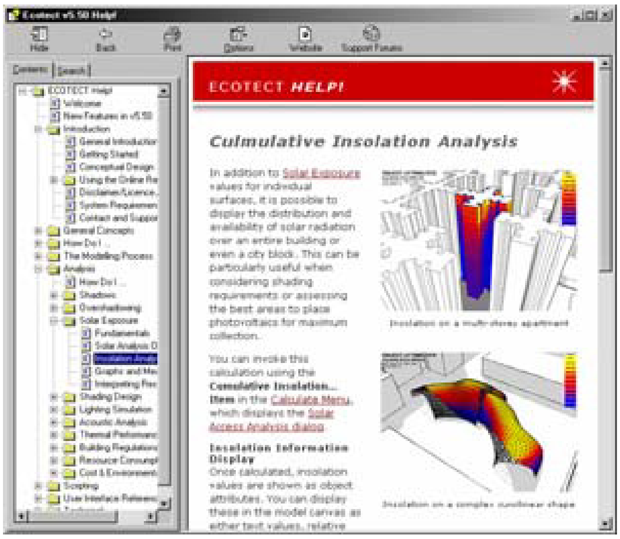


• Resource use and costing - From the 3Dmodel of a building, you essentially have a live spread sheet from which you can extract area, volumes, distances for materials quantities and cost calculations.
It is also possible to calculate energy and resource use (depending on equipment, occupancy and usage schedules) as well as power generation via solar collectors (photo voltaic).



• Interactive help and documentation –To make learning and using the ECOTECT easier and faster, the release of v5.50 provides interactive help scripts to lead you through the process of finding the right page, panel, dialog or item to accomplish the specified task right within the actual ECOTECT interface.

This same process can also be used for complex demonstrations, and anyone can use the same scripting language to create their own custom help, analysis processes or real-time demonstrations.



Strengths
A complete building analysis tool which is highly visual and interactive. ECOTECT allows the user to "play" with design ideas at the conceptual stages, providing essential analysis feedback from even the simplest sketch model.
It also continues to guide the user as more detailed design information becomes available through the complete range of analysis.

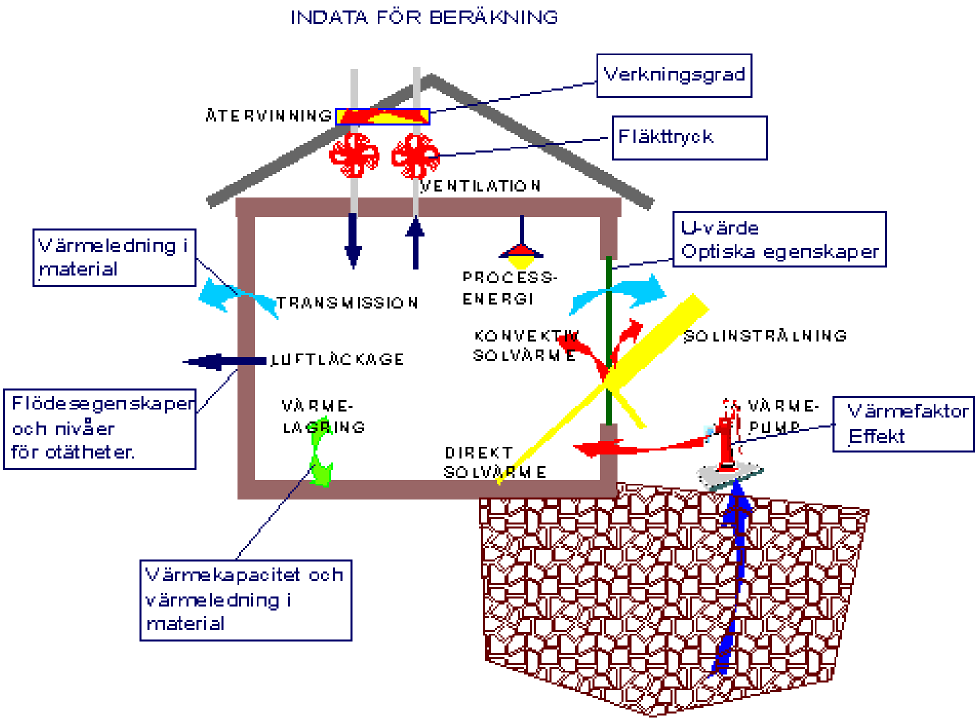
Relevant design stages
Intended for use at early design stage so as to provide the most useful and cost effective environmental feedback to the designer.
However, an ECOTECT model can continually be developed from sketch design to final validation and provide analytical feedback throughout.

Audience
ECOTECT is designed and written by architects and intended mainly for use by architects - although the software is used extensively by engineers, local authorities, environmental consultants, building designers, as well as owner-builders and environmental enthusiasts alike.

ArchiVIP
ArchiVIP enables architects to quickly calculate the energy implications of early design decisions. Through a very simple user interface an architect can make detailed and complex energy calculations with an extremely small amount of input data.

ArchiVIP uses a VIP+ simulation kernel and a middle layer that transforms very simple in-data into a complex physical model. ArchiVIP dramatically reduces the time and expense traditionally associated with whole-building energy simulation analyses.

The result from ArchiVIP™ can be further analysed and refined directly into VIP+,which is a fully functional energy simulation software.



Value proposition
• Drives down the costs of building design and comprehensive building energy analysis.
• Speeds project completion times, eliminating time-consuming plan take-offs and analysis.
• Improves model accuracy, sharing files between ArchiCAD and ArchiVIP.
• Identifies appropriate systems for the building early in the design cycle.

Main features
Super-fast and simple entire building energy analysis.
ArchiVIP is accessed from within ArchiCAD and used the wide range of building design information in the model to create a geometrically correct thermal model of the building,
with appropriate zoning and orientation.
The building is then run through the VIP+ hourly simulation model using typical year weather data for the building's location.

Annual energy consumption, costs, and a wide range of data on the building heating and cooling loads, spaces, and systems is summarized and presented on the Web.

Relevant design stages
ArchiVIP is intended to be used at all design stages to evaluate multiple design proposals for building energy performance.

Audience
ArchiVIP is intended to be used by practicing architects alone and in collaboration with designers, engineers, construction managers, power-user energy simulation consultants and researchers using VIP+.

4. Study case

To show how Energy Audit and energy management works in BIM environment, I wanted to take an existing building and design it in BIM software to show the impact, changes and results in Green Energy Audit using the BIM software and it's advantage.

However I have decided that it will be better to design and draw a building from nothing because of doing so I can apply different building effects and systems. Which will give my building a variety of data that one actual building can't do.
Using a construction style from the 60's - 70's in Milan and a real building in via Elba, and that inspired the idea of the model created.

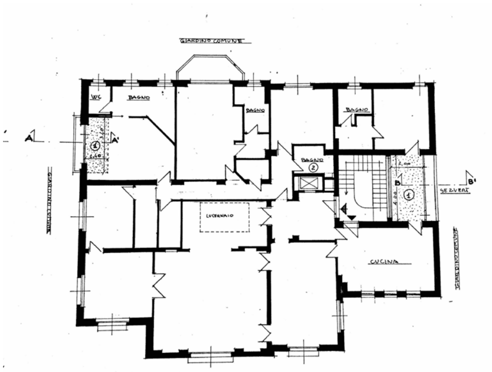
Therefore the building itself is located in via Elba 11, Milan, Italy.
So I can use the energy audit in a standard workflow on my model, which at the end will give me the results and data, as it was an existing building, located in the city of Milan.
The building is a simple brick shell structure with 6 pillars from armed cement, the component such as windows and doors are from wood.

The building is four story tall, the uses is a residential house with two entrances, the main oriented to the South and the second to the North.
On the ground floor we have 5 garages, entrance with staircase ,rooms (mechanical, storage, garbage) and also garages.

First, second and third floors are residential with 3 types of apartments from one bedroom to three bedrooms.
Instead in the roof I have divided it into two different types: one is a flat accessible roof and the other one is a gabled classic roof, under the gabled roof there are two rooms: one is mechanical room and the second is a storage room.

After reading and searching about BIM I have decided to use Archicad software to design and project my model in 3D so I can apply this methods to get as much information as I can to see what needs to be modify and change into the building to bring it to the next level of energy.

Below there are pictures and floor plan of the existing Building in Via Elba 11 , MIlan , Italy



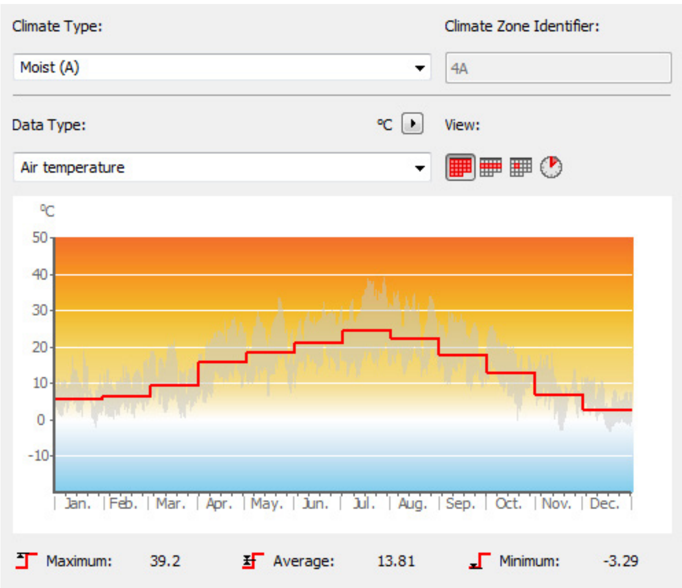
Below there are renders of the building created in archicad

These are the main phases in Archicad software:

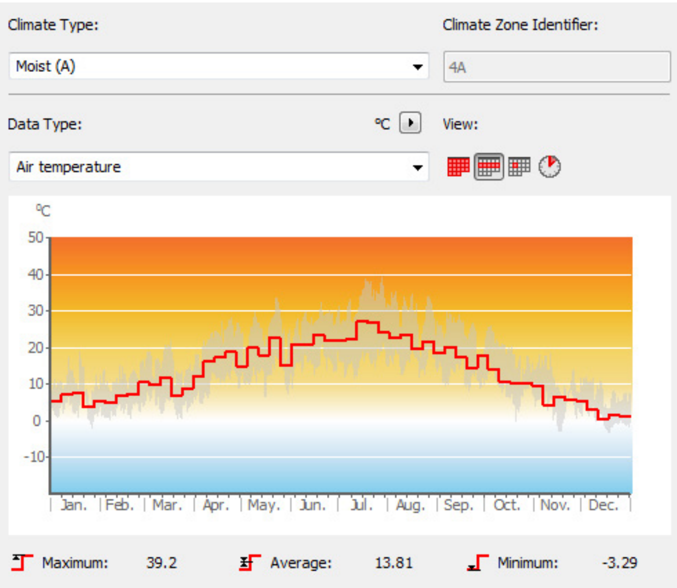
4.1 Climate analysis

By using the Archicad software I can located my building wherever i want in the world and get a climate analysis of the building and it's enviroment, in my case i located my 3D building in Milan, Italy. In the images below we can see the results as it was a real building located there.

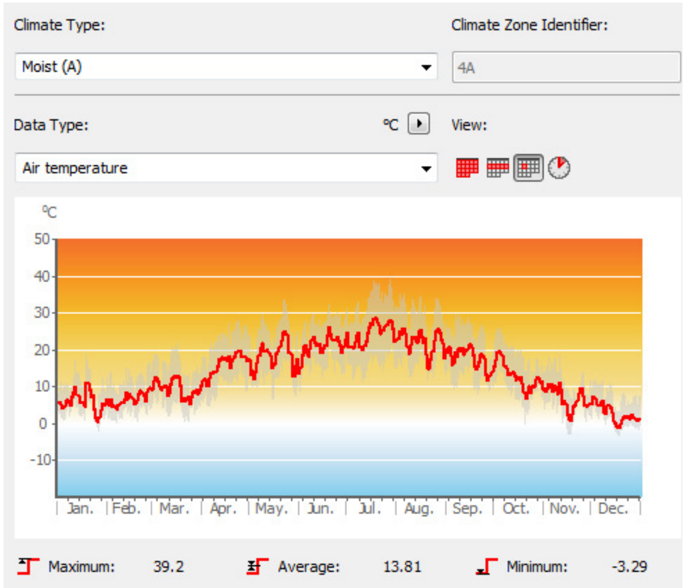
1. Air Temperature



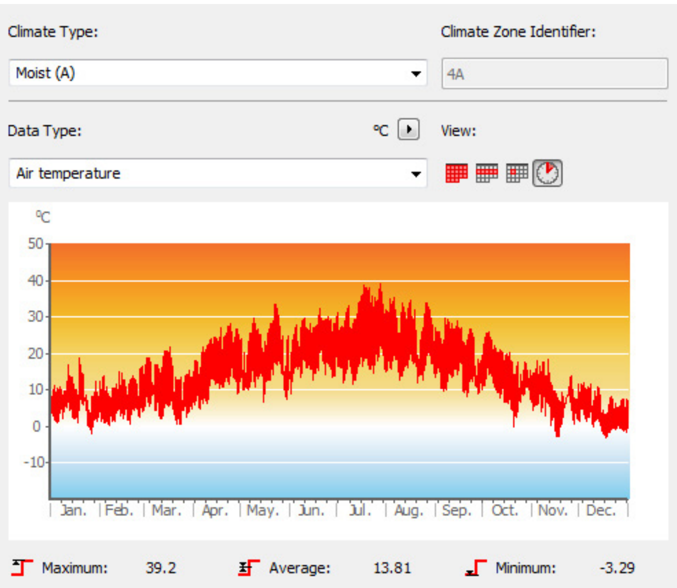
Month



Week

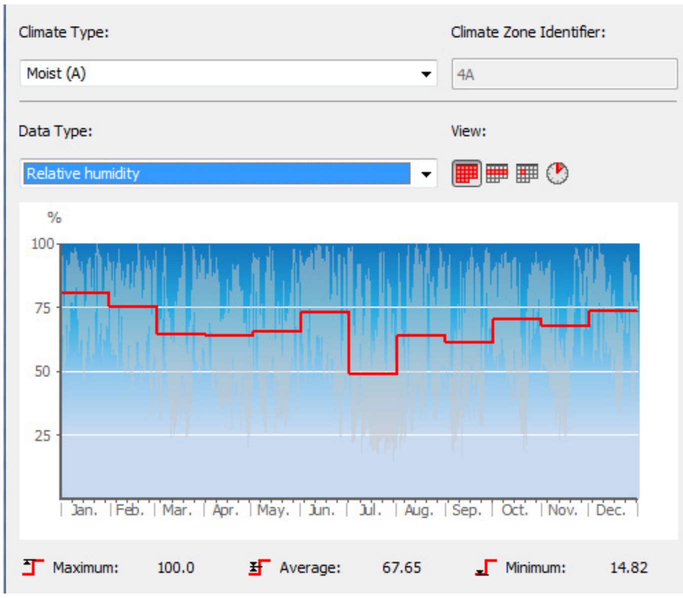


Day

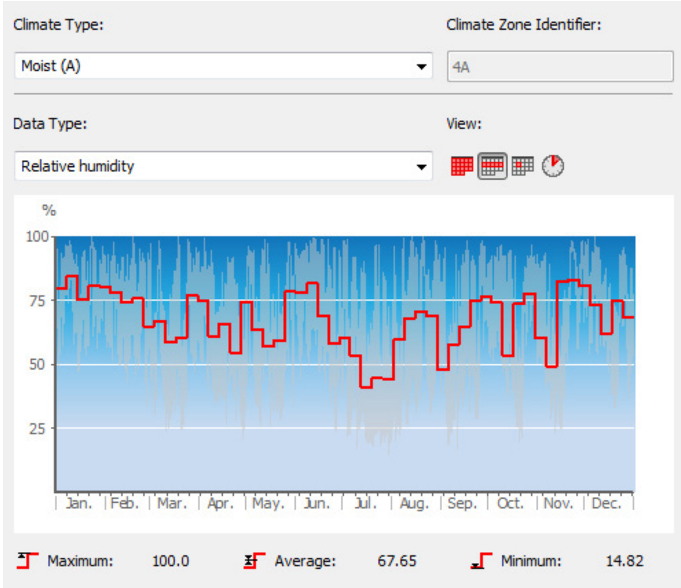


Hour

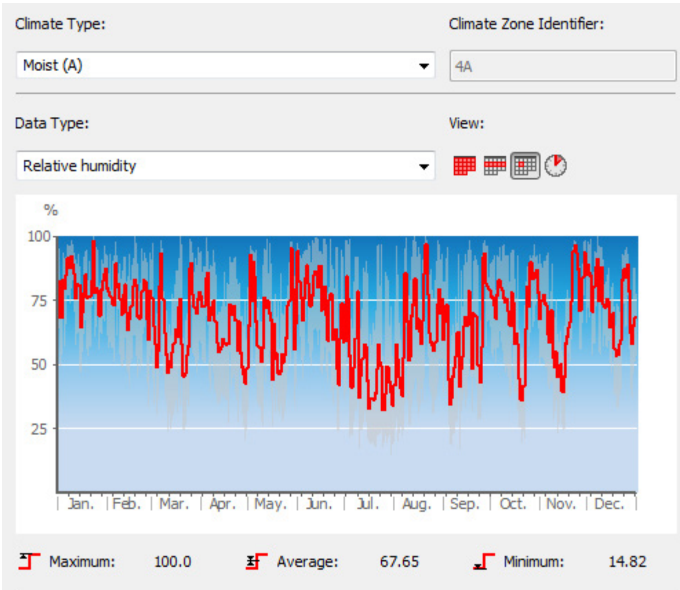
2. Relative Humidity



Month



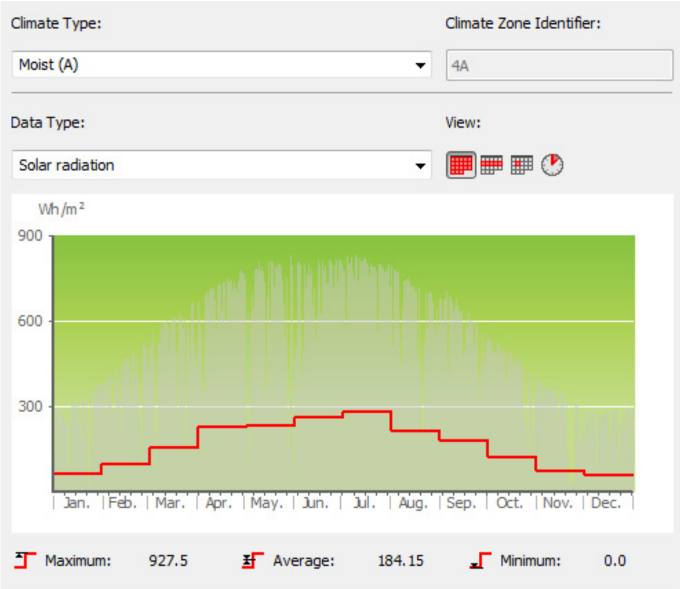
Week



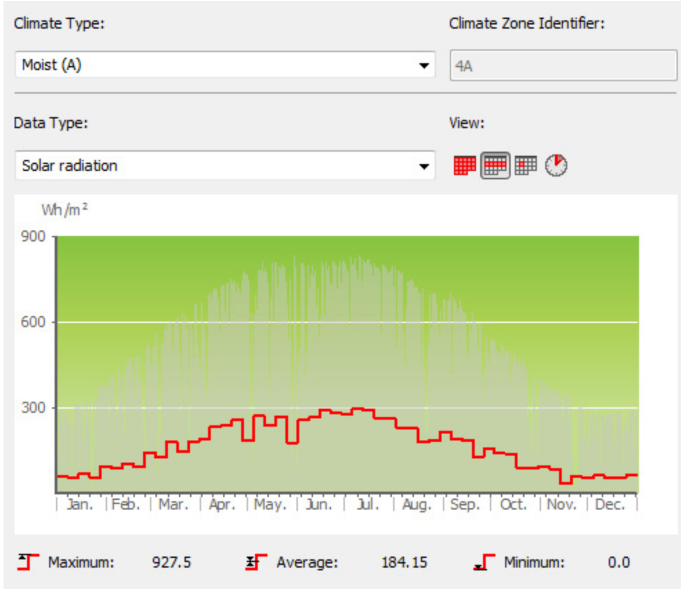
Day

Hour

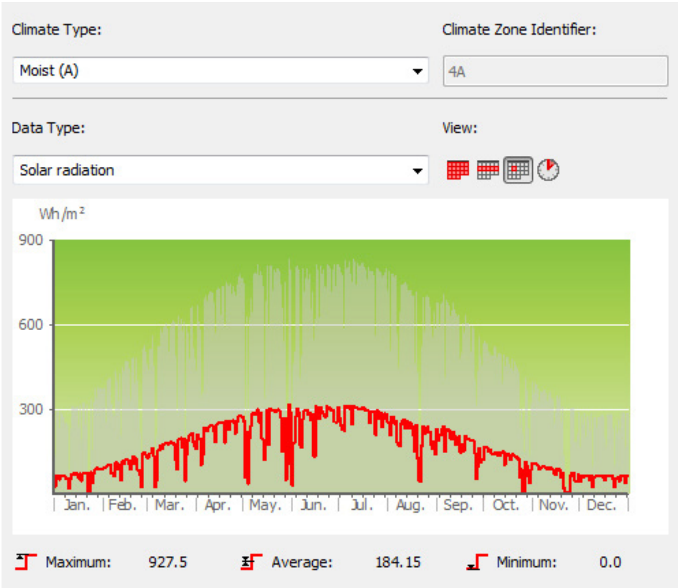
3. Solar Radiation



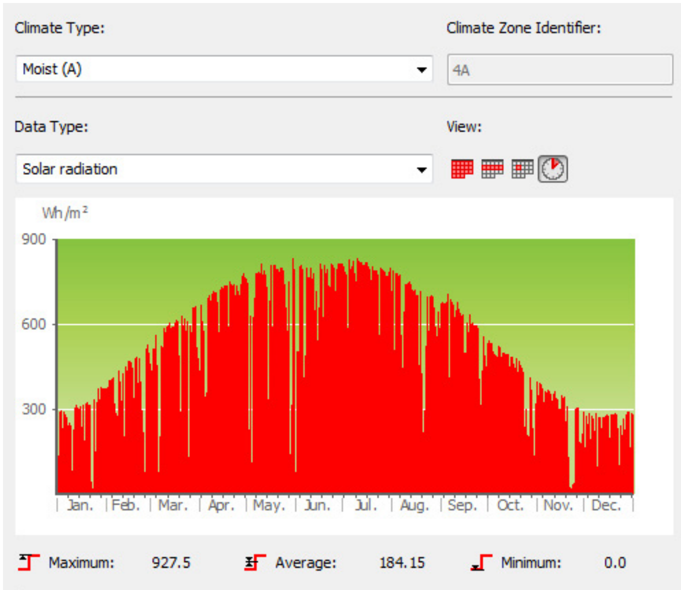
Month



Week

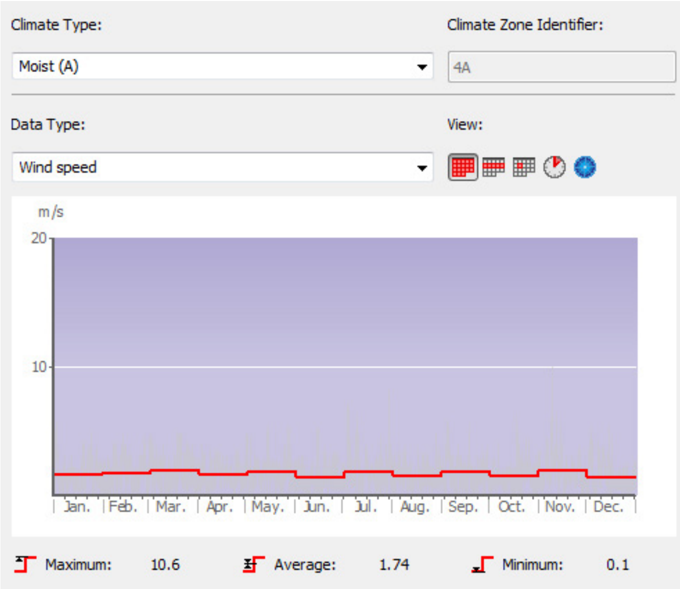


Day

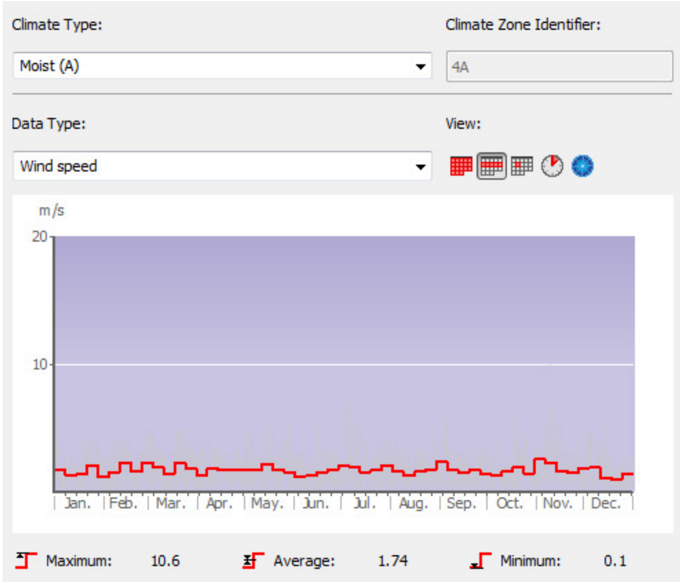


Hour

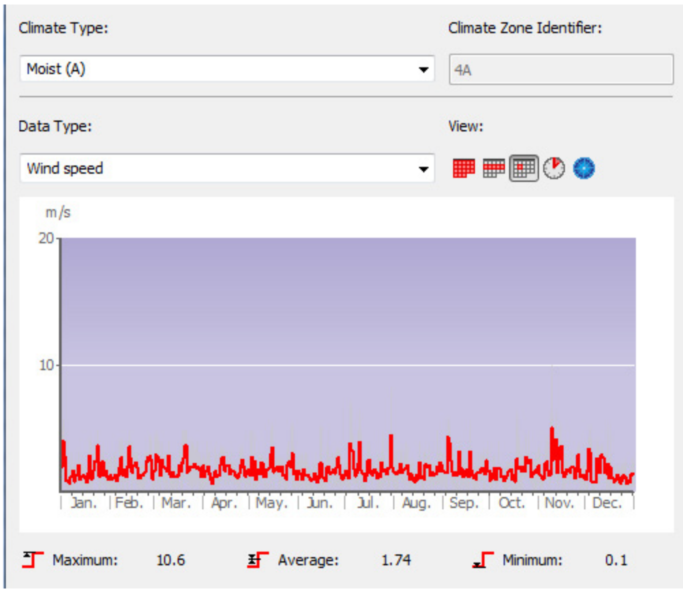
4. Wind Speed



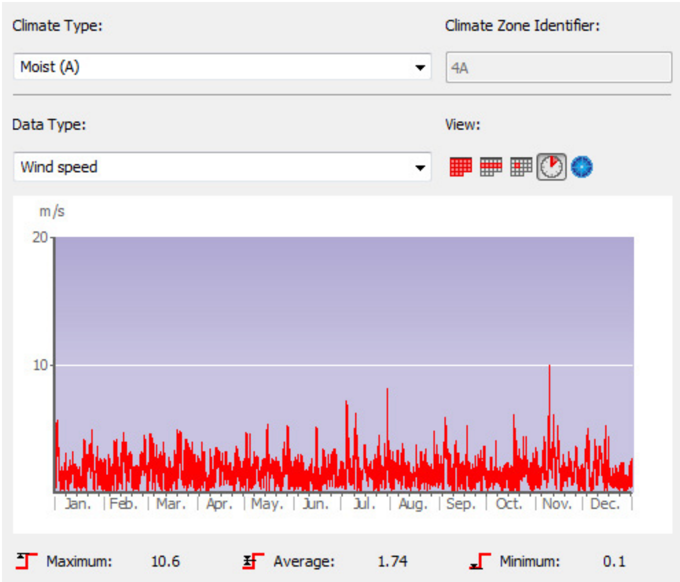
Month



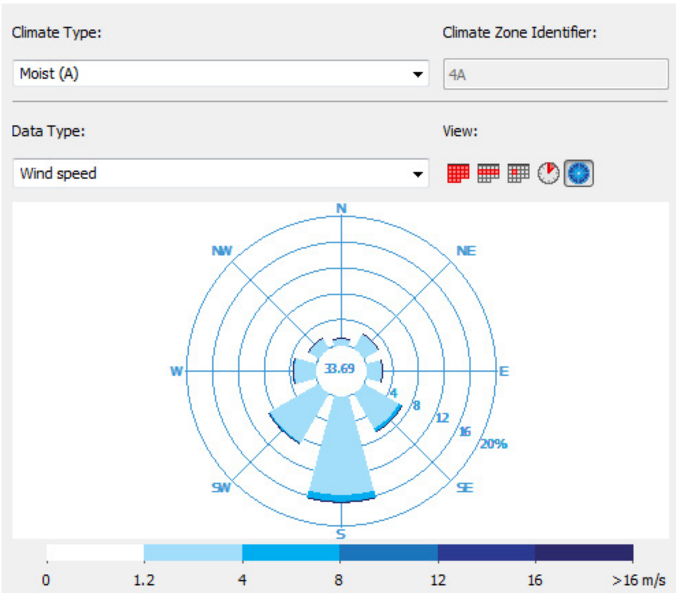
Week



Day



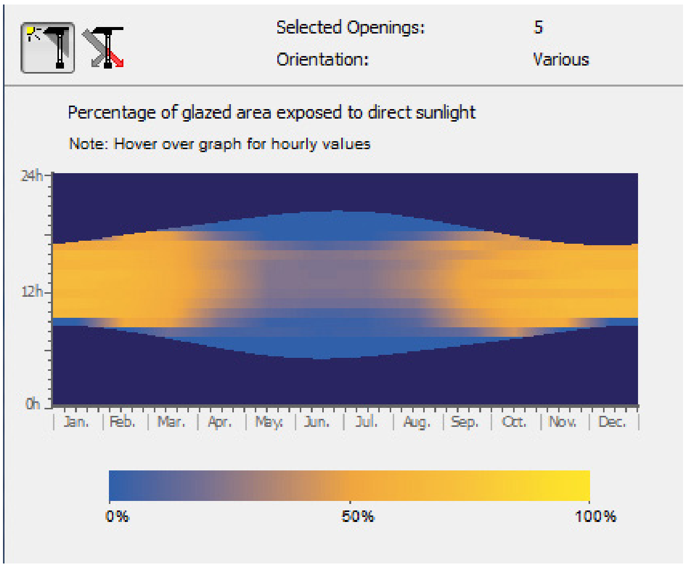
Hour



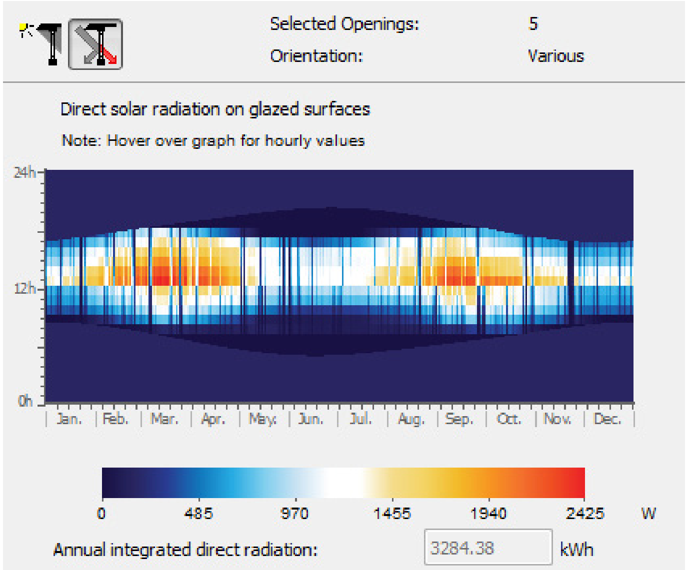
Rose

4.2 Solar Analysis

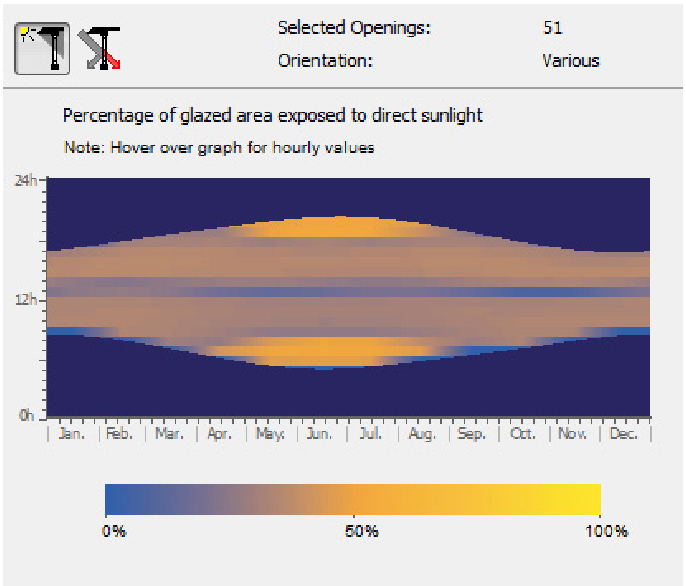
After uploading all the opening of the building the program can calculate the solar radiation we can see the effect of a direct and non direct solar radiation in the building.



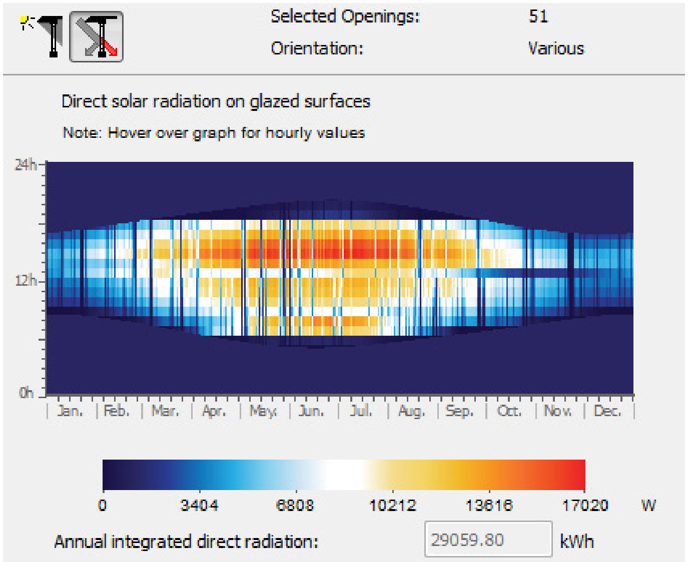
Direct radiation (doors)



Non Direct radiation (doors)



Direct radiation (windows)



Non Direct radiation (windows)

In this analysis we see the effect during the whole year in months on the horizontal axe and the hours of the day in the vertical axe.

4.3 Whole building energy efficiency design Workflow optimization

- Create baseline building reference file
- Add building systems to the baseline building
- Apply project specific low energy building systems and renewable energy systems solution set to designed building
- Run energy simulation

I began developing my project after creating the building in Archicad I had to start putting all the building systems and materials in their places so I can start working on the energy report and to be able to run the simulation.
By creating the material and composite of the walls, floors, roof , doors and windows I was able to have an idea of how the building wall be effect in the energy simulation. and using that to start thinking which and how will I need to change in the building components will affect the energy of the building, thinking not only about the building structure but also about the tools that effect it's energy : Heating, Cooling and Ventilation.

there are many parameters to do the calculations necessary but the great thing about the program that ones you put all of them in a meter of seconds you can have an idea about your building energy consume and costs.

The first report below is of the exciting building and right after of the same building but after modifications made in the energy systems for example : envelope, building systems costs etc...

4.3.1 Archicad Energy Report exciting building

Energy Performance Evaluation

01 Elba 11

Key Values

General Project Data

Project Name:	Elba 11	
City Location:	Milan	
Latitude:	45° 28' 0" N	
Longitude:	9° 11' 0" E	
Altitude:	120.00	m
Climate Data Source:	Strusoft server	
Evaluation Date:	4/14/2016 12:36:39 PM	

Building Geometry Data

Gross Floor Area:	**1218.00**	m²
Treated Floor Area:	**1070.86**	m²
External Envelope Area:	**882.04**	m²
Ventilated Volume:	**2881.23**	m³
Glazing Ratio:	**10**	%

Building Shell Performance Data

Infiltration at 50Pa:	**2.53**	ACH

Heat Transfer Coefficients	U value	[W/m²K]
Building Shell Average:	**1.97**	
Floors:	**--**	
External:	**1.25 - 3.00**	
Underground:	**--**	
Openings:	**2.50 - 5.99**	

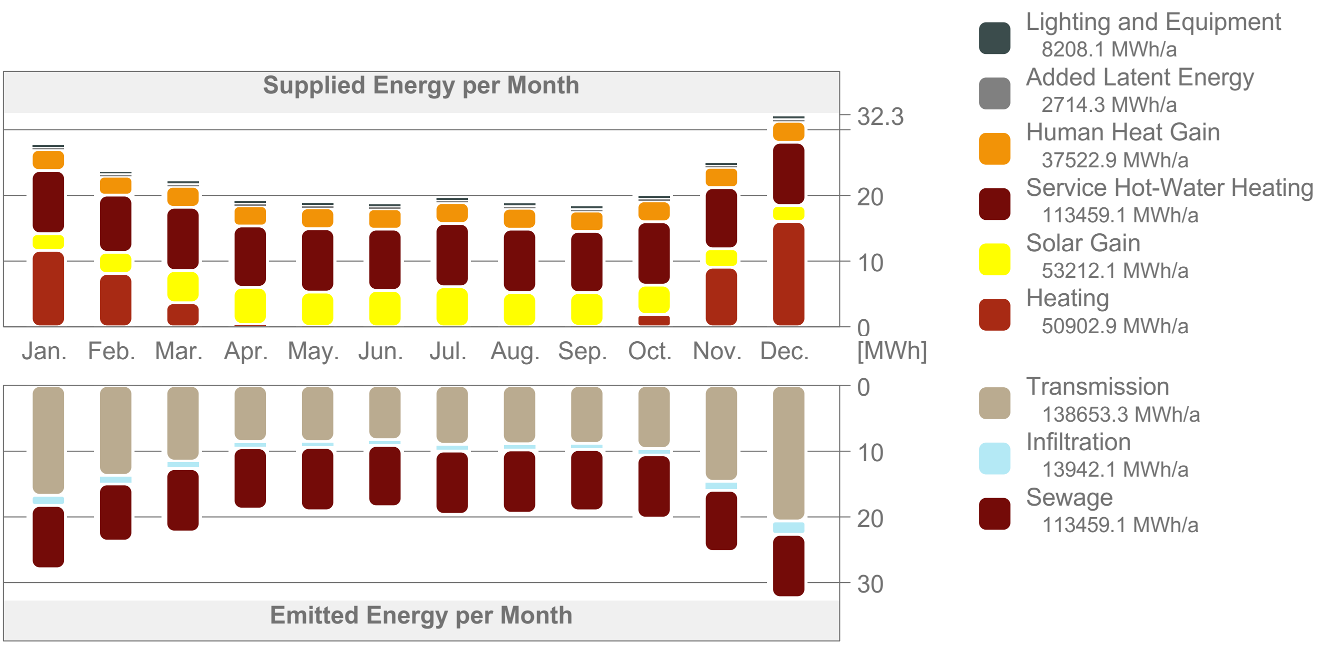
Specific Annual Values

Net Heating Energy:	**47.53**	kWh/m²a
Net Cooling Energy:	**0.00**	kWh/m²a
Total Net Energy:	**47.53**	kWh/m²a
Energy Consumption:	**161.15**	kWh/m²a
Fuel Consumption:	**161.15**	kWh/m²a
Primary Energy:	**191.83**	kWh/m²a
Fuel Cost:	**14.95**	EUR/m²a
CO_2 Emission:	**34.81**	kg/m²a

Degree Days

Heating (HDD):	**2525.27**
Cooling (CDD):	**2125.05**

Project Energy Balance



Thermal Blocks

Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 Sample Thermal Block	66	Residential	1218.00	2881.23
Total:	**66**		**1218.00**	**2881.23**

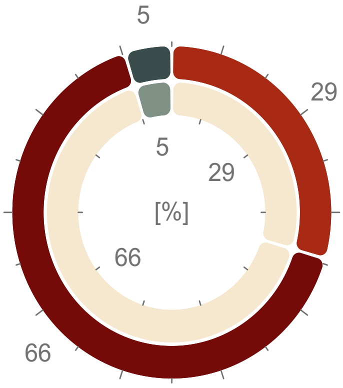
Energy Performance Evaluation

01 Elba 11

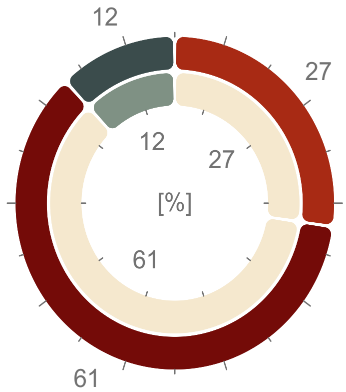
Energy Consumption by Targets

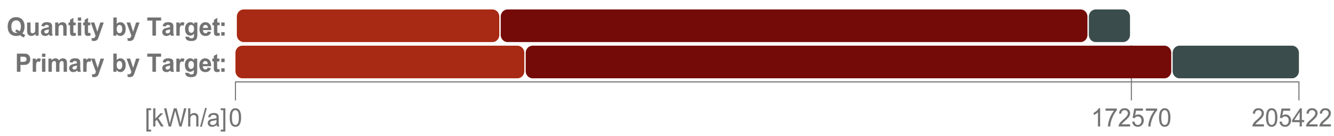
Target Name	Energy			CO_2
	Quantity	Primary	Cost	Emission
	kWh/a	kWh/a	EUR/a	kg/a
Heating	50902	55993	4450	10995
Cooling	0	0	0	0
Service Hot-Water	113459	124805	9920	24507
Ventilation Fans	0	0	0	0
Lighting & Appliances	8208	24624	1641	1772
Total:	**172570**	**205422**	**16012**	**37275**

Energy Quantity

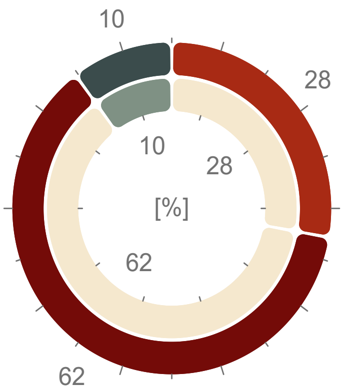


Primary Energy

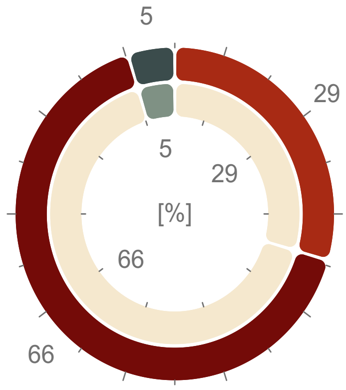




Energy Cost



CO_2 Emission



Energy Sources

Fossil

Natural Gas

Secondary

Electricity

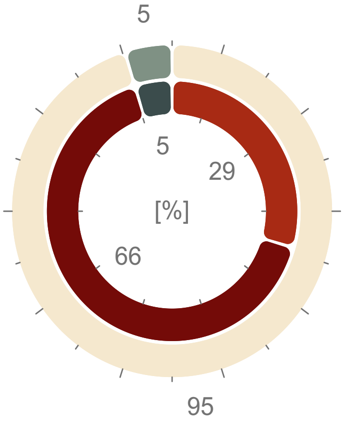
Energy Performance Evaluation

01 Elba 11

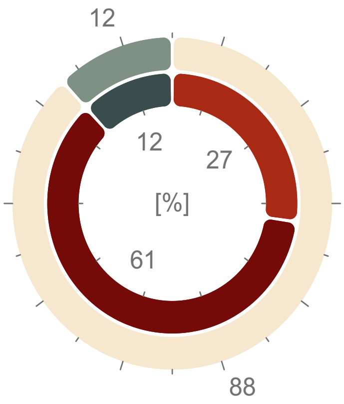
Energy Consumption by Sources

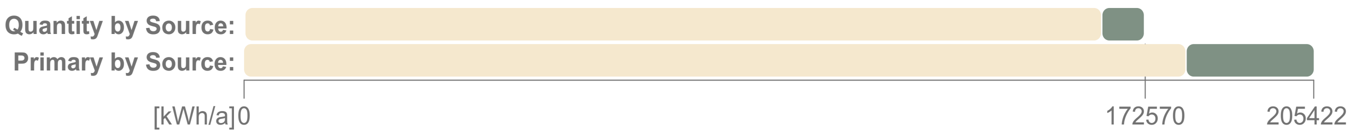
Source Type	Source Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost EUR/a	CO_2 Emission kg/a
Fossil	Natural Gas	164361	180798	14371	35502
Secondary	Electricity	8208	24624	1641	1772
	Total:	**172570**	**205422**	**16012**	**37275**

Energy Quantity

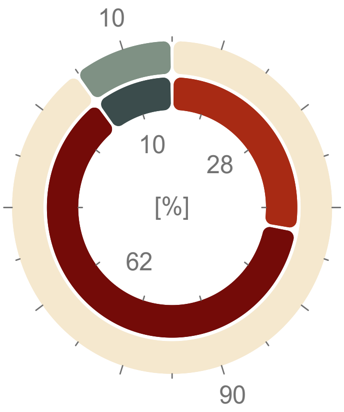


Primary Energy

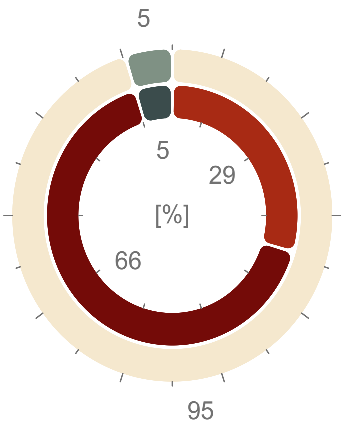




Energy Cost



CO_2 Emission



Energy Targets

- Heating
- Service Hot-Water Heating
- Cooling
- Ventilation Fans
- Lighting
- Equipment

Environmental Impact

Source Type	Source Name	Primary Energy kWh/a	CO_2 emission kg/a
Fossil	Natural Gas	180798	35502
Secondary	Electricity	24624	1772
	Total:	**205422**	**37275**

4.3.2 Archicad Energy Report modified building

Energy Performance Evaluation

01 Elba 11

Key Values

General Project Data

Project Name:	Elba 11	
City Location:	Milan	
Latitude:	45° 28' 0" N	
Longitude:	9° 11' 0" E	
Altitude:	120.00	m
Climate Data Source:	Strusoft server	
Evaluation Date:	4/14/2016 3:38:39 PM	

Building Geometry Data

Gross Floor Area:	**1227.79**	m²
Treated Floor Area:	**1069.92**	m²
External Envelope Area:	**921.28**	m²
Ventilated Volume:	**2878.30**	m³
Glazing Ratio:	**10**	%

Building Shell Performance Data

Infiltration at 50Pa:	**1.21**	ACH

Heat Transfer Coefficients	U value	[W/m²K]
Building Shell Average:	**0.57**	
Floors:	**--**	
External:	**0.22 - 3.00**	
Underground:	**--**	
Openings:	**1.68 - 2.52**	

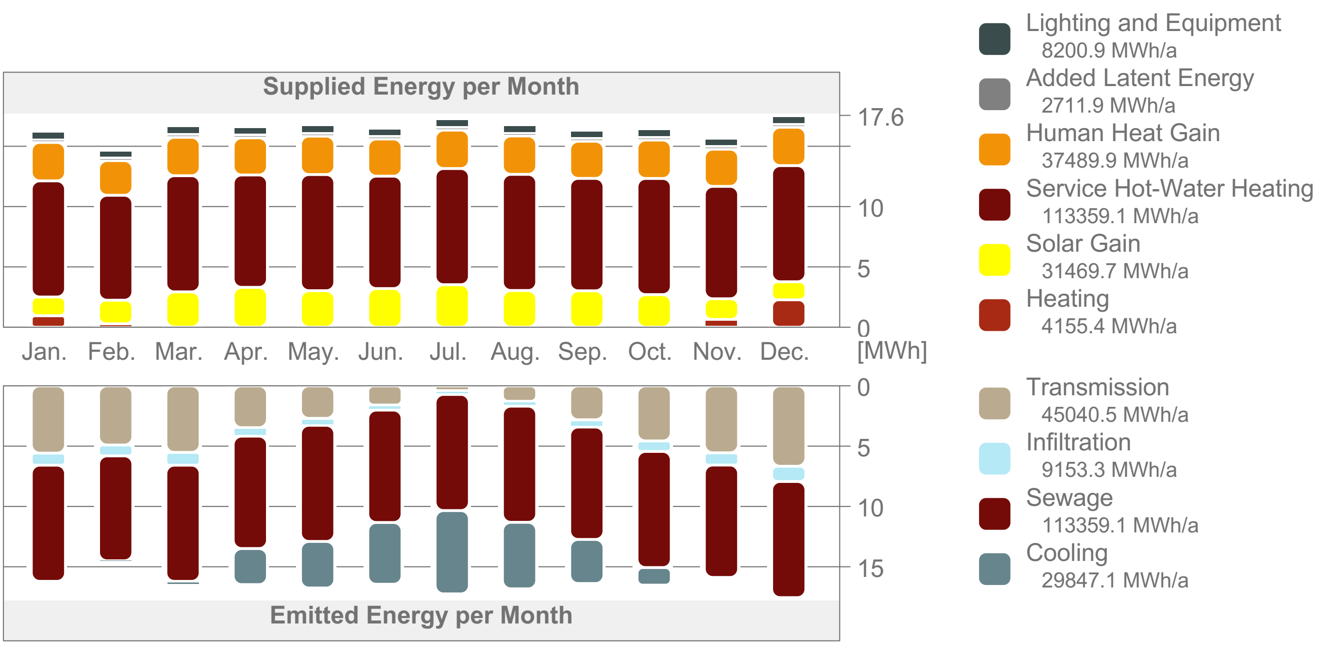
Specific Annual Values

Net Heating Energy:	**3.88**	kWh/m²a
Net Cooling Energy:	**27.90**	kWh/m²a
Total Net Energy:	**31.78**	kWh/m²a
Energy Consumption:	**145.40**	kWh/m²a
Fuel Consumption:	**127.44**	kWh/m²a
Primary Energy:	**216.11**	kWh/m²a
Fuel Cost:	**13.26**	EUR/m²a
CO_2 Emission:	**27.53**	kg/m²a

Degree Days

Heating (HDD):	**2525.27**
Cooling (CDD):	**2125.05**

Project Energy Balance



Thermal Blocks

Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 Sample Thermal Block	66	Residential	1227.79	2878.30
Total:	**66**		**1227.79**	**2878.30**

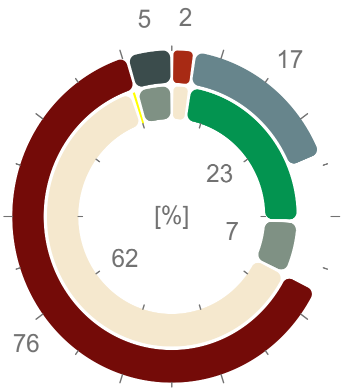
Energy Performance Evaluation

01 Elba 11

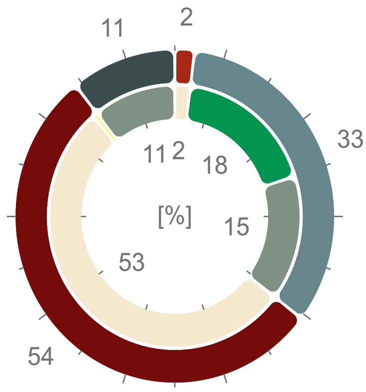
Energy Consumption by Targets

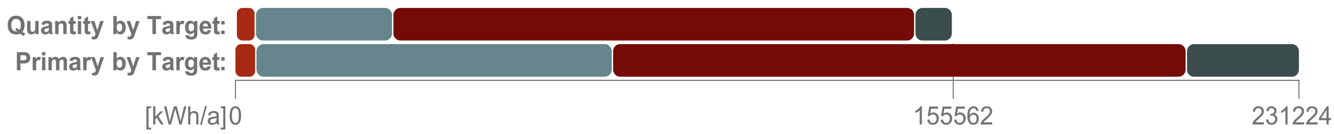
Target Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost EUR/a	CO_2 Emission kg/a
Heating	4155	4570	363	897
Cooling	29847	77435	2379	2569
Service Hot-Water	113359	124615	9804	24213
Ventilation Fans	0	0	0	0
Lighting & Appliances	8200	24602	1640	1771
Total:	**155562**	**231224**	**14187**	**29451**

Energy Quantity

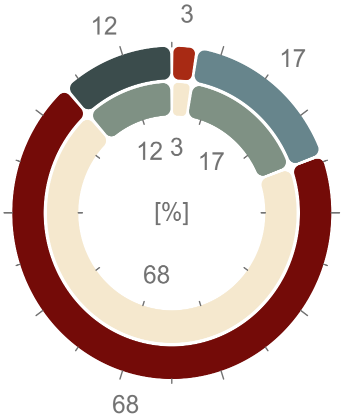


Primary Energy

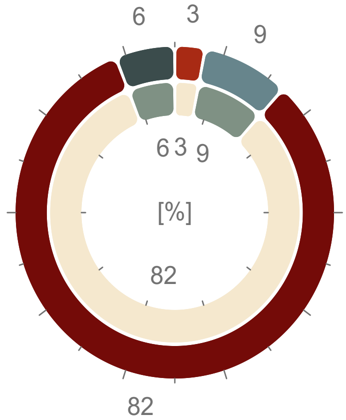




Energy Cost



CO_2 Emission



Energy Sources

Renewable
- Solar (Thermal & PV)
- External Air

Fossil
- Natural Gas

Secondary
- Electricity

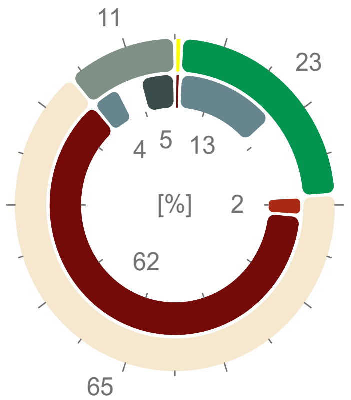
Energy Performance Evaluation

01 Elba 11

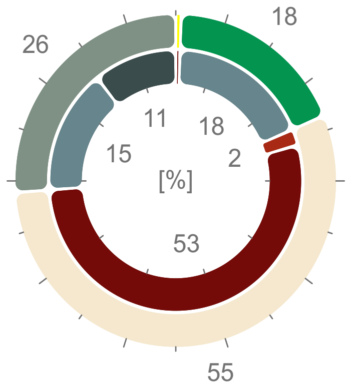
Energy Consumption by Sources

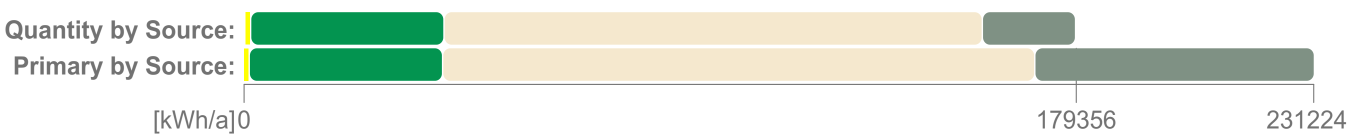
Source Type	Source Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost EUR/a	CO$_2$ Emission kg/a
Renewable	Solar (Thermal & PV)	1261	1261	NA	0
	External Air	41744	41744		0
Fossil	Natural Gas	116229	127851	10162	25105
Secondary	Electricity	20122	60367	4024	4346
	Total:	**179356**	**231224**	**14187**	**29451**

Energy Quantity

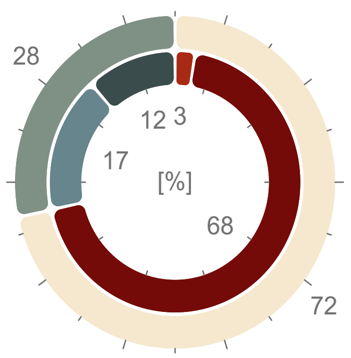


Primary Energy

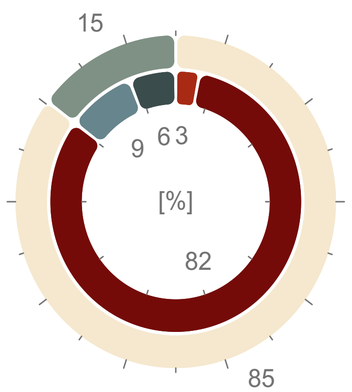




Energy Cost



CO$_2$ Emission



Energy Targets

- Heating
- Service Hot-Water Heating
- Cooling
- Ventilation Fans
- Lighting
- Equipment

Energy Performance Evaluation

01 Elba 11

Environmental Impact

Source Type	Source Name	Primary Energy kWh/a	CO_2 emission kg/a
Renewable	Solar (Thermal & PV)	1261	0
	External Air	41744	0
Fossil	Natural Gas	127851	25105
Secondary	Electricity	60367	4346
	Total:	**231224**	**29451**

4.3.3 Work Sheets

	Green Energy Audit **CONTRACT DEFINITION**	**CL 1.0**

Client/Owner
Name: Mr. Shon______________________
Address: Via Elba 11______________________ Postcode/ZIP 20144
City: Milan______________________ State Italy
Tel. ____________ Fax ____________ E-mail ______________
VAT ____________

Building location
Intended use
Address: Via Elba 11 ______________________ Postcode/ZIP 20144
City: Milan______________________ State Italy

Dimensions
Gross Volume (m^3) 1,344.75 Net floor Area (m^2) 268.95

AUDIT X **WALKTHROUGH** X **STANDARD** X **SIMULATION**

Scope of the AUDIT
X Energy saving X Improvement of comfort
X Energy valorisation ☐ Environmental valorisation
☐ Other (specify) ______________________

Items
X Building envelope (shell)
X HVAC systems X Electrical Systems ☐ Lighting Systems
☐ Other (specify) ______________________

Planned Activities
X Retrieval of documentation X Surveys
☐ Global survey ☐ Supplementary surveys
X Instrumental surveys X Monitoring
☐ Infrared audit X Heat flow survey
☐ Other (specify) ______________________

External Experts
X Electrical Engineer X HVAC Engineer X Thermography Auditor
☐ Other (specify) ______________________

Offer scheme

Base amount	€ ____________	
Inspections and surveys	€ ____________	Planned No.
Specific activities	€ ____________	____________
Instruments rental	€ ____________	
Other charges	€ ____________	
Total amount	€ ____________	
	(amounts excluding VAT)	

Payment ____ % ____________
____ % ____________ (terms)
____ % ____________

Delivery time ______________________

Energy Auditor ______________________ Client/Owner______________________

JOB Code		Auditor	Date	Sheet ____ of ____

	Green Energy Audit **GENERAL DATA**	**CL 1.1**

Building location Address: Via Elba 11________________________ Postcode/ZIP 20144
City: Milan________________________ State Italy

Intended use
X Residential ☐ Offices ☐ Kindergarten
☐ Primary school ☐ Secondary School ☐ Commercial building
☐ College ☐ Other (specify) ________________

Year of construction **1960**

Year of mayor renovation ☐ Facilities ____________ ☐ Building __________

Thermal zone No.	Description	Gross Volume (m^3)	Net floor Area (m^2)	Facility equipment
1	The whole building	1,344.75	268.95	

Facilities Codes

HS	Heating System
DHW	Domestic Hot Water System
AC	Summer Air Conditioning System
ST	Solar Thermal System
PV	Solar Photo Voltaic System
CHP	Combined Heat and Power (Cogeneration System)
____	________________________

Notes

JOB Code	Building	Auditor	Date	Sheet ____ of ____

	Green Energy Audit **LIST OF DOCUMENTS**	**CL 1.2**

Building

Documents	Description
Territorial framework	☐ Plan with territorial framework of the building from which is possible to define the guidelines and the context of the surrounding area (e.g. buildings that could cause shadow, vegetation, etc..)
Design drawings	X Plans (scale 1:100)
	☐ Sections (scale ________)
	☐ Elevations (scale ________)
Building envelope (shell)	☐ Characteristics of opaque envelope
	☐ Characteristics of transparent envelope
Other documents (specify)	☐
	☐
	☐
	☐

Building facilities

Documents	Description
HVAC Systems	☐ Functional diagrams
	☐ Project on plan
	☐ Technical report
	☐ Safety report
	☐
	☐
Electrical Systems	☐ Functional diagrams
	☐ Project on plan
	☐ Technical report
	☐ Safety report
	☐
Documentation for other facilities (specify)	☐
	☐
	☐
	☐

Operation & Maintenance

Documents	Descriptions
Specify	X Floor Plan 1:100
	☐
	☐
	☐

Contact person

E. S ________________________________ role owner ______________________________________

Phone No.___________________________ Mobile No. ______________________E mail _______________

JOB Code	Building	Auditor	Date	Sheet ____ of ____

	Green Energy Audit **ACTIVITIES PLAN**	**CL 1.3**

General data

Date of Offer request	5.9.2015
Offer submission date	26.9.2015
Date of Offer acceptance	8.10.2015
Date of documentation acquisition	11.11.2015

Meetings

No.	Description		Date	Documents issued
1	Preliminary meeting	Scheduled	15.11.2015	X Report
		Effective		Pictures
2	Secondary	Scheduled	22.11.2015	☐ Report
		Effective		Floor plan
3		Scheduled		☐ Report
		Effective		
4		Scheduled		☐ Report
		Effective		
5		Scheduled		☐ Report
		Effective		

Surveys on site

No.	Description		Date	Documents issued
1	Taking pictures and measurements	Scheduled	25.11.2015	Plans, sections
		Effective		
2		Scheduled		
		Effective		
3		Scheduled		
		Effective		

Monitoring

No.	Description		Start date	End date	Documents issued
1		Scheduled			
		Effective			
2		Scheduled			
		Effective			
3		Scheduled			
		Effective			

Infrared Audit

No.	Description		Date	Documents issued
1		Scheduled		
		Effective		
2		Scheduled		
		Effective		

Technical report delivery Scheduled date ______________ Effective date ________________

JOB Code	Building	Auditor	Date	Sheet ____ of ____

	Green Energy Audit **OPERATING MODE**	**CL 3.0**

Zone No. ________________ Set Point °C ____________

Winter Heating period			
from	15 October	to	15 April

Scheduled times

	ON	System activated	**OFF**	System off or attenuated

						X	X	X	X	X	
0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
						X	X	X	X	X	
12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24

Days during which the system is activated

Number of days per week during which the system is activated			
Closing period No. 1 from		to	
Closing period No. 2 from		to	

Zone No. ________ Set Point °C ____________

Summer Cooling period			
from		to	

Scheduled times

	ON	System activated	**OFF**	System off or attenuated

0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24

Days during which the system is activated

Number of days per week during which the system is activated			
Closing period No. 1 from		to	
Closing period No. 2 from		to	

Notes

JOB Code	Building	Auditor	Date	Sheet ____ of ____

	Green Energy Audit **BUILDING ENVELOPE (SHELL) – OPAQUE WALLS**	**CL 4.2**

Zone No. ________

No.	**Orientation**	**Wall Code**	**Thickness** (m)	**B** (m)	**H** (m)	**Area** (m^2)	**Boundary Code**	**Type of Windows (*)**						
								1	**2**	**3**	**4**	**5**	**6**	**7**
	N	N1	0.27	16.6	12.4	205.84						A		
												B		
												C		
								D						
	E	E1	0.27	16.4	13.6	223.04							A	
													B	
								E						
	S	S1	0.27	16.6	14	232.4				B				
										C				
	W	W1	0.27	16.4	13.6	223.04							A	
													B	
										C				

Boundary Codes

1 Outside
2 Unheated or uncooled spaces
3 Heated or cooled spaces with different temperature: Winter set-point ___ °C Summer set-point _____ °C
4 Heated or cooled spaces with different temperature: Winter set-point ___ °C Summer set-point _____ °C
5 Heated or cooled spaces with different temperature: Winter set-point ___ °C Summer set-point _____ °C

Codes for walls with precomputed U values

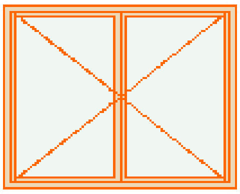
1 Description ________________________________ U value (W/m^2K) __________________________
2 Description ________________________________ U value (W/m^2K) __________________________
3 Description ________________________________ U value (W/m^2K) __________________________
4 Description ________________________________ U value (W/m^2K) __________________________
5 Description ________________________________ U value (W/m^2K) __________________________

(*) with reference to the windows schedule of the checklist 4.3 report the number of window in the facade

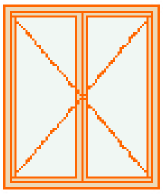
JOB Code	Building	Auditor	Date	Sheet ____ of ____

Zone No. ________

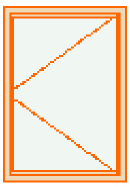
Window Code A

Scheme	Glass type	CLEAR
	Window type	
	External shading	
	Internal shading	
	Air tightness	☐ good ☐ average X poor
	Maintenance	☐ good ☐ average X poor
	h. shutter box (m)	
Base (m) 1.2 / Height (m) 1.5	h. sub window (m)	
Area (m^2) 2.7	NOTE S	

Window Code B

Scheme	Glass type	CLEAR
	Window typology	
	External shading	
	Internal shading	
	Air tightness	☐ good ☐ average X poor
	Maintenance	☐ good ☐ average X poor
	h. shutter box (m)	
Base (m) 1.2 / Height (m) 1.5	h. sub window (m)	
Area (m^2) 1.8	NOTE S	

Window Code C

Scheme	Glass type	CLEAR
	Window typology	
	External shading	
	Internal shading	
	Air tightness	☐ good ☐ average X poor
	Maintenance	☐ good ☐ average X poor
	h. shutter box (m)	
Base (m) 1 / Height (m) 1.5	h. sub window (m)	
Area (m^2) 1.5	NOTE S	

JOB Code	Building	Auditor	Date	Sheet ____ of____

Heat production system

Outside the building	X Urban district heating ☐ District heating ☐ Centralised thermal power plant
Inside the building	X Centralised thermal power plant ☐ Centralised with building substation ☐ Autonomous boilers ☐ Mixed production
Total heat capacity	_____________ (kW)

Heat distribution system

Heat transfer medium	☐ Hot water ☐ High pressure hot water ☐ Air
Distribution	☐ Single distribution circuit ☐ Independent distribution circuits (one for each zone) ☐ Other (specify) ______________________________________
Outer diameter of the main pipe	____________ ☐ (mm) ☐ (DN)
Quality of thermal insulation	Inside plant room ☐ Good ☐ Average ☐ Poor Outside plant room ☐ Good ☐ Average ☐ Poor
Pipe installation	☐ Outside ☐ Tunnel ☐ In ground
Characteristics of the pumps	Main F ____________ H ____________ Circuit __________ F ____________ H ____________ Circuit __________ F ____________ H ____________ Circuit __________ F ____________ H ____________ F= Flow rate - H = Total head

Control and regulating system

Type	X Centralised control ☐ Zone control
Remote control	☐ YES ☐ NO

Existing systems and equipment (*)

Boilers	X Qty 1__________________
Heat pumps	☐ Qty ___________________
Heat exchangers	X Qty Radiators___________
Biomass boilers	☐ Qty ___________________
CHP (Cogenerators)	☐ Qty ___________________
Solar Thermal systems	☐ Qty ___________________
Photo Voltaic solar systems	☐ Qty ___________________

(*) For each system or equipment item a checklist must be compiled

Notes

JOB Code	Building	Auditor	Date	Sheet ____ of ____

	Green Energy Audit **WALKTHROUGH – RESIDENTIAL**	**CL 6.00**

Building characteristics

Building typology	☐ Single family house ☐ Terraced house X Multi family house ☐ Apartment block ☐ Tower building ☐ Other (specify) ______________ the building consists of 3 flats (apartments) and __________ housing unit for non residential uses (specify) _____________
Dimensional characteristics	Gross volume 1,344.75 (m^3) Net area 268.95 (m^2)
Year of construction	1960
Retrofit action already taken	☐ Roof insulation year ________ ☐ External wall insulation year ______ X Windows replacement year 2011 X Boiler replacement year 2011 ☐ Other (specify) ______________________________ year ________ ☐ Other (specify) ______________________________ year ________ ☐ Other (specify) ______________________________ year ________

Characteristics of facilities

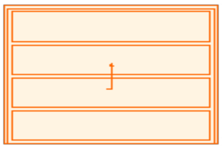
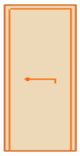
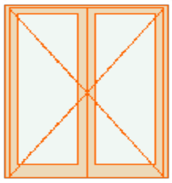
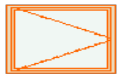
Heating system	☐ Autonomous X Centralised
Heat generation	X Boiler ☐ Heat pump ☐ Air heater ___________________ ☐ Heat exchanger (district heating) ☐ CHP Heat capacity (kW) ______________ Energy carrier X Natural gas ☐ Diesel oil ☐ LPG ☐ Other (specify ____
Heating terminals	X Radiators ☐ Heating panels ☐ Other (specify) ______________ ____
Control and regulating system	☐ Manual X Centralised ☐ Local ☐ Zone
Energy metering system	☐ Yes X No
DHW production	☐ Geyser ☐ Autonomous with storage tank X Electric boiler ☐ Combined boiler (heating and DHW) ☐ Heat exchanger (district heating)
Summer cooling	☐ No X Air centralised ☐ Hydronic centralised (fan-coil units) ☐ Split system ☐ Multisplit ☐ Other (specify) ____ Cooling capacity (kW) ______________

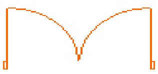
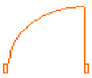
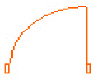
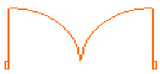
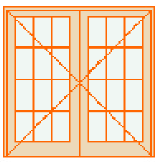
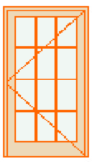
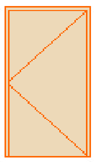
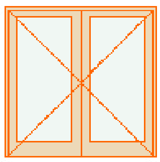
Notes

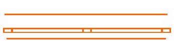
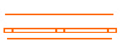
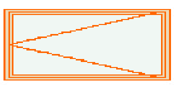
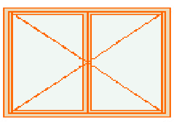
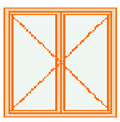
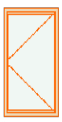
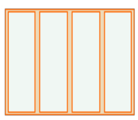
JOB Code	Building	Auditor	Date	Sheet ____ of ____

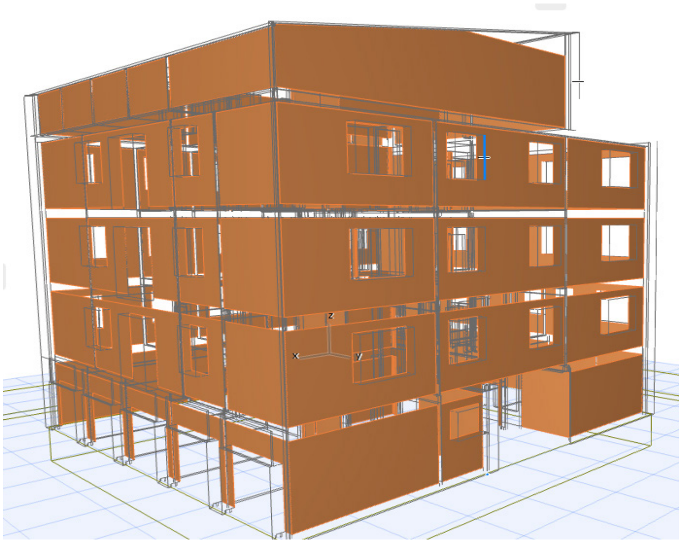
4.3.4 Archicad Documentation

All Openings Schedule

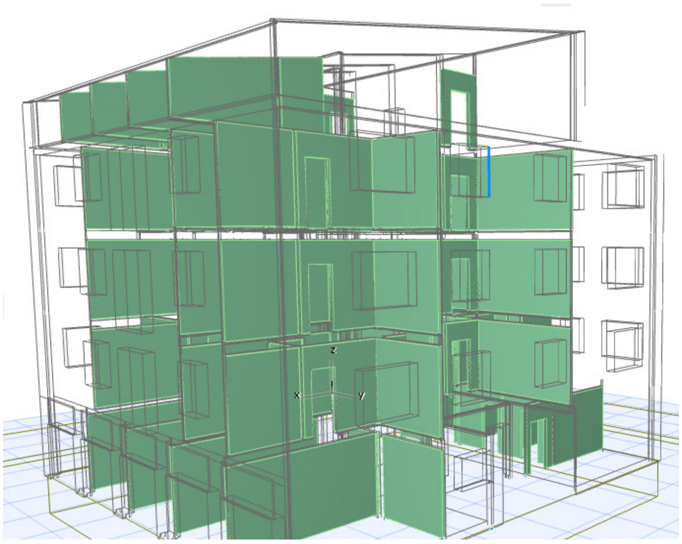
Full Element ID	DOO - 021	DOO - 033	DOO - 037	WD - 001
Opening Name	Vertical Sliding Garage Door 19	Pocket Door 19	Double Door 19	Window 19
Quantity	1	1	1	1
Zone Number	02	20	26	
W x H Size	2.500x2.100	0.800x2.100	1.800x2.500	1.200x1.000
Orientation		R	R	R
Sill height	0	0	0	1.5
Head height	2.1	2.1	2.5	2.5
2D Symbol				
View from Side Opposite to Opening Side				

Full Element ID	DOO - 004	DOO - 006	DOO - 015	DOO - 016
Opening Name	Double Door 19	Door 19	Door 19	Double Door 19
Quantity	1	1	1	1
Zone Number	08	08	01	07
W x H Size	1.600x2.100	0.900x2.100	0.900x2.100	1.600x2.100
Orientation	L	L	L	R
Sill height	0	0	0	0
Head height	2.1	2.1	2.1	2.1
2D Symbol				
View from Side Opposite to Opening Side				

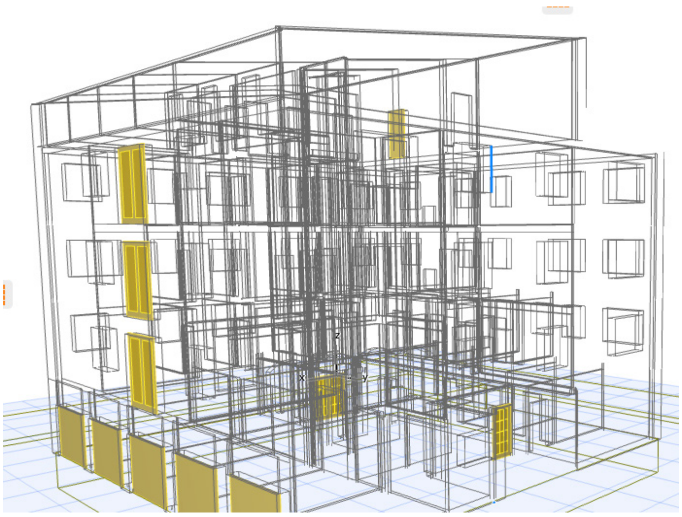
Full Element ID	WD - 005	WD - 006	WD - 007	WD - 010	WD - 014
Opening Name	Window 19	Double Sash Window 19	Double Sash Window 19	Window 19	ash Window 19
Quantity	1	1	1	1	1
Zone Number					
W x H Size	1.800x1.000	1.800x1.500	1.200x1.500	1.000x1.500	2.400x1.500
Orientation	L	L	L	L	
Sill height	1.5	1	1	1	1
Head height	2.5	2.5	2.5	2.5	2.5
2D Symbol					
View from Side Opposite to Opening Side					



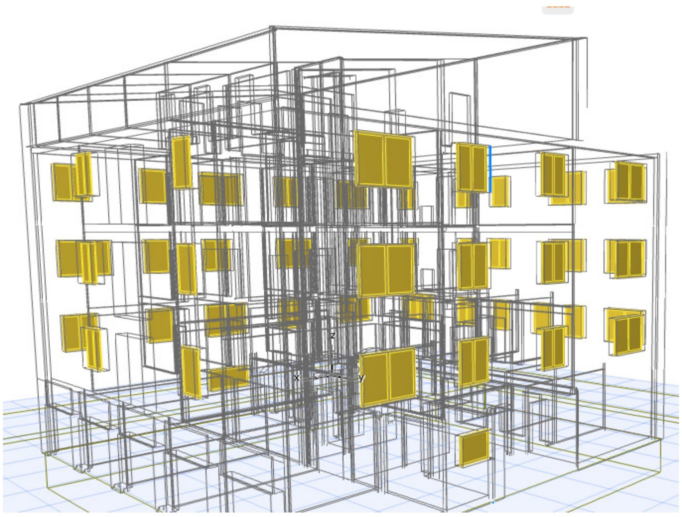
3D External Wall



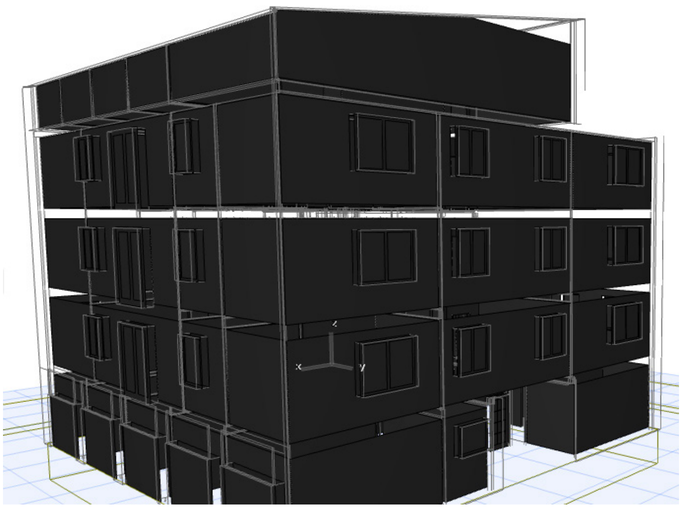
3D Internal Wall



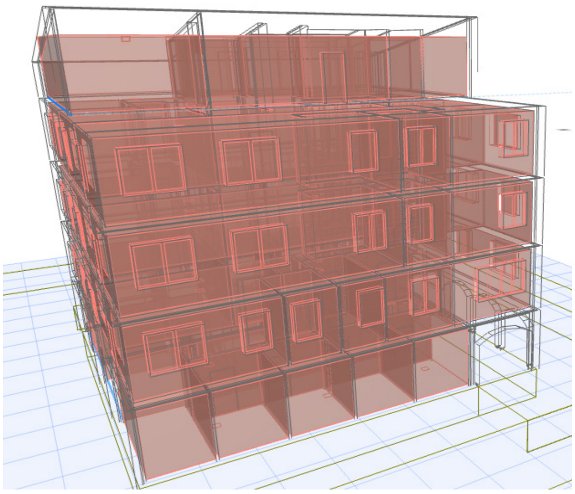
3D Openings Doors



3D Openings Windows



3D Thermal block



3D Zone Volume

5. Conclusions

Integrated in the ArchiCAD environment, Energy Evaluation offers an easy-to-use workflow for performing dynamic building energy calculations on projects of any size.
Using the same dynamic building energy simulation technology as the standard compliant EcoDesigner* for ArchiCAD add-on, Energy Evaluation is an energy evaluation tool that enables architects to monitor and control all architectural design parameters that influence building energy performance.

The Energy Evaluation tool performs reliable dynamic energy evaluation at all stages of the design process, so that architects can make informed decisions regarding their buildings' energy efficiency.
Including Energy Evaluation in the architectural design workflow makes it easy to create projects that conform to or even exceed energy efficiency regulations and comply with building energy standards.

• Create and visualize multiple thermal block Building Energy Model (BEM) geometry directly from the ArchiCAD BIM using the Energy Model Review Palette.
As in my case study i created one thermal block for the whole building and uploaded the zones which i created for each part of the building that has a thermal raport.
By doing this it gives the software the tools to work and calculate the thermal parts which after we can see in the final energy report, also adding to the thermal block the HVAC systems i wish to have on my building so in my case i added a boiler at the first part and other HVAC systems for the new building.

• Use the Model-Based Solar Study to determine the intensity of solar irradiation on each external glazed opening individually, on every hour of the reference year – including the shading effect of the surroundings (buildings, plants etc.) and shading devices.
Creating vegetation surround my building and locating it in the area i have decided in Milan than uploading all the opening of building gives us at the end the solar study we can saw before.

• Export the ArchiCAD model geometry and material property data via IFC or as an XLS spreadsheet, to be processed by external energy analysis applications.
Using the archicad software i did not export the 3D model out to use in a different software because i could have done the energy report i wished on the main software so i could avoid this part. But it is always possibile to export it and to do different checks in other softwares, some i have shown before.

• Run the dynamic energy simulation, using the VIP Core engine that is integrated in ArchiCAD, to produce an Energy Performance Report.
This report provides information on the project's yearly energy consumption, carbon footprint and monthly energy balance.
After creating the building, choosing the materials (doors, windows etc..),uploading location, costs of materials and structure systems i was able to start making a first energy report to get a picture of how the energy in my model works and the effects it has, so i could learn what needs to be done and change to bring it to the next level of energy.

To sum my conclusions and my work in field of:
Energy Audit and Energy Management in BIM Environment

I would say that BIM is an important tool to our future in architecture furthermore can be in service to any studio of architects, engineers or even schools of architecture cause as we can see today, it gives us the tools and possibility to understand how will our design/project will be effected in the early phases of it.
Therefore we can do energy simulations and get facts about parts of the structure, the building systems, the surrounding anywhere we wish to put it in the world.
All of that just by having a computer and a BIM software and not waiting more than a few minutes to get its calculations about the project we are facing.

BIM is able to predict information which in the past we had to wait for months or even years to understand.
So I believe that this isn’t the future in the world of architecture but it’s the present passing from 2D or 3D to the next generation 4D and 5D,
who wouldn’t like to know how his building will react in our world not only by look, but in its behavior to its surroundings and all of this in the phase of thinking and drawing before you even have to put on brick in the construction site itself.

I believe that using this option of BIM software we will be able to solve many problems already in the early phases of our projects.

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