ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

ESCUELA TÉCNICA SUPERIOR INGENIERÍA DE EDIFICACIÓN

Studio-analysis of one of the buildings of the University Center for Energy Efficient Buildings (UCEEB) and justification of the conditions of energy efficiency (Buštěhrad)

FINAL MASTER PROJECT

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DEDICATION

This project is dedicated to my parents for all the support they have given me throughout my college life, my brother, Luis Palmero for your advice and support in my last years of college, and Elisabeth Hofmann because without your help this year would not have been possible.

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Thanks to prof. Ing. Karel Kabele for your help, D. Javier Benlloch for accepting me without any qualms, and of course, not forgetting the Czech Technical University in particular the faculty of Civil Engineering for allowing me to do this project in Prague.

ABSTRACT IN ENGLISH

A zero energy building or net zero energy building is a term applied to buildings with a net energy consumption close to zero in a typical year. In other words, the energy comes from the same building using renewable energy sources must be equal to the energy required by the building.

A conventional building is a building that does not follow the rules of environmental or bioclimatic approach.

The proposal for this work is based on the two previous concepts, it is the adequacy of a conventional building belonging to the Czech Technical University in Prague, setting it to become zero-energy one.

Although zero energy buildings remain uncommon in developed countries, are gaining in importance and popularity. Proximity to mass zero energy buildings implies a potential solution to a range of social and environmental problems, including reducing CO_2 emissions, reducing dependence on fossil energy to run heating/air conditioning systems, imports oil and oil products, and rational use of fossil fuel for other uses improve supply problems in a scenario of energy crisis, rising costs and fossil resource depletion.

There will be a study of the possible technologies to use, and then a selection of the most suitable for the building depending on the functionality, use, geographic location, and finally, the economic aspect.

These technologies range from all of the same facilities (plumbing, sanitation, electricity and heating/air conditioning), also issues such as thermal and acoustic insulation.

Following the above in the description, the objectives of this final master project will analyze the performance of a building to help reduce CO_2 emissions which in turn reducing the use of fossil material for installations of the same building partially capable or able to produce on their own the energy needed for proper operation.

I must stress that this is a building without building, therefore, the work in question is a preliminary study on how to do an efficient building.

The project is structured in two parts: the state of affairs on the building, art history, and gathering information from all existing technologies for the realization of this project, and a second experimental part, where we first define studied housing, construction characteristics and methodology. And then develop energy requirement studies inside a space representative, at different times of year. Ending with a conclusion.

ABSTRACT IN SPANISH

Un edificio convencional es una construcción que no sigue las normas del enfoque ambiental o bioclimático.

La propuesta para este trabajo está basado en los dos conceptos anteriores, se trata de la adecuación de una edificación convencional perteneciente a la Czech Technical University in Prague, ambientándolo para que se convierta en uno de energía cero.

Aunque los edificios energía cero siguen siendo infrecuentes en los países desarrollados, están ganando en importancia y popularidad. La proximidad de hacer masivos edificaciones de energía cero implica una solución potencial a una gama de problemas sociales y ambientales, incluyendo la reducción de las emisiones de CO_2, la reducción de dependencia de la energía fósil para el funcionamiento de los sistemas de climatización, las importaciones de petróleo y derivados, y el uso racional de combustible fósil para otros usos mejorando los problemas de abastecimiento en un escenario de crisis energética, precios crecientes y agotamiento del recurso fósil.

Se hará un estudio de las posibles tecnologías a utilizar y a continuación una selección de las más idóneas para el edificio dependiendo de la funcionalidad, el uso, la situación geográfica, y por último, el aspecto económico.

Estas tecnologías abarcan desde todas las instalaciones del mismo (fontanería, saneamiento, electricidad y climatización), también temas como aislamiento térmico y acústico.

Tras lo expuesto en la descripción, los objetivos del presente proyecto final de máster serán analizar la realización de una edificación que ayude a la reducción de las emisiones de CO_2 que a su vez de la reducción de la utilización de material fósil para las instalaciones del mismo, siendo este edificio capaz o parcialmente capaz de producir por sus propios medios la energía necesaria para su correcto funcionamiento.

El proyecto está estructurado en dos partes: el estado de la cuestión sobre la edificación, historia del arte, y recopilación de información de todas las tecnologías actualmente existentes para la realización de este proyecto; y una segunda parte experimental, donde en primer lugar se definirá el edificio objeto de estudio y sus características constructivas. Y a continuación se desarrollaran los estudios de requerimiento energético en el interior de un espacio representativo, en diferentes épocas del año. Finalizando con una conclusion.

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STATE OF THE ART

1. INTRODUCTION TO SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT:

It is becoming increasingly difficult to ignore the elevated amount of energy and resources consumed by people as a consequence of a progressive population growth.

Over the past century, there has been a dramatic increase in energy/water consumption and waste production which, if not controlled, can be harmful not only for our present environment and health but also for those of the generations to come.

Although there is not a commonly international definition for the term "sustainability", the term itself is directly linked to the first serious worldwide discourse on sustainable development (1987) when the United Nations published the well-known *Brundtland Report (Our common Future).*

On this report, Gro Brundtland, prime minister of Norway, who chaired the UN World Commission on Environment and Development, first defined sustainable development as:

"*…the development which meets the need of the present without compromising the ability of future generations to meets their own need."*

Since the publication of the Brundtland report, sustainability has become an all-encompassing discipline because truly sustainable development must include all facets of human activity-agriculture, manufacturing, transporting, building and infrastructure.

According to Sage, sustainable development refers to the fulfillment of human needs though simultaneous socio-economic and technological progress and conservation of the earth's natural systems. Sustainable world progress is dependent upon continued economic, social, cultural, and technological progress. To achieve this, careful attention must also be paid to preservation of the earth's natural resources. Sustainable development is a term generally associated with the achievement of increased techno-economic growth coupled with preservation of the natural capital that is comprised of environmental and natural resources. It requires the development of enlightened institutions and infrastructure and appropriate management of risks, uncertainties, and information and knowledge imperfections to assure intergenerational equity, intra-generational equity, and conservation of the ability of earth's natural systems to serve humankind.

To summarize the concept, three different areas can be directly linked to the achievement of sustainable development:

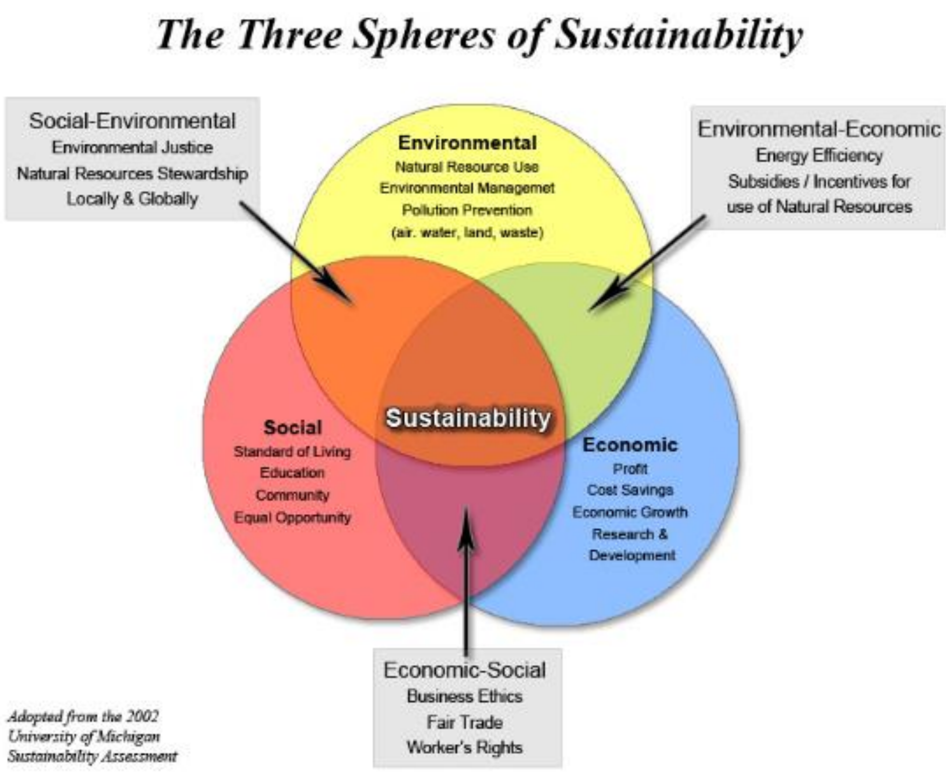

Figure 1 The three spheres of sustainability. [6]

The scope of sustainability is frequently described as including three spheres - social, environmental and economic. To use an accounting metaphor, sustainability projects must be evaluated according to a "triple bottom line" of social, environmental and economic responsibility.

2. INTRODUCTION TO SUSTAINABLE CONSTRUCTION:

While concepts such as green construction, ecological construction or sustainable architecture have now been used for a while, the term of Sustainable Construction was first introduced by Charles J. Kibert (1994) during the first international conference on sustainable construction held in Tampa:

"Sustainable construction is the creation and responsible management of a healthy built environment based on resource efficient and ecological principles"

The International Council for Research and Innovation in Building and Construction (CIB) defined sustainable construction as:

"The sustainable production, use, maintenance, demolition, and reuse of buildings and constructions or their components", while sustainable buildings and built environments are seen as "The contributions by buildings and the built environment to achieving components of sustainable development" (CIB, 2004, p. 02).

Other definitions that clarify the main objectives of this type of constructions are the ones given by Huovila and Richter (1997) and by Lanting (1998):

"Sustainable construction aims at minimizing the use of energy and emissions that are harmful for environment and health, and produces relevant information to customers for their decision making".

"...a way of building which aims at reducing (negative) health and environmental impacts caused by the construction process, by buildings or by the built environment".

2.1. PRINCIPLES OF SUSTAINABLE CONSTRUCTION

Professor Charles J. Kibert of the University of Florida proposed 5 principles of sustainable construction:

I. Minimization of resources consumption.
II. Maximization of resource reuse.
III. Use of renewable and recyclable resources.
IV. Protection of the natural environment.
V. Creation of a healthy and non-toxic environment.

These principles will be individually explained within the following sections of how to assess the environmental impact of a product throughout its entire life-cycle.

There are three ways by which the civil engineering and construction industry can act to achieve sustainable construction:

- Creating built environments.
- Restoring damaged and/or polluted environments.
- Improving arid environments.

Miyatake suggests that in order to achieve a sustainable construction, it is necessary for the construction industry to change its processes of creating the built environments. This could be coined as bringing change from linear processes to cyclic processes within the construction industry, meaning that the industry has to change the way in which all the construction activities are undertaken.

With the use of energy, materials and resources needed to create buildings and other civil engineering projects, a huge volume of discharge waste during and at the end of the facility's life is resulted.

Therefore, changing this linear process into cyclic process will bring increased, renewed and reused resources, and decrease in significant use of energy and other natural resources.

On the order hand, in order to restore damaged and polluted environments, efforts have been done such as treatments of damaged and contaminated soils, water and air.

The idea behind improving arid environments is to improve large scale arid environments like deserts and introduce adaptive conditions for plants, animals and human beings.

When assessing construction sustainability the following components have to be evaluated (Anik et al, 1996):

- Prevention of unnecessary use of land and the avoidance of unnecessary construction.
- Restricting the brief of construction to the necessary minimum.
- Selection of the most efficient use of building materials.

- Optimal exploitation of natural resources and the efficient use of energy in production and use of buildings, i.e. throughout the entire integrated life cycle of the building.
- Assurance of optimal new construction and sustainable refurbishment.

Responsibility of Architecture

Due to its role, volume and impact, it is evident that architecture has a direct responsibility to the immediate (city) ecosystem. As Graham [Graham 2002] points out, every architectural artifact, regardless of its size gig or small [1] connects to the earth; [2] depends on nature for resources; [3] causes environmental change; and [4] affects both human and nonhuman life. Since part of the problem is architectural, so should be the solution, such as designing based on sustainable and ecological principles; developing and using advanced green technologies and materials; and promoting and demanding high-performance buildings. Some of these issues, such as ecological design have been around for decades. Others have been proposed and promoted, but sporadically rather than consistently.

Architecture's main responsibility is not to pick and choose the "best" solution but to incorporate all options that might generate workable solutions. There is no single formula of what and how much to use. Clearly, there is an urgent need of a new way of thinking and designing. In order to, fully address its responsibilities, architecture should abandon old methods, technologies, and materials and push for a new paradigm shift. The design objectives should be based on sustainable, ecological, and performance criteria rather than trends and aesthetics; be environmentally conscious rather than market-driven; and be inherently resourceful rather than globally destructive. Briefly described, the responsibility of green architecture includes:

- *Smaller buildings.* Smaller building are economically feasible, efficient, and require low maintenance. Because of their compact size, smaller buildings use less material, need less energy, and produce less waste. Architects should focus on small, yet functional and ecologically sensitive buildings by conserving space and preserving the environment.
- *Sustainable materials and technologies.* Architects should focus on using durable, low-maintenance, recyclable, and economical materials and technologies. Constant breakdowns, wear-and-tear, and replacement of materials and technologies will make buildings unsustainable. Using abundant, local elements, if possible, with little to no transportation costs is highly preferable. Architects should also consider elements that are easily dismantled and reused or recycled at the end. They can be salvaged, refurbished, or remanufactured, including saving materials and technologies from disposal and renovating, repairing, restoring, or generally improving the appearance, performance, quality, functionality, or value.
- *Ecological materials and technologies.* Materials and technologies should consist of low-emission, nonpollutant elements with low manufacturing impacts. Ecological materials should facilitate a reduction in polluting emissions from building maintenance and should not be made from toxic chemicals. Architects should focus on clean burning technologies by excluding the components such as substances that deplete stratospheric ozone and associated with ecological damage and health risks, including mercury and halogenated compounds, and HCFCs (hydrochlorofluorocarbons). Additional ecological technologies such as stormwater and wastewater systems that reduce surface water and groundwater pollution should be incorporated.

- *Sustainable resources.* Buildings should rely on sustainable resources, such as energy and water, focusing on supplying their own gray water and power. Such buildings may operate entirely off the power grid, or they may be able to feed excess energy back into the grid. Solar, thermal, and wind, if available, powers are the usual alternatives. Buildings should also consider the proximity to and from water resources, supplies, and existing waste management systems. Architects should also consider the climatic conditions for their favor and benefit from them, such as sun, wind, and water. Residential and daylight-needing buildings should not be designed in sun-trapping/blocking areas (i.e., in between buildings, etc.). The buildings should be accessible to public transportation (and bicycle paths) to reduce private vehicle use, to save energy, and to reduce air pollution.
- *Sustainable environments.* One of the main responsibilities of any architects is to create sustainable environments that are protective, healthy, habitable, and promote social and sustainable networks. Buildings should provide protective environments where the occupants feel safe and secure against the various elements such as natural causes, built environments, and people. Building should also provide healthy and habitable environments for people; designed to maximize productivity by minimizing effects of buildings such as sick building syndrome.
- *Resource ecology.* By taking ecological issues intro account, architects should design and construct buildings in the right places and in the right way, for the benefit of both the occupants and the ecological resources. The reduction of the natural resources consumption should be targeted right from the start, at the design stage. The calculation and control activities should focus on the building's natural resource use, such as water, energy, landscape, and waste management. Soil type and groundwater conditions must be taken into consideration before the building

is designed and constructed. The type and stability of soil should be taken seriously, not only because of the building damage but also potential problems to the soil ecological such as erosion, pollution, sedimentation, and various forms of soil degradation.

- *Environmental ecological.* One of the main responsibility of architects is to respect the ecology of the environment, and to design the buildings in a way not to pollute the environment and harm the ecosystem. Faulty and poorly designed and/or installed building infrastructure systems, such as inadequate gray water and sewage pipes, stormwater management, and drainage systems, can contribute do drainage, flooding, and soil and ground water pollution. Architects should make sure to provide proper drainage systems which collect runoff from impervious surfaces (e.g., roofs and roads) to ensure that water is efficiently conveyed to water ways through pipe networks. Designs should promote minimizing water usage and providing water water-efficient landscaping. The materials, technologies, and the type of energy used in the buildings should be selected from nonpollutant elements, such as alternative energy resources and low-VOC building products.

  Architects should also implement global stewardship principles by acting locally and thinking globally. Use local resource as much as possible by reducing the embodied energy of the building products, and by considering global ecological consequences of their actions. Land selection, biodiversification, and building orientation should be integrated into the design before the building is constructed. Avoid changing the ecosystems for the sake of building landscape and/or orientation, such as cutting off plants or creating artificial ecosystems, which might contribute to erosion and flooding. Instead, buildings should contribute to the environment by absorbing sun rays and stabilizing the soil.

- *High-performance materials and technologies.* The materials and technologies used in buildings should be efficient, effective, and productive. The material efficiency can be achieved by using recycled elements with minimal waste or adding engineered components, such as engineered clumber and I-joists. Technological efficiency should apply to the entire building cycle, including water and energy efficiency. These elements should also be effective by producing desired results and productive such as changing and storing the energy and water.
- *Resource performance.* A building's resource performance in determined by the contribution to the resources of the location. Buildings should perform as economic, ecological, and environmental contributors by various different ways. The location and function of the building should contribute to the economic viability in the area by creating jobs, enhancing property values, and bringing other businesses into the area. The material and technological elements of the building should also be used in a way to reduce the environmental impact of the building such as absorbing sun rays and CO_2 emission from the atmosphere.
- *Environmental performance.* Buildings should be physically, functionally, and socially adaptable to the environment and perform according to environmental changes. Changes in climate, social patterns, or trends should not end the building life cycle but give birth for different uses for the building. The functional and environmental quality of the building should also be considered as the main design objective.

2.2. DEFINITIONS AND OPERATIONALIZATIONS OF GREEN ARCHITECTURE

The term "green" is of one the most widely used but poorly defined terms in architecture today. While the terms "green", "sustainable", and "ecological" are often used interchangeably to describe environmentally responsive architecture, in reality each term has its own history and sociopolitical connotations, as well as its own architectural definition, use, and operation. Green architecture is an umbrella term, which involves combination of values (environmental, social, political, and technological) and thus seeks to reduce the negative environmental impact of buildings by increasing efficiency space. Therefore, the definitions of the following terms are essential to understand and define green architecture.

Sustainable

The term "sustain", derived from the Latin "sustenere", means to keep in existence to capable of being maintained in a certain state or condition [Lawrence 2006]. Because of the ecological roots of the term, it is mostly used to address environmental and climatic concerns. However, sustainability was first introduced as a global socioeconomic concept during the 1970s and defined later in "Our Common Future" by Brundtland Commission as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" [UN 1987]. Therefore, depending on the context, there are different approaches and definitions of sustainability. For example, in an ecological context, sustainability is defined as the ability of an ecosystem to maintain ecological processes, functions, biodiversity, and productivity into the future [Naiman, Bilby and Kantor 1998; Waltner-Toews, Kay and Lister 2008].

In an architectural context, sustainability is defined as a term that describes economically affordable, environmentally healthy, and technologically efficient and high-performance buildings [Edwards 2005; Steele 2005; Sassi 2006; Smith 2006; Steinfled 2006; Williams 2007; Newman and Jennings 2008; Vallero and Brasier 2008]. Besides architecture and ecology there are other definitions of sustainability in other fields: technological [Dorf 2001; Anastas and Zimmerman 2003; Teich 2003; Olson Rejeski 2004], material [Spiegel and Meadows 2006; Kibert 2007], economic [Brown 2001; Lopez and Toman 2006], and behavioral [Ehrenfeld 2008; Murphy 2008].

Sustainable Architecture

In architecture, sustainability is used as a general term to describe technologically materially, ecologically, and environmentally stable building design. Within the context of sustainable architecture, stability is established via three major components:

I. Technological and material sustainability (elements).
II. Resource sustainability.
III. Environmental sustainability.

Creating sustainable buildings requires that one consider the sustainability of their technological and material elements, resources, and environment. An element's sustainability is measured by its durability, maintenance level, and recyclability. Economic issues related to its construction, profitability, and building stocks value should also be considered. Resource sustainable can be measured based on its site condition, cost-effectiveness of the operational and life cycle of the building, accessibility, and favorable natural forces. Finally, creating healthy, habitable, and safe environments with social and institutional capacity should be the primary focus for environmental sustainability. The architect's challenge, therefore, is to find a balance among technological and materials considerations, resource availability, and environmental sustainability. (see Table 1)

TABLE 1 COMPONENTS FOR SUSTAINABLE ARCHITECTURE [5]

ELEMENTS	RESOURCES	ENVIRONMENT
Durable	On-site conditions	Healthy
Economical	Cost-effective (operational/life cycle)	Habitable
Low-maintenance	Accessibility	Social/institutional capacity
Recyclable	Natural forces (favorable)	Safety and security (protective)

- **Sustainable elements**

The primary elements of any buildings are the technologies and materials. These elements play an important role on the sustainability of a building. Their embedded sustainable properties and intrinsic values make up the elements of sustainable architecture.

– Durability: Materials and technologies should be strong, resilient, stable, and long lasting. Freedom from constant breakdown, wear and tear, and replacement help the buildings to be sustainable. Green buildings should use durable materials that resist decay, wear, and mold with a high level of tolerance, and technologies that can be used over a relatively long period without being depleted and/or changed.

– Economical: Elements should be cost-effective and economical. Abundant local elements with little or no transportation costs should be used if possible. Consider higher efficiency, durability rate, and low-maintenance records when making choices. The economics of technologies should be calculated based on their performance and output ratio, not on the nominal purchasing value. For example, solar panels cost more at the outset but are highly economical, in terms of energy costs, throughout the life cycle of the building.

– Low-maintenance: Sustainable elements should be selected from materials and technologies that do not require constant servicing and/or replacement due to wear and tear, deterioration, or decline in performance. Materials should be self-sufficient and carefree. For example, preinsulated siding materials, which are composed of siding adhered to a layer of insulated foam board with special flexible adhesives, make the material solid, rigid, impact resistant, and quite efficient, with much less maintenance because of its compact composite nature. Low-maintenance technologies should be ecofriendly, renewable, and self-sufficient. Advances in energy harvesting technologies, such as thermoelectric, piezoelectric, and others can replace the rechargeable-battery systems as self-sufficient devices. By replacing batteries, these technologies eliminate toxic waste from disposable batteries, reduce power consumption and environmental waste, and require much less maintenance with a very low impact.

– Recyclability: Elements should be capable of being easily dismantled, reused, or recycled. Consider, whether they can be salvaged, refurbished, or remanufactured, including saving technologies from disposal by renovating, repairing, or restoring. Elements from salvaged products with pre- and postconsumer recycled content, and products made from agricultural waste should be selected.

- **Sustainable resources**

Resource sustainability requires four important principles: economy/cost effectiveness, on-site conditions, accessibility, and (favorable) natural forces.

– Economy/cost-effectiveness: In order for a building to be economical and cost-effective, the land, utilities, and operational costs should be affordable. Green construction costs should be comparable, if not lower, to traditional construction materials and labor. Overheads should be estimated to be paid back in less than two years. Green building operating expenses should be significantly lower. Energy savings and water reduction technologies should yield a considerable saving, such as 30 percent, or more. Waste generation should be minimized in order to reduce the repairs, maintenance, and landfill tipping fees. In order to reduce operational expenses, indoor air quality should be optimal, which in turn can lead to reduced owner liability by reducing insurance premiums over the life of the building. Moreover, green buildings qualify for subsidies and tax credits for the cost of green technologies and materials. An increasing number of states have started to offer tax credits and additional financing for as much as 50 percent of the cost for green technologies and materials.

– On-site conditions: On-site conditions, including location and functional qualities, should be favorable for a green building. These include proximity to the necessary resources and utility lines, such as water supply, gas mains, electrical poles, and waste management systems.

- Accessibility: Accessibility to transportation should be included in green building design. Close-proximity, high-density mixed developments should be considered to minimize walking distance, to save energy, and to reduce cost. Easy access to public transportation: bus or metro should be provided. Urban refill and reduced site disturbance should also be considered.
- Natural forces: Buildings should be designed based on consideration of existing natural forces and should be built to benefit from them. For example, in cold climates, buildings could be designed in close proximity, such as row-housing units, where common side walls reduce heat loss. The orientation of the building should be selected for proper wind protection (or wind-cooling) and sun exposure. Residential and other building types that require daylight (i.e., hospitals) should be designed carefully so as not to lose solar access. Also important are natural ventilation potential and good ambient air quality. Sensitivity to water quality and runoff minimization issues need to be considered.

- **Sustainable Environments**

Green buildings should provide healthy, habitable environments for its occupants. Buildings with comfortable layouts should be structurally sound and use nontoxic materials and technologies with adequate ventilation and proper filtration. Green buildings should also provide protection from natural, social, and building-related events, and provide and environment for social and institutional connections to occur.

- Healthy: Green buildings should provide healthy environments for occupants that reduce the risk of various airborne diseases, such as asthma or allergies, to prevent sick building symptoms. Zero- or low-emission building products should be used to improve indoor air quality. Architects should avoid using building materials an cleaning/maintenance products that emit, toxic gases, such as volatile organic compounds (VOC) and formaldehyde, which can have a detrimental impact on occupants' health and productivity. Adequate ventilation and a high-efficiency, in-duct filtration system should be provided. Green buildings should offer specific solutions to prevent indoor microbial contamination by: selecting materials resistant to microbial growth; providing effective drainage from the roof and surrounding landscape; installing adequate ventilation in bathrooms; allowing proper drainage of air-conditioning coils, and designing building systems to control humidity.
- Habitable: Green buildings should contain at least minimum habitable requirements for buildings, which include physical safety of the building such as load, separation and classification of the occupants, openings, fire protection, construction type, and adequate structural systems. In addition to local codes, the building's structural, construction, electrical, and plumbing codes should be in line with international building codes. In a business setting, buildings should maximize productivity by minimizing operator fatigue and discomfort.
- Social/institutional capacity: On the nontechnical level, sustainable environments are responsive to the social networks, activities, and events of the occupants. Green building design should consider prevalent social patterns, attitudes, and networks to create effective solutions for their inhabitants. Buildings should enhance a sense

of community and social opportunities, such as providing inviting open spaces and public environments [Lang, Burnette, Walter and Vachon 1974; Lang 1994]. Green buildings should consider incorporating the nature and the interrelationship of organizational design and spatial arrangements, the nature of communities and neighborhoods, and the relationship between family organizations and neighborhood layouts.

– Safety and security: Green buildings should be designed to provide physical protection to the occupants; for instance, by preventing accidents through the choice of building materials and technologies, or supporting the building to withstand natural disasters like earthquakes, high winds, and floods. Buildings should avoid floodplains, or at least raise ground floors above flood levels. A sufficient and simple means of egress is essential to ensure a safe exit in case of fire. Green buildings should also provide a sense of privacy, clear boundaries, users' control, and personalization for occupants, with clear territorial demarcations. According to an empirical study done by Oscar Newman, people own and take control of an area where territorial demarcations are clear. Newman found that crime rates were lower in areas where [1] a clear set of territorial markers differentiate public spaces from semipublic and private spaces; [2] no undefined open spaces exist; [3] opportunities exist for natural surveillance such as watching other people as part of everyday life through the placement of halls, windows, and seating where people gather and overlook other areas; and [4] the use of building and landscaping forms and materials that communicate a positive, defensible image of the residents to outsiders [Newman 1972; Lang, Burnette, Walter and Vanchon 1974; Lang 1994].

Ecology

The term, “ecology” was first coined by Ernst Haeckel (1834-1919) in 1866 as *Okologie,* from Greek Oikos and came into English in 1873. Haeckel first defined the term as “the comprehensive science of the relationship of the organism to the environment” [Frodin 2001]. As a term, “ecology” has Greek roots, reflecting an early concern with humanity. *Oikos* means home oh house in Greek and by extension it means the whole inhabited earth, the *oikoumeme,* the house of all manking. Logos meaning reason or study, is a common suffix applied to many of the sciences, indicating the human mind at work on a given subject [Hughes 1975].

In general, ecology studies the interactions between organisms and their environments. The environment includes physical properties, which consist of biotic and abiotic factors.

Ecological Architecture

Ecological architecture is mainly concerned with how ecological properties impact the building, its occupants, and the environment. The term is generally used as a framework to describe multilevel ecological building design and its balance with nature. This balance is established via three major components:

I. Ecological elements (technological and material).
II. Resource ecology.
III. Environmental ecology.

- **Ecological elements**

Ecological elements should be selected from natural or minimally-processed earth resources. They should be biodegradable, renewable, and clean elements with low-embodied energy.

TABLE 2 COMPONENTS FOR ECOLOGICAL ARCHITECTURE [5]

ELEMENTS	RESOURCES	ENVIRONMENT
Clean (nonpollutant/ low-emission)	Resource share	Pollution (air/water/land)
Earth resources	Soil/landscape	Global stewardship
Biodegradable	Site selection	Biodiverse
Low-embodied energy	Water resources and use	Land use
Renewable	Waste management (low solid waste)	

– Clean (nonpollutant/low-emission): Materials and technologies should consist of low-emission, nonpollutant elements with low manufacturing impacts. Ecological materials should facilitate a reduction in polluting emissions from building maintenance and should not be made from toxic chemicals. These materials clearly exclude the components [1] with substances that deplete stratospheric ozone [2] and are associated with ecological damage or health risks, including mercury and halogenated compounds. Ecological elements should avoid ozone-depleting substances (ODS), such as hydrochlorofluorocarbon (HCFC) and hydrobromofluorocarbon (HBFC).

Green buildings should incorporate clean building technologies based on non-fossil-based, renewable energy sources (i.e., wind power, solar power biomass, hydropower, biofuels) to reduce the use of natural resources, and cut or eliminate emissions and wastes. Today, clean technologies are competitive with their conventional counterparts with low carbon footprints and additional benefits, such as cost and efficiency.

- Earth resources: Materials and technologies should be selected from natural or minimally processed earth resources, due to their renewability, low energy use, and low risk of chemical releases during their life cycles. Elements that reduce raw material use should especially be the choice for green buildings, mainly because of their resource conservation. Engineered certified products from renewable resources should be considered as the first choice. For example, a manufacture wood certification, such as Forest Stewardship Council (FSC) is the best way to ensure that the wood material is not produced from natural forests or others habitat around the world. These products contain wood content as low as 17 percent, and the rest of the fiber content is from recycled resources.
- Low-embodied energy: Material and technologies that eliminate or reduce energy for excavation, production, manufacturing, construction, and demolition activities (including salvaged and pre- and postconsumer recycled content) should be selected for green buildings. Since local elements do not require long-distance transportation, shipping, and servicing, they are inherently low-embodied products. Special attention should be given to the elements that save energy and water by reducing heating and cooling loads and conserving energy.
- Renewable: Elements that utilize alternative renewable energy resources, instead of fossil fuels and conventionally generated

electricity are highly beneficial from an ecological standpoint. Renewable materials should be selected from products that are made from rapidly growing natural resources. These materials have reduced net emissions of CO_2 across their life cycle and have broad economic benefits.

– Biodegradable: Biodegradable building materials in green buildings are easiest to recycle and, therefore, can reduce waste, pollution, and energy use. Since these materials come from nature (such as plants and minerals), they are broken down easily by microorganisms, and return to their natural states over time. They are readily disassembled into individual materials. Natural biomaterials such as clay, brick, straw, and additives such as biopolymers and biodegradable resins should be selected as building material choices.

- **Ecological resources**

Sharing the resources among buildings, site selection, soil type, and groundwater conditions must be taken into consideration before the building is designed and constructed. Water and waste-management resources should be ecologically constructed and used.

– Resource share: Buildings are responsible for one-sixth of the world's fresh water withdrawals, one-quarter of its wood harvest, and two-fifths of its material and energy flows [Roodman and Lenssen 1995]. All architectural projects (including buildings, parks, memorials, etc.) should share resources with each other effectively and efficiently.

  Green buildings that are connected enjoy an equal share of resources with maximized distribution. For instance, row, attached, and cluster housing share utilities like heat, water, and sewage. Reducing the natural resource consumption should be targeted right from the start, at the design stage. Architects should focus on design issues such as shared outdoor areas, energy, water and sewage networks, the building's frame, and mechanical and electrical services.

– Soil/landscape: Architects should select the right soil and landscaping for the building type. Soil type and groundwater conditions must be taken into consideration before the building is designed and constructed. Groundwater conditions are important because of their impact on waterproofing as well as structural design. Architects must make sure that water tables underneath the foundation will not be harmed or leaked into/from the sewage system. A high water table may require costly structural and waterproofing techniques and make a site unsuitable.

  Construction damage to biotic factors (such as trees and plants) should be minimized. The type and stability of soil should be taken seriously, not only because of possible building damage but also because of potential problems to the soil ecology such as erosion, pollution, sedimentation, and various forms of soil degradation. For example, when too much erosion occurs in a specific area, the water washes away many of the nutrients in the soil. Architects should also avoid converting ecologically productive environments into suburban sprawl or extending out onto land that is reclaimed from the sea (i.e., Hong Kong). Although this action might seem to provide valuable room for development, it results in the loss of rich fishing grounds and ecologically valuable wetlands [Hudson 1979].

- Site selection: Site selection is one of the most important resource factors in ecological architecture. Natural qualities, such as water, orientation, vegetation, view, and climate must be considered. Man-made factors like location, utilities, services, other buildings, roads, etc., should be integrated into green building design. Specific site conditions such as steep slopes over 15 percent, severe climatic exposure, earthquake danger areas, flood zones, and unstable soil should be avoided.
- Water resources and use: Availability of and access to clean water, along with water conservation, should be the main priorities of green building design. Buildings should avoid excessive use of groundwater for activities other than cleaning and cooking. Architects should install water-saving, ecofriendly devices, recycles gray water for flushing and landscaping, and harvest rainwater. Water-efficient landscaping should be provided. A building site planted with native plants coexists much better with its natural surroundings. Green buildings should use no more than 50 percent of the potable water for irrigation that a typical commercial property of similar size in that area would use. Green buildings should use 30 percent less water than the baseline calculated for traditional buildings (not including irrigation). In order to maximize water efficiency, architects should install water efficient fixtures and appliances.
- Waste management: Waste management should be dealt with as an on-going process at different stages throughout the building cycle. A significant amount of waste is generated by the construction of a typical building. Green buildings should be designed to eliminate waste by using modular systems of construction, recycled products, and efficient use of materials.

Demolition waste should be recycled by using a percentage of reclaimed materials in other construction projects.

During the building's life cycle, disposal of all waste should be recycled and treated. All treatment activities must take place within the building with an impermeable surface and sealed drainage system.

- **Ecological Environments**

The prevention of pollution (air, water, and land) is one of the main objectives of green buildings. Global stewardship should be implemented by thinking globally and acting locally. Biodiversification issues should be incorporated into design by preserving existing ecosystems. Planning for responsible land use should address these issues by considering climate, existing ecosystems, and the natural environment.

– Pollution control: The materials, technologies, and type of energy used in the buildings should be selected from nonpollutant elements. Architects should avoid using products that contain compounds that pollute the air (both indoors and out).

Inadequate or faulty pipelines and sewage system installation should be avoided at all costs. Leakage from these systems pollutes soil and groundwater. Runoff water, including flood control and water supplies, should be managed with a well-designed stormwater system. Green buildings should provide proper drainage systems that collect runoff from impervious surfaces (e.g., roofs and roads) to ensure that water is efficiently conveyed to waterways through pipe networks. Architects should consider using integrated water management (IWM) techniques, including stormwater harvest (to reduce the amount of water that can cause flooding), infiltration (to restore the natural recharging of groundwater), biofiltration or bioretention (e.g., rain gardens) to store and treat runoff to be released at a controlled rate, and wet-land treatments (to store and control runoff rates and provide habitat in urban areas).

- Global stewardship: Green architects should think globally and act locally. Green buildings should promote and pursue nonrenewable alternative energies, renewable and recyclable materials, and energy- and water-saving technologies. Whereas the material and technological choices should be selected locally, their ecological implications and ramifications of those choices should be considered in the long term and globally.
- Biodiverse: Green buildings should be designed to be in contact with nature, integrating biodiverse systems, such as trees, gardens, and green roofs. If artificial ecosystems are introduced, they should be adaptable to their new environment. Green roof scan be designed as part of the building construction, where they provide natural insulation, filter and control stormwater runoff, absorb up to 90 percent of the rain water, and reduce the urban heat island effect. Landfills and soil erosions can be prevented by displacing soil in different parts of the construction and adding trees, shrubs, and other biotic factors to the site.
- Land use: Land use should be planned to save resources and energy use over a large area and to create diverse uses and activities. From an ecological perspective, land use should be responsive to the needs of the building occupants and other members of the community, considering such factors as transportation, infrastructure, and landscape. Trees and other natural

features should be protected by developing a preservation plan with no disturbance zone, and by avoiding trenching, grade change, and compacting soil. Undeveloped land should be protected by leaving it in its natural state, not by being excavated or altered. Leaving the site in its natural state allows for storm water to percolate into the ground, rather than running off into artificial storm drains and costly treatment facilities.

- **Performance**

Performance is defined as the manner of functioning, implying action that follows established patterns or procedures, or fulfills agreed-upon requirements. The term has transitive properties such as execution (carrying out what exists in plan or in intent),

Discharge (completion of appointed duties and tasks), and fulfillment (complete realization of ends or possibilities). It also has intransitive properties such as accomplishment (successful completion of a process rather than the means of carrying it out).

In architecture, building performance id defined as a measurable outcome of the functional, structural, and environmental qualities of the building. These qualities are measured by determining how well the building supports the need of its users, including materials and technologies, resources, and environmental behavior of the building. The major concerns for the health, safety, and welfare of the building occupants are addressed by building codes, standards, and regulations [Bullen 2006]. As a general framework, green building performance considers all building components during the life cycle by integrating all the subsystems and parts of the building to work together. This is established via three main operational components (see Table 3):

I. Performance of the elements (materials and technologies).
II. Resources performance.
III. Environment performance.

TABLE 3 COMPONENTS FOR HIGH-PERFORMANCE ARCHITECTURE [5]

ELEMENTS	RESOURCES	ENVIRONMENT
Efficiency	Economic	Adaptability
Effectiveness	Ecobehavior	Functionality
Productivity	Design	Environmental quality

- **Performance of elements**

The elements should perform efficiently (in terms of energy, water, cost, and resources), effectively based on their behavioral and physical properties, and productively such as adding value on resources consumed.

– Efficiency: Green-efficient materials and technologies are high-performance elements that have high source adaptability and are easy to operate, retain, and recover. They use less energy to perform as well or better than traditional elements. They are energy-, water-, cost-, and resource-efficient, reliable elements that produce more with the least possible waste of time and effort, and reduce the overall impact of the built environment on the occupants and the natural environment.

  Energy efficiency in green buildings can be accomplished through the reduction of energy consumption by using energy-efficient lighting, heating, and cooling systems; developing strategies for passive (solar) design and natural lighting; and considering alternative and renewable energy sources for energy generation and retention.

Water efficiency can be accomplished by minimizing wastewater with conserving elements; using self-closing systems and microirrigation to supply water for landscaping; and using recycled water for toilet flushing or a gray water system that recovers rainwater or other nonpotable water for site irrigation.

Resource efficiency can be accomplished by utilizing locally available elements with recycled, renewable content with minimal waste. These materials and technologies can be reclaimed from disposal and reused by renovating, repairing, restoring, or generally improvising the appearance, performance, quality, functionality, and value.

– Effectiveness: The effectiveness of elements measures the performance level, which includes all physical, structural, thermal, and behavioral performance factors of the materials and technologies. The results derived from green elements should exceed the actual results of the standard industry elements.

  Effective behavioral qualities:

    - Strength
    - Stability
    - Fire/heat resistance
    - R-value
    - Conduction

  Physical properties:

    - Structure
    - Thermal
    - Light

- Electrical

– Productivity: The productivity of materials and technologies is measured based on the relationship and ratio between produced result and the resources consumed. A green building should function productively by using energy economically, by protecting the occupants by reacting to environmental and ecological conditions automatically. New smart green materials and technologies benefit the occupants of the building and the environment because of their timely adjustments; e.g., they are constantly monitoring changes and adapting to them. For example, according to Siemen's report, heating and cooling systems, and continuous monitoring and management of lights, coupled with access and control detectors can cut electricity use by 45 percent and reduce energy consumption by 17 percent. When used properly, smart materials can create productive solutions by producing, converting, and storing surplus energy for future use.

- **Resource performance**

Green buildings should contribute to the surrounding are economically, and preserve and protect the ecosystem. They also should incorporate active and passive green strategies, consider market realities, and respect building grammar and human behavior.

– Economic: Green buildings should contribute to the economy by providing opportunities for long-term growth for residents, retailers, and commercial tenants, as well as for entire area. A new green building development can create a community-based economy, where people spend most of their time and can find all the goods and services required to meet their daily needs.

- Ecobehavior: The Ecobehavior of a building can be assessed by measuring its preservation, protection, and enhancement of biodiversity and ecosystems. Ecobehavior can be achieved by improvising air and water quality, reducing waste streams, and conserving and restoring natural resources.
- Design: Green buildings should address the issues of material, technological, environmental, social, and economical aspects of architectural design by balancing active and passive strategies, market realities, building aesthetics, and human behavior. Green building design performance relies on the implementation and coordination of these issues. The separation and/or alienation of any one of these issues will make the green design process incomplete and may produce disappointing results.

- **Environmental performance**

Green building should be adaptable to the climate, and to environmental changes. Architects should ensure the environmental quality for all occupants by providing comfortable, healthy, and habitable buildings.

- Adaptability: Green buildings should be physically, functionally, and socially adaptable to the environment and perform according to environmental changes. Changes in climate, social patterns, or trends should not end the building's life span, but should rather give birth to different uses for the building.
- Functionality: The functionality of a green building is determined by the capability of operation of the elements and the resources on the environment. The building should serve well the original function it was designed for. Moreover, multi-functionality adds to the life span and value of a building and the return of equity.

– Environmental quality: The environmental quality of green buildings should ensure that they are healthy for their occupants, more comfortable, and easier to live in due to lower costs and maintenance requirements. Green buildings should maximize daylighting; have appropriate ventilation and moisture control; and avoid the use of hazardous and toxic materials. Additional consideration must be given to ventilation and filtration to mitigate chemical, biological, and radiological leakage.

Green

Green is an abstract concept, which requires the inclusion of the terms: sustainability, ecology, and performance. Though there is a categorical relationship between the sub-terms, each category is nevertheless independent and mutually exclusive. For instance, a building can be sustainable but not ecological or green, whereas a green building must be a combination of sustainable, ecological, and performative. The level of greenness is determined based on the level of interaction of these three categories. (see Fig. 1)

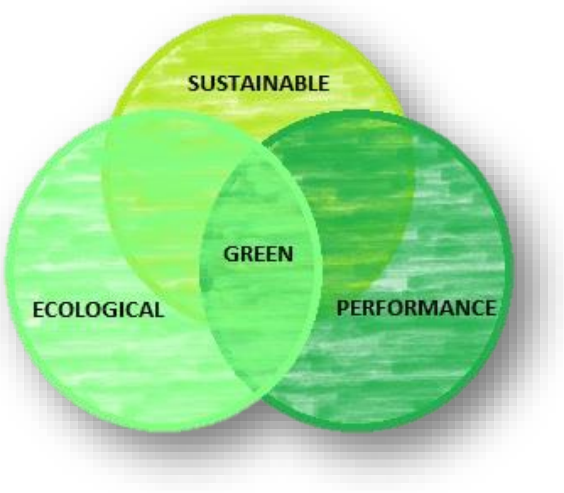

Figure 2 Relationship between the green categories.

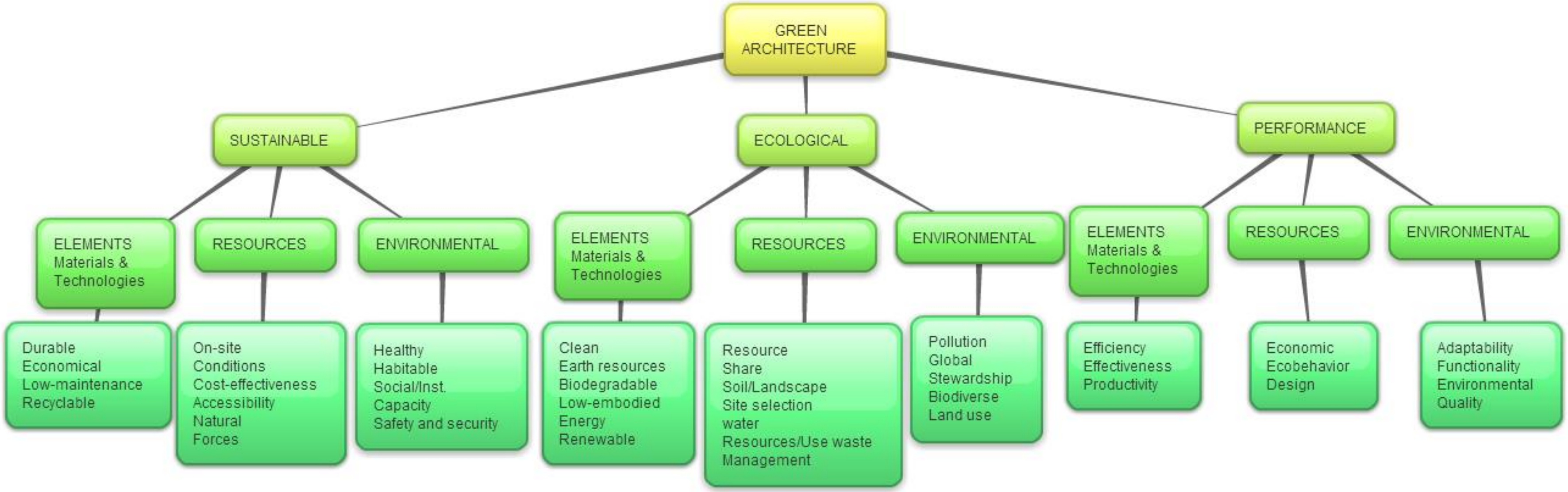

Figure 3 Taxonomy of Green architecture. [5]

3. SUSTAINABLE CONSTRUCTION MATERIALS:

Since building materials constitute a large part of the environmental burden created by a building, one of the easiest ways of beginning to incorporate sustainable design principles in our projects is by the careful selection of environmentally sustainable building materials.

The assessment of environmental materials begins with establishing criteria for evaluating building materials. These criteria should complement the overall environmental project goals with often extensive research to evaluate prospective products.

Based on the environmental material criteria established for a green building project, selection of appropriate building products and systems can be accomplished.

When selecting green building materials, environmental criteria and proper application of the materials should be considered. The following are the three phases of the environmental assessment process:

- Research.
- Evaluation.
- Selection.

The research phase includes gathering information directly manufacturers such as:

- Obtaining material safety data sheets (MSDs).
- IAQ test data (if available).
- Environmental Statements.
- Recycled content data.
- Durability information.
- Product warranties.

Once the research and information gathering is complete, the evaluation phase begins including the confirmation of the information provided by the manufacturers and requests for missing or incomplete data. The evaluation and assessment can be accomplished by comparing similar types of building materials based on the environmental criteria.

The final phase of the environmental assessment process consists on the selection of sustainable materials which is based on the product that best meets the established environmental criteria and the most appropriate for the project.

3.1. FIVE SUSTAINABLE MATERIALS

As global populations increase, so too will the need for accommodation. However, current mainstream building methods are unsustainable, producing large amounts of CO_2 both during construction and throughout a building's life. Thankfully, sustainability is becoming a priority for developers, and with many exciting innovations happening in the construction industry, sustainably addressing global accommodation needs seems possible. Here's five materials that could help:

- **Wool bricks:**

  Developed by Spanish and Scottish researchers with an aim to obtain a composite that was more sustainable, non-toxic, using abundant local materials that would mechanically improve the bricks strength, these wool bricks are exactly what the name suggests. Simply by adding wool and a natural polymer found in seaweed to the clay of the brick, the brick is 37% stronger than other bricks, and more resistant to the cold wet climate often found in

Britain. They also dry hard, reducing the embodied energy as they don't need to be fired like traditional bricks.

- **Solar tiles:**

  Traditional roof tiles are either mined from the ground or set from concrete or clay (all energy intensive methods). Once installed, they exist to simply protect a building from the elements despite the fact that they spend a large portion of the day absorbing energy from the sun. With this in mind, many companies are now developing solar tiles. Unlike most solar units which are fixed on top of existing roofing, solar tiles are fully integrated into the building, protecting it from the weather and generating power for its inhabitants.

- **Sustainable concrete:**

  Whilst 95% of a building's CO_2 emissions are a result of the energy consumed during its life, there is much that can be done to reduce that 5% associated with construction. Concrete is an ideal place to start, partly because almost every building uses it, but mostly due to the fact that concrete is responsible for a staggering 7-10% of global CO_2 emissions. More sustainable forms of concrete exist that use recycled materials in the mix. Crushed glass can be added, as can wood chips or slag (a byproduct of steel manufacturing). Whilst these changes aren't radically transforming concrete, by simply using a material that would have otherwise gone to waste, the CO_2 emissions associated with concrete are reduced.

- **Paper insulation:**

  Made from recycled newspapers and cardboard, paper-based insulation is a superior alternative to chemical foams. Both insect resistant and fire-retardant thanks to the inclusion of borax, boric acid, and calcium carbonate (all completely natural materials that have no associations with health problems), paper insulation can be blown into cavity walls, filling every crack and creating an almost draft-free space.

- **Triple-glazed windows:**

  In fact, super-efficient windows would better describe this particular building material. The three layers of glass do a better job of stopping heat from leaving the building, with fully insulated window frames further contributing. In most double-glazed windows, the gas argon is injected between each layer of glass to aid insulation, but in these super-efficient windows, krypton (a better, but more expensive insulator) is used. In addition to this, low-emissivity coatings are applied to the glass, further preventing heat from escaping.

A building that combined all five of these methods would be an admirably sustainable option for housing. Whilst the construction industry tends to progress at a slow pace, the importance of sustainability is a high profile issue, and one which is only likely to increase. With sustainable building materials already fully developed, it is now up to consumers to actively demand their use and building developers to respond promptly.

3.2. ASSESSMENT AND SELECTION OF THE ENVIRONMENTAL IMPACT OF MATERIALS

3.2.1. CONCEPT OF LIFE-CYCLE DESIGN AND ITS PHASES

The environmental impact of materials is caused during their complete life time, from the gathering of raw materials, manufacturing, distribution and installation to their final reuse or disposal, a process known as "cradle-to-grave".

That is why it is necessary to analyze each step of a material's life-cycle in order to evaluate the environmental impact of a product.

The principles of Life Cycle Design provide important guidelines for the selection of building materials. A material's Life-Cycle can be organized into three different phases paralleling the line cycle phases of a building site:

- Pre-building phase.
- Building phase.
- Post-building phase.

I. <u>The Pre-building Phase</u>

It refers to the manufacturing process, describing the production and delivery of materials up to the point of their installation. This includes discovering raw materials in nature as well as extracting, manufacturing, packaging and the delivery/transportation to the construction site.

This phase has the most potential for causing environmental damage because of the environmental consequences produced by:

- Raw material procurement methods.
- Manufacturing process.
- Distance from the manufacturing location to the building site.

A material is only considered renewable if it can be grown at the same rate that meets or exceeds the rate of human consumption. So the extraction of raw materials from nonrenewable sources has severe consequences causing ecological damage.

This ecological damage includes the *loss of wildlife habitat*, due to the microclimate alteration and the damage of certain ecosystems which leads to the extinction of a high number of species. It also includes the *erosion of the top soil and runoff into streams and rivers,* resulting on a plant die-off and a decrease of the amount of oxygen to other life forms.

Not to forget the *water and air pollution* from waste and toxic by-products of mining and harvesting operations. The machinery needed, burns fossil fuels and the combustion engines emit several toxic gases such as:

- Carbon monoxide.
- Carbon dioxide.
- Sulfur dioxide and nitrous oxide.

II. The Building Phase

This phase includes the On-site Construction Process from the moment materials are delivered to the site, including its installation, operation, maintenance and repairments.
From the perspective of the designer, multiple choices will have to be made in order to increase the material's useful life and its durability, such as reducing construction waste and selecting more durable materials.

III. <u>The Post-building Phase</u>

This one could be the least considered and understood phase of the building life cycle, occurring when the building or material's life span has been expired.

From this point on, two main concepts should be differentiated depending on whether we are thinking of reusing or recycling some of the products or waste them:

- Deconstruction.
- Demolition.

In the context of physical construction, "deconstruction" is the selective dismantlement of building components, specifically for reuse, recycling and waste management. It has also been defined as "construction in reverse". It differs from "demolition", where a site is cleared of its building by the most expedient means.

The process of dismantling structures is an ancient activity that has been revived by the growing field of sustainable and green building. Buildings, like everything, have a life-cycle. Deconstruction focuses on giving the materials within a building a new life once the building as a whole can no longer continue.

When buildings reach the end of their useful life, they are typically demolished and hauled to landfills. Building implosions or "wrecking-ball" style demolitions are relatively inexpensive and offer a quick method of clearing sites for new structures.

On the other hand, these methods create substantial amounts of waste. Components within old buildings may still be valuable, sometimes more valuable than at the time the building was constructed.

To sum up, the demolition of buildings and disposal of the resulting waste has a high environmental cost because degradable materials may produce toxic waste, alone or in combination with other materials. So the energy embodied in the construction of the building itself and the production of these materials will be wasted if these "resources" are not properly utilized.

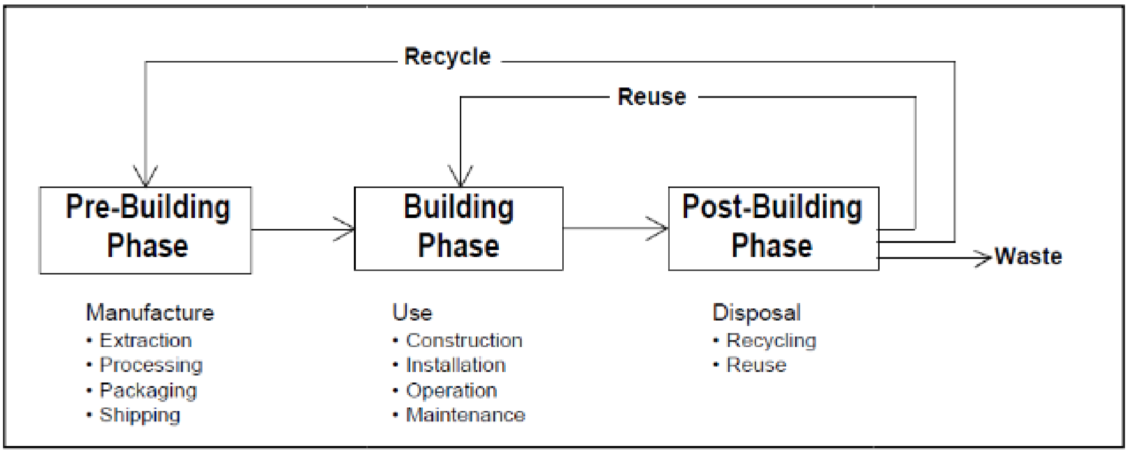

Figure 4 Phase of the building materials' life cycle. [6]

3.2.2. ASSESSMENT OF SUSTAINABLE BUILDING MATERIAL'S FEATURES

The past thirty years have seen increasingly rapid advances in the fields of the selection and incorporation of more environmentally building materials to the construction projects.

As mentioned before, it is not only important to focus on a single attribute of a material's life-cycle but, in order to understand the whole environmental impact of a product, it becomes necessary further research and a more complex study of the behavior of the material through the different phases.

On this section, these relationships are studied: the three main phases of a life-cycle design of a material with the different types of sustainable features that a product can accomplish through its entire life. The greater amount of these features a material has, the more sustainable it will be and the less environmental impact it will cause.

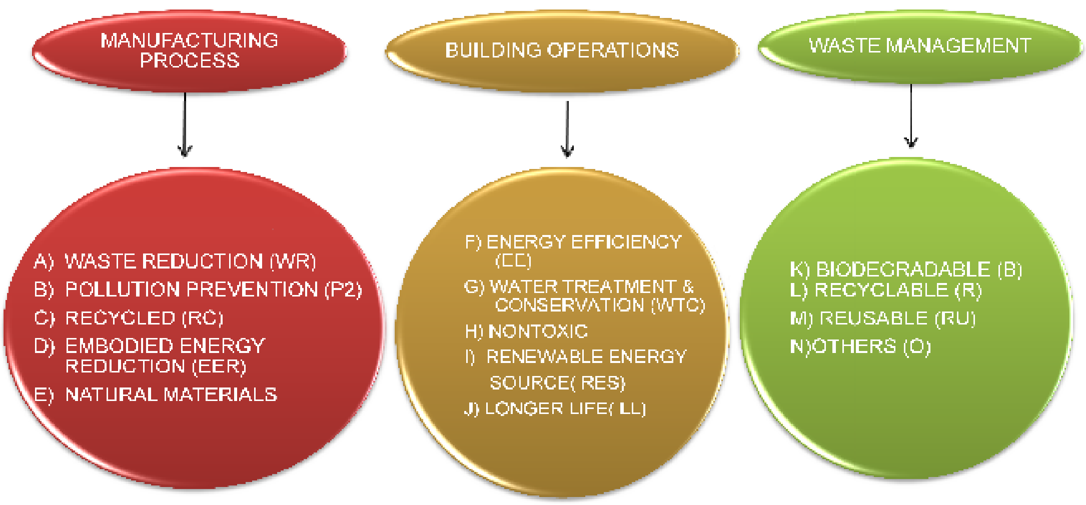

Figure 5 Green features of Sustainable building materials. [6]

On the next pages, each one of these features and the way to achieve them will be explained.

The *Pre-building Phase* of a material's life-cycle refers mainly to the manufacturing process where some of the next features can be improved with the finality of reducing the amount of green house gases emitted into the atmosphere.

- **Waste reduction**

  In industries, using more efficient manufacturing processes and better materials will generally reduce the production of waste. The application of waste minimization techniques has led to the development of innovative and commercially successful replacement products. Waste minimization has proven benefits to industry and the wider environment.

  That is why; manufacturers have taken a few steps over the standard regulations to obtain a more efficient and environmentally sustainable production process.

  On the one hand, this goal can be achieved by reducing the amount of scrap materials which can be immediately re-incorporated at the beginning of the manufacturing line so that they do not become a waste product.

  On the other hand, industries can create power from the use of their own waste products such as reusing the water used for cooling equipment after being filtered instead of wasting it into the waste stream.

- **Pollution prevention measures**

  By reducing the amount of air, water and soil pollution during the manufacturing process, the indoor air quality improves not only for the building itself but for the workers as well.

  When we generate waste or pollution, we must safely and legally manage that waste of pollution. Here are some reasons to prevent pollution:

  - Improved work environment and worker safety.
  - Reduced liability.
  - Increased efficiency.
  - Fewer regulatory requirements.
  - Better environmental protection.

- **Recycled**

  A product featuring *recycled content* has been partially or entirely produced from post-industrial or post-consumer waste. The incorporation of waste materials from industrial processes into usable building products reduces the waste stream and the demand on virgin natural resources.

  By recycling materials, the embodied energy they contain is preserved, so the energy used in the recycling process for materials is far less than the energy used in the original manufacturing.

  Key building materials that have potential for recycling include glass, plastics, metals, concrete, brick, and wood.

- **Embodied energy reduction**

  The construction industry requires the extraction of vast quantities of materials and this, in turn, results in the consumption of energy resources and the release of deleterious pollutant emissions to the biosphere.

  Each material has to be extracted, processed and finally transported to its place of use.

  They energy consumed during these activities is critically important for human development, but also puts at risk the quality and longer term viability of the biosphere as a result of unwanted or "second" order effects.

  Many of these side-effects of energy production and consumption give rise to resource uncertainties and potential environmental hazards on local, regional or national scales.

  Energy and pollutant emissions such as carbon dioxide (CO_2) may be regarded as being "embodied" within materials. Thus, embodied energy can be viewed as:

  "The energy consumed by all of the processes associated with the production of a building, from the acquisition of natural resources to product delivery, including mining, manufacturing of materials and equipment, transport and administrative functions" (CSIRO 2008).

  The next table shows the quantity of embodied energy and embodied carbon emissions of different material (bricks, mortar, concrete, glass…):

MATERIALS	Embodied Energy (MJ/Kg)	Carbon Energy (KgC/Kg)
BRICKS		
General	3	0,06
Limestone	0,85	-
CEMENT		
General	4,6	0,226
Portland cement, wet kiln	5,9	0,248
Portland cement, dry kiln	3,3	0,196
Fibre cement	10,9	0,575
Mortar (1:3)	1,4	0,058
Mortar (1:4)	1,21	0,048
Mortar (1:0,5:4,5 cement;lime;sand mix)	1,37	0,053
Mortar (1:1:6 cement;lime;sand mix)	1,18	0,039
Mortar (1:2:9 cement;lime;sand mix)	0,85	0,038
CONCRETE		
General	0,95	0,035
Precast Concrete, cement;sand;aggregate	2	0,059
1:1:2 (high strength)	1,39	0,057
1:1,5:3 (used in floor slabs,columns...)	1,11	0,043
Fibre-reinforced	7,75	0,123
Road and pavement	1,24	0,035
GLASS		
General	15	0,232
Fibreglass	28	0,417
Toughened	23,5	0,346
STEEL		
General	24,4	0,482
General, primary	35,3	0,749
General, secondary	9,5	0,117
Galvanised sheet primary	39	0,768
Stainless	56,7	1,676
TIMBER		
General	8,5	0,125
Glue laminated timber	12	-
Hardboard	16	0,234
MDF	11	0,161
Particle board	9,5	0,139
Plywood	15	0,221

Figure 6 Embodied and Carbon energy of different materials. [8]

- **Natural materials**

  Natural material are generally lower in embodied energy and toxicity than man-made materials because they require less processing and are less damaging to the environment. Many, like wood, are theoretically renewable and by incorporating low-embodied-energy materials into building products, these become more sustainable.

  During the *Building Operation's Phase* certain aspects that contribute to the sustainability and to the energy and water reduction of our buildings must be studied and analyze during the design process of the project.

- **Energy efficiency**

  Investing in efficiency is critical to meeting future energy demand and mitigating climate change. It reduces greenhouse gas emissions and improves productivity. By reducing the energy demand, efficiency also makes renewable energy more affordable.

  Adopting cost-effective standards for a wider range of technologies could, by 2030, reduce global projected electricity consumption by buildings and industry by 14%, avoiding roughly 1300 mid-size power plants. Between 1990 and 2006, increased energy efficiency in the manufacturing sectors of 21 member countries of the International Energy Agency resulted in a 21% reduction of energy use per unit of output.

  So in order to assess the energy efficiency, crucial factors must be evaluated during the design phase such as; the resistance to heat flow "R-value", the rate of heat lost "U-value", the shading coefficient, the illumination efficiency measured in “lux” or the control of the contribution of natural light into a building.

- **Water treatment and conservation**

  In recent years, there have been an increasing amount of studies on improving new innovative waste water technologies with the objective or reducing the amount of potable water used for flushing fixtures, to minimize the quantity of water that must be treated by municipal septic systems as well as to increase the quality of the water.

  According to Jon-Jin Kim, there are two to accomplish the water/treatment conservation feature:

  - By restricting the amount of water through the fixtures, using water-saving showerheads, faucets and vacuum-assisted or composting toilet.
  - By recycling the water that enters the site, separating the waste-water stream into “*Greywater*” (obtained from the cooking or hand-washing) from “*Blackwater*”. This can be achieved by installing a greywater treatment and disinfection system.

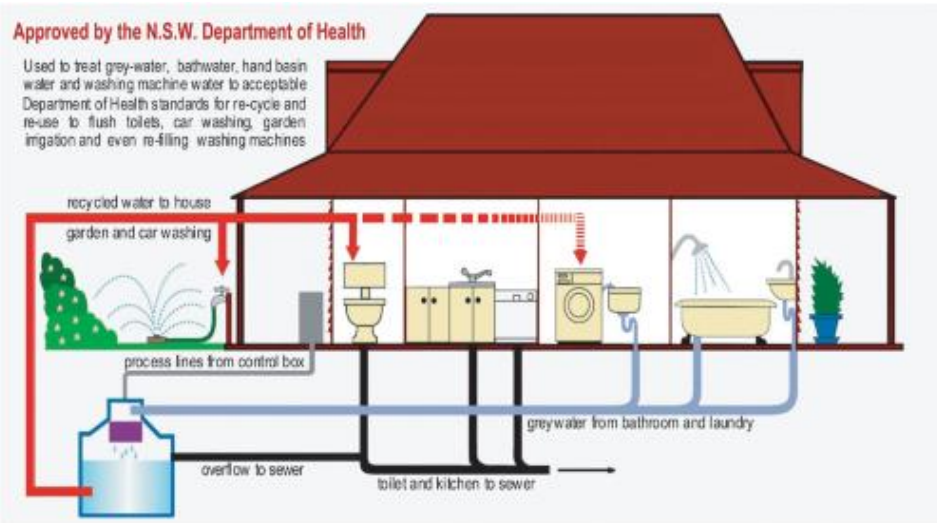

Figure 7 Household greywater recycling diagram. [6]

- **Use of non-toxic or less-toxic materials**

  The relative sustainability of materials is also a function of its impact on human health. A number or modern building materials, particularly adhesives used in wood products and floor finishes (carpets, linoleum, vinyl and floorings), paints, sealers and sealants emit indoor air pollutants, which are harmful to human beyond a certain level of concentration.

  The most commonly discussed indoor air pollutants are:

  – Volatile organic compounds (VOCs).
  – Microbial contaminants (fungi, bacteria, viruses).
  – Non-viable particles.
  – Inorganic chemicals (nitrogen oxides, carbon monoxide, carbon dioxide, ozone).
  – Semi-volatile organic compounds (SVOC-including pesticides and fires retardants).

  Major health effects of indoor pollutants:

  – Infectious disease: flu, cold, pneumonia.
  – Cancer, other genetic toxicity, teratogenicity (Ecotoxicity).
  – Asthma and allergy.
  – CNS, skin, GI, respiratory, circulatory, musculoskeletal, and other systemic effects.
  – SBS (Sick Building Syndrome).

  In addition to the impact of these materials on human health, it is also important to know their environmental impact because some materials will either release toxic materials during their use or degrade into harmful substances in landfills.

- **Renewable energy sources**

  As the earth natural resources are finite, it becomes more and more necessary to adopt currently new renewable energy sources that supplement or eliminate the traditional cooling, heating and electrical system of our buildings in order to reduce the environmental impact.

  Some of the main renewable technologies are:

  - Solar power.
  - Wind power.
  - Hydropower.
  - Biomass.
  - Biofuel.
  - Geothermal energy.

- **Longer life**

  From a sustainability perspective, a material, component or system may be considered durable when its useful service life is fairly comparable to the time required for related impacts on the environment to be absorbed by the ecosystem.

  Material with a longer life relative to other materials designed for the same purpose need to be replaced less often.

  Durable materials that require less frequent replacement will require fewer raw materials and will produce less landfill waste over the building's lifetime. Two important factors are related to the longer life of materials:

  - Durability.
  - Low maintenance.

Materials with longer life-cycling will be more cost-effective than some other materials that need to be replaced more often and on the other hand it should be considered that a short period in cleaning materials reduces the exposure of the building occupants to cleaning chemicals.

Finally, during the last phase of a material's life-cycle design, *"the Post-building phase"*, concepts such as biodegradability, recyclability and reusability of the materials, have to be considered because once the building's materials lifespan has expired, three possible solutions can be given for those (from a waste management point of view) from the deconstruction o demolition process:

- Landfill (grave).
- Recycle (Post-consumer waste as a raw materials for manufacturing).
- Reuse (Post-consumer waste in refurbished/salvaged products).

- **Biodegradability**

  An important green feature for sustainable materials is their biodegradability, which refers to the potential of the material to naturally decompose itself when its usefulness expires.

  Organic materials can return to the earth rapidly, while others, like steel, take a long time reducing them to the natural condition. One consideration to take into account is whether the material in question will produce hazardous materials as it decomposes, either alone or in combination with other substances.

- **Reusability and recyclability**

  Reusability of materials is a function of their age and durability. Very durable materials may have many useful years of service left once the building in which they are installed is decommissioned, and may be easily extracted and reinstalled in a new building site.

  So one of the ways of making a building more sustainable is by using materials that have been recovered from a demolition or deconstruction site because it reduces the amount of raw materials and the impact on landfills.

  Some entities such as the Building Materials Reuse Association (BMRA) are increasing opportunities for the recovery and reuse of building materials in an environmentally sound and financially sustainable way with the next objectives:

  - Providing opportunities for Members and others interested parties to share information and increase knowledge and understanding of deconstruction and reuse of building materials.
  - Educating the construction and demolition industry, the general public, institutional and governmental organizations about:
    - Benefits of deconstructing building for reuse and recycling ways that used building materials may stimulate economic activity via new markets and job creation while also promoting environmental benefits.
    - Certifications and standards that will increase the marketability, value and use of reclaimed building

materials in new and renovation construction projects.

- And conducting research and creating new knowledge.

Recycling is a process that uses waste materials into new products to achieve certain conditions such as:

- Preventing waste of potentially useful materials.
- Reducing the consumption of fresh raw materials.
- Reducing energy usage.
- Reducing air pollution (from incineration) and
- Reducing water pollution (from land filling).

With the application of these conditions, not only the need for "conventional" waste disposal is reduced but also the greenhouse gas emissions.

Recycling is a key component of modern waste reduction and is the component of the "Reduce, Reuse, and Recycle" waste hierarchy.

Figure 8 The three "R"s. [6]

3.2.3. TOOLS FOR ASSESSING THE ENVIRONMENTAL IMPACT AND SUSTAINABILITY OF BUILDING

As a result of the increased interest on the application of Sustainable Practice (green construction), a great number of organizations have developed codes and rating systems to study the environmental performance of buildings in the construction sector, establishing minimum requirements for constructive elements such as materials or energy efficiency systems.

The next table shows some of the diverse tools used by different countries to analyze and control the environmental impact of a construction:

BUILDING ENVIRONMENTAL ASSESSMENT TOOLS	
COUNTRY	TOOL
Australia	Nabers / Green Star /Basix
Brazil	Aqua / LEED Brasil
Canada	LEED Canada / Green Globes / Built Green Canada
China	GBAS
Finland	PromisE
France	HQE
Germany	DGNB / CEPHEUS
Hong Kong	BEAM Society Limited
India	Indian Green Building Council / GRIHA
Italy	Protocollo Itaca / Green Building Council Italia
Japan	CASBEE
Republic of Korea	Korea Green Building Council Certification
Malaysia	GBI Malaysia
Mexico	LEED Mexico
Netherlands	BREEAM Netherlands
New Zealand	Green Star NZ
Spain	VERDE
United States	LEED / Living Building Challenge / Green Globes /Build it Green / NAHB NGBS / International Green Construction Code / Energy Star
United Kingdom	BREEAM
United Arab Emirates	Estidama
Czech Republic	SBToolCZ

Figure 9 Building environmental assessment tools. [9]

Among some of the most known green building rating systems are BREEAM (United Kingdom), LEED (United States and Canada), DGNB (Germany) and CASBEE (Japan), in which they award credits (determining the level of achievement) for optional building features that support green design in categories such as:

- Location and maintenance of building site.
- Conservation of water.
- Energy Efficiency.
- Building materials.
- Occupant comfort and health.

LEED (Leadership in Energy & Environmental design)

Following the information of the U.S. Green Building council (USGBC) in 1993, the organization's members quickly realized that the sustainable building industry needed a system to define and measure "green building", USGBC began to research existing green building metrics and rating systems.

The first LEED Pilot Project Program, also referred to as LEED Version 1.0 was launched at the USGBC Membership Summit in August 1998. After extensive modifications, LEED Green Building Rating System Version 2.0 was release in March 2000, with LEED Version 2.1 following in 2002, LEED Version 2.2 following 2005 and the last in 2009 for new construction.

LEED certification involves five primary steps:

- Choose which eating systems to use.
- Register, The LEED process begins with registration. Once registration forms are submitted and payment is complete, your project will be accessible in LEED Online.

- Submit your certification application and pay a certification review fee. Fees differ with project type and size.
- Review. Await the application review.
- Certify. Receive the certification decision, which you can either accept on appeal.

There are several LEED Rating Systems, which are groups of requirements for projects that want to achieve LEED certification. Each group is geared towards the unique needs of a projector building type. Following, a list of the several rating systems LEED works with:

- LEED-NC for new construction and major renovations.
- LEED-EB for existing buildings.
- LEED-CI for commercial interiors.
- LEED-CS for core and shell.
- LEED-H for homes.
- LEED-ND for neighborhood development.
- LEED-S for schools.

The next figures show the five major credit categories of LEED 2009 (Indoor Environmental quality, Materials and Resources, Energy and Atmosphere, Water Efficiency, Sustainable sites), which a total of 100 possible base points, and 10 extra bonus points divided for Innovation and design and Regional Priority. Depending on the numbers of points that a building obtains, it will be given one of the four different levels of certification (certified, silver, gold, or platinum):

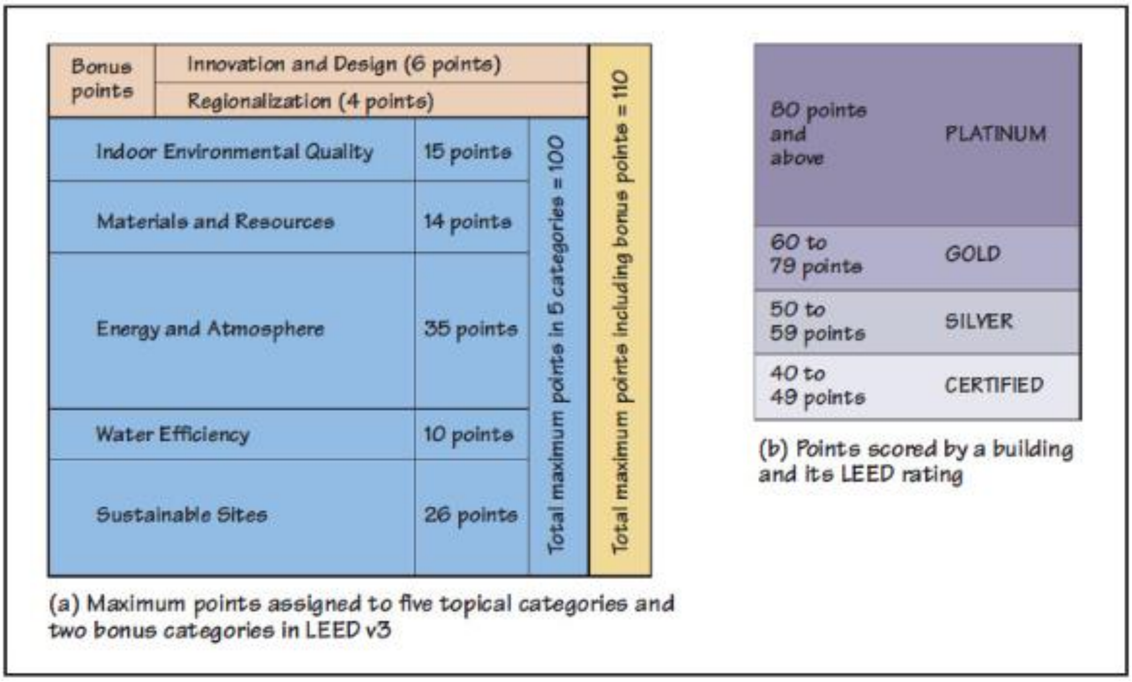

Figure 10 LEED Certification. [10]

4. ADVANTAGES AND DISADVANTAGES OF GREEN BUILDING:

One of the most important components of green building are energy and water efficient technologies which are generally not available in regular buildings. Although green building is more effective and good for bottom line, when creating it construction employers and designers should take into consideration some disadvantages too.

4.1. ADVANTAGES OF GREEN BUILDING

- **Cost:**

  Very often green building is considered to be expensive as usually all kind of modern building methods. However it saves much more money from the moment of creating during its lifetime as ordinary buildings. It works with any kind of green structures - office buildings, schools, churches, factories and others type of buildings. Designing and building green structures cost approximately the same as regular buildings. Even if they are higher in cost a little bit, because of some special requirements, during their usage they save so much energy that the money spent on its creation will return at least 10 times. A green building can be expensive as much as a conventional building.

- **Energy efficiency:**

  Green building has a great advantage of reducing both embodied and operating energy consumption. Studies proved that those buildings which are built with wood will have a lower embodied energy than buildings made of brick, steel or other materials. What about operating energy? Designers try to find solutions to reduce it too. They use extra-insulation, high-performance windows, and passive solar design.

The latter is very efficient especially if the windows are effectively placed. Also other ways of renewable energy are used too. Wind power and hydro power can also notably reduce the influence on environment.

- **Water Efficiency:**

  Water consumption is another objective in sustainable building. Water can be wasted by drip irrigation, leaking (toilet leaking can waste up to approx. 341 liters per day), pool showers. Recycling rainwater and using it for toilet flushing can save waste-water. Water saving shower heads, ultra-low flush toilets and other conserving fixtures can minimize waste-water.

- **Material efficiency:**

  Green buildings are built from green, rapidly renewable, non-toxic, reusable and recyclable materials as lumber, bamboo, straw, recycled metal/stone, sheep wool, compressed earth block, concrete, cork etc.

- **Temperature regulation:**

  Urban heat islands are elevated temperatures mostly in urban areas, formed mostly on surfaces where permeable and moist became impermeable and dry due to some buildings, roads etc. Urban heat island effect is caused mostly by the heat holding properties of tall buildings and urban (often toxic) materials - asphalt, concrete. It can be compensated by more green areas around the buildings such as green roofs and rain gardens.

- **Indoor air quality:**

  When constructing green buildings great emphases are put on the ventilation system. It can be powered in different ways - passively, naturally or mechanically. It doesn't matter in which it is powered, the most important thing that a building should have a properly designed ventilation system in order to have a filtered and cleaner air. During construction low or zero emission materials are used. Most materials used for ordinary buildings are toxic, some of them radiate gases or include volatile organic compounds. It has a bad influence on occupant's health and productivity. According to the data of the US Environmental Protection Agency indoor air pollution can be 2-5 times worse than outdoor air quality. It can cause early asthma and other respiratory disease. It is provoked by radon gas that's found in conventional buildings. Another considerable feature of air quality is the control of dampness. If ventilation from bathrooms, kitchen and other isolated rooms is bad, it can lead to mold growth, dust mites or to the emergence of other bacteria. To avoid this problem effective ventilation system is not always enough; well-insulated building envelop is also needed.

- **Indoor environmental quality:**

  Except poor air quality other circumstances like poor lightening, temperature variances, furniture, carpeting, pesticides, paints and high concentration of pollutants are causing different diseases - headaches, dermatological problems, allergies etc. The environmentally friendly circumstances of green building create healthier atmosphere.

- **Maintenance:**

  Green buildings need less maintenance. For example most green buildings don’t require exterior painting so often. Also as far as natural sources were used during its construction, they are not destroyed so quickly.

- **Improved employee attendance and productivity:**

  Natural lightening, good ventilation, healthy circumstances all influence the health of green structures’ occupants. People are becoming less sick, they are more productive and their impact on work is more high and effective. A study made among 31 green buildings showed that in LEED-certified buildings the absence of employee was decreased into 40 percent. Another research showed 30 percent less sick days plus a 10 percent growth income per employee. This way green office is more attractive and retaining for employees.

- **Higher property value:**

  Green buildings have low energy cost. Their use of gas, water, energy is highly reduced. A building can keep a high sale value if it contains sustainable components.

  A green building can be easily tuned into a net zero building. A net zero building or zero energy home is an active house. Instead of spending money on it, you can earn money with it. These buildings have almost zero consumption. Moreover they can create more energy than they need, they can supply energy (electricity) back into the electrical grid.

4.2. DISADVANTAGES OF GREEN BUILDING

- **Air-cooling features:**

  Particular cooling components that control precisely the indoor temperature in green buildings don't exist. The only thing that influences it is natural ventilation, which cannot be regulated.

- **Location:**

  To amend sun exposure, green building may need a correct structural orientation. It influences how natural light enters the building, how to shade some part of it. As far as the building will contain recycled resources the location of the building is affected by the land's humidity, the circumstance of the surrounding area.

- **Availability of materials:**

  In urban areas materials can be found easily than in rural areas. Green buildings require special materials. A lot of eco-friendly materials are not available, so sometimes these materials are hard to find and transportation fees may be high. If you order them from the internet you should pay additional cost for shipping and handling.

- **Time:**

  To build a green building in some cases takes more time than an ordinary one. Sometimes it takes too much time to find the needed material. The client can delay the construction.

- **Green roofs:**

  Green roofs consist of several layers plus a vegetation layer, culture medium, drainage, isolation, waterproofing membrane, and roof support.

Green roofs are heavier than simple once, so the roof's strength should be improved in order to construct this type of roof correctly.

- **Cost:**

  Many believe that the cost of green building is cost-prohibitive. You need to invest a lot of money. However later with energy saving possibilities the invested money may come back.

- **Low indoor quality:**

  Green buildings are eco-friendly and healthy, but too much emphases are put on sealing them. This isolation may cause indoor pollution. It can be harmful to the health of the occupants. Damage to health can also cause fluorescent lights. Their radiation in isolated places can lead to health problems.

As we can see all the advantages and disadvantages are environmental, economic and social. They are influenced mostly by its cost, energy efficiency and influence to our health. Although the advantages of green building are impressive, there are still some restrictions. For this reason designers and project managers should look through all the requirements for green building.

PROJECT: Building of the University Center for Energy Efficient Buildings (UCEEB)

1. DESCRIPTION:

The building under study is a building built in the University Center for Energy Efficient buildings (UCEEB) pretend. The location is Třinecká 679, 273 43 Buštehrad, Czech Republic. Its located 27 km from Prague

The building will feature residence, offices and study areas. On the ground floor, apart from being the ground connecting the two buildings, has a canteen and a gym. These two blocks and both have 4 storeys.

Figure 11 Building's site. [7]

1.1. BUILDING COMPONENTS

- Structure:

  Reinforced concrete with an average amount of 100 kg. steel B 500 S, in flat or sloping slabs, concrete HA 35/B/20/IIIa, soft consistency and maximum size 20 mm.

  Forged unidirectional nerves made of laminated steel profiles IPN for singing 20 +5 cm., And interaxis 70 cm., for the average light to 7-7.5 m., expanded polystyrene slab, steel mesh B 500 T, and concrete compression layer HA 35/B/20/IIIa.

- Enclosures:

  Wall to coat, 11.5 cm. thick, perforated bricks 24x11.5x9 cm., sitting with cement mortar made of M-40 work meetings (1:6), together with 1 cm.

  Partition consists of a 90 mm galvanized structure, with channels like an element horizontal and uprights like a vertical element, with a wheelbase of 60 cm., And double plasterboard 12.5 mm. thick, bolted to each side of the metal structure. (Partitions)

  Partition consists of a 90 mm galvanized structure., with channels like an element horizontal and uprights like a vertical element, with a wheelbase of 60 cm., And double plasterboard with plaster mass and waterproofed surfaces to areas wet and 12.5 mm. thick, bolted to each side of the metal structure. (Bathrooms and toilets)

2. SITE AND PLANS:

With respect to the North, the building is target 23º. Taking the main facade (building entrance) to the southeast, and the rear facade in the North West.

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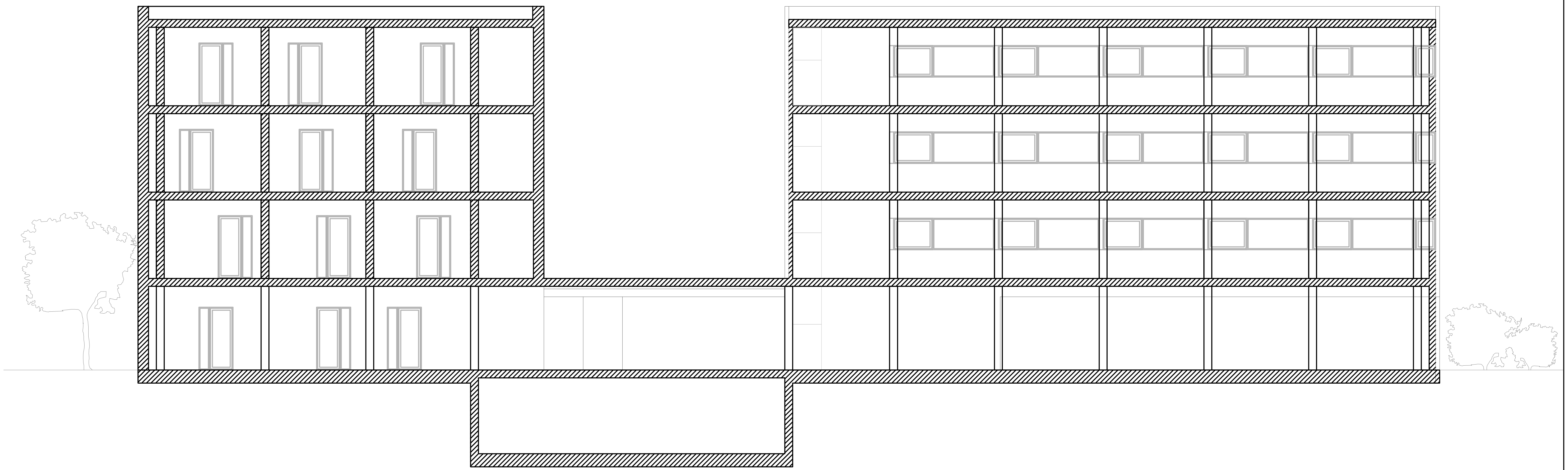
UCEEB



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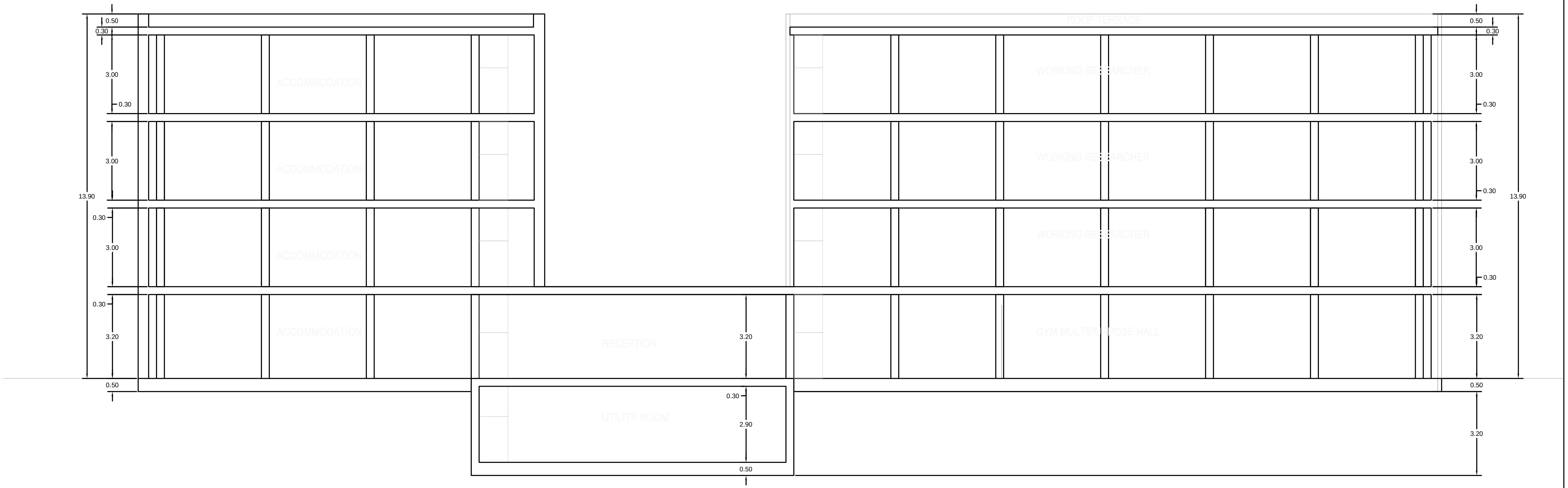

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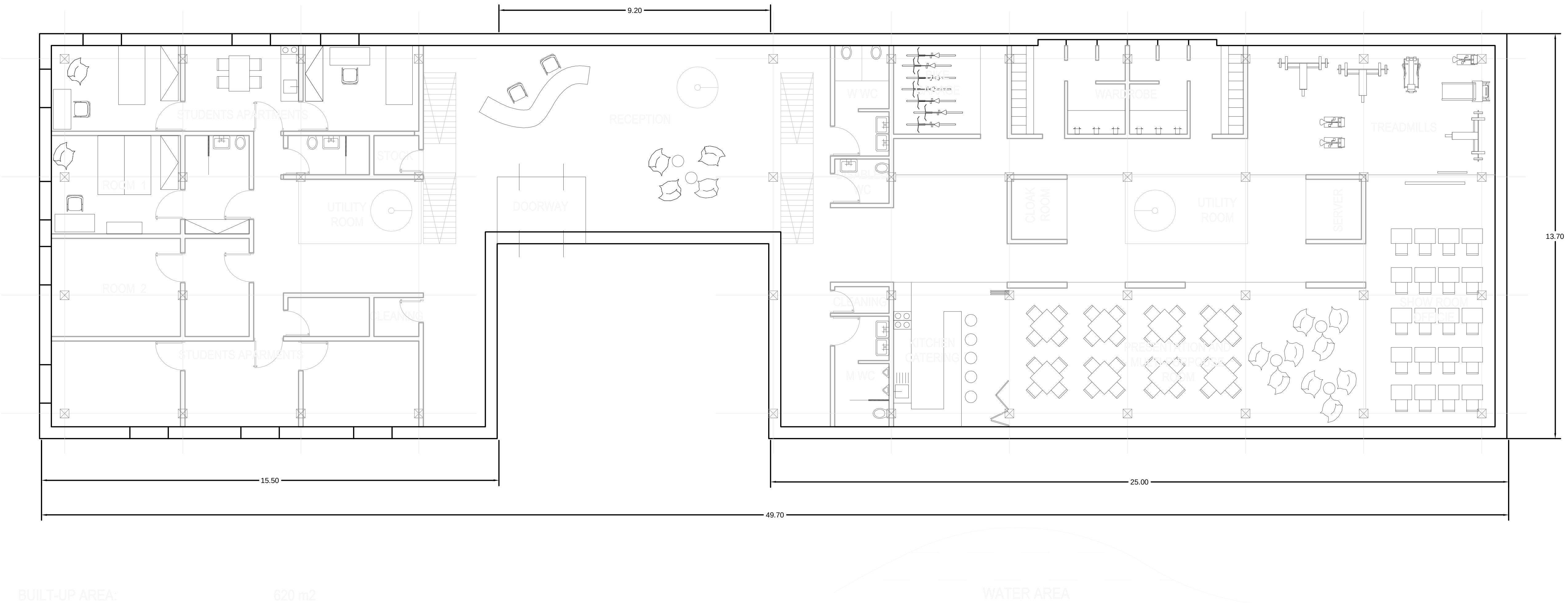

BUILT-UP AREA:		620 m2	
FLOOR AREA:			
RESEARCH WORK	0,8 * 317 =	253 m2 x 4 storey =	1012 m2
ACCOMMODATION	0,8 * 160 =	128 m2 x 4 storey =	512 m2
INPUT	0,8 * 100 =	80 m2	
TOTAL			1604 m2

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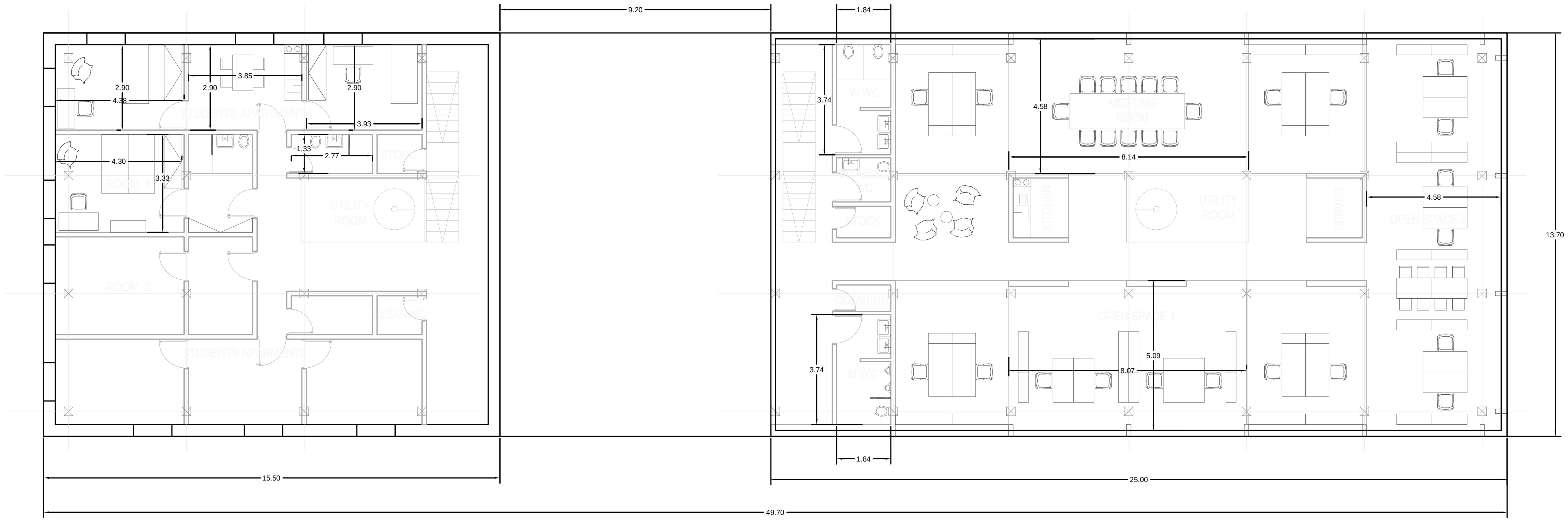

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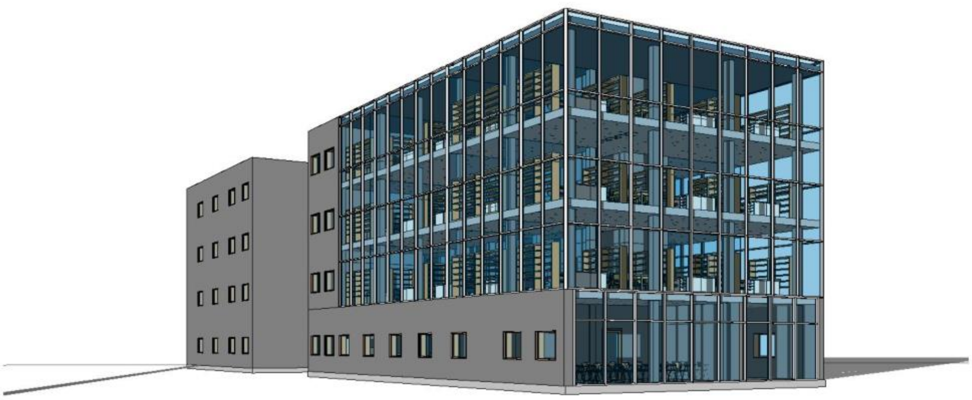
3. 3D IN REVIT:



4. FACADE:

For the choice of facade, I have relied on two buildings. The first is a building in Prague, Technická knivovna Narodni (National Library of Technology) for the use of triple-glazed windows; and second Genyo Building in Granada (Spain) having a building integrated photovoltaic BIPV system double-skin.

- **Genyo Building (Granada)**

  Architects: Planho

  Location: Granada, Spain

  Area: 5.633 m^2

  Year: 2008

  The available land and the functional use of the building led us to think about a high-rise building. The position, aspect, orientation, direction and shape of the plot of land were determining factors in its implementation and planning.

  The front of the lineal block facing south-east, seen in a very rational way, allows a view of the Sierra Nevada and the fertile plains of Granada. The facade facing north-east, is shown with a more irregular solution, in tune with the views of the consolidated city, houses all the laboratories' support units.

  In this way a conceptual approach takes place whereby a knowledge-research duality is produced. This reproduces the duality between consolidated city and new city; the part of knowledge which transmits strength, experience, protection, etc., "embraces" the research part which identifies with new things, with things of the future and with all that which has yet to be made. Walking through the inner corridor with every single wall being planned and executed to reflect the vision of conceptual duality, one will participate in what is consolidated and what is in the future, in knowledge and what we have yet to learn.

  The coating of the building reflects the proposed functional concept; highly technological, based on partially photovoltaic glass in the rational facade and with a ventilated facade made with corrugated aluminum sheets positioned vertically with discrete apertures in the facade which faces the consolidated city.

The program is developed in five levels (basement + 4); the basement being designated for parking and services. Basically it consists of a linear block in double centerline which houses all the research units and their support zones (laboratories) in the four levels. The ground floor serves as a base, taking up the whole plot of land, holding common spaces and the entrance hall. The building has a gross floor area of 5.633 m^2.

Figure 11 Images of Genyo Building. [11]

- **Technická knivovna Narodni (Prague)**

  Architects: Projektil architekti / Roman Brychta, Adam Halíř, Ondřej Hofmeister, Petr Lešek

  Location: Prague, Czech Republic

  Client: Státní technická knihovna, Ministerstvo školství, mládeže a tělovýchovy

  Interior Collaborators: Hipposdesign, R.Babák, O.Tobola

  General Contractor: Sdružení Metrostav a.s., OHL ŽS a.s.

  Site area: 11,740 m^2

  Constructed area: 51,434 m^2

  Planning year: 2004-2006

  Project year: 2006-2009

  The idea of the new technical library is quite old and started in the 90′s. The architectural competition took place in 2000. The investor is the ministry of education on behalf of the State technical library. Our design got 1st prize among approximately 50 proposals. There wasn't any second prize and, instead there were three third prizes. Afterwards, there was a time gap till the year 2004 in which the ministry of education chose to sponsor another competition to decide who would continue in the building design. After the plans where finished in 2006 the developer Sekyra Group was chosen to construct in a PPP like program. The real building contractor was then the partnership Metrostav - OHLŽS. Building construction started in the year 2006 and was finished in January 2009. Currently books are being moved in.

  There are more sources of the architectural concept of the building. Firstly there is a spatial context influence which involves the historical urbanistic plans for the whole area as well as its present significance. Secondly the concept is our answer to the idea of the institution and especially to the role of the library in today's society. That is why on the ground floor there is a minimum of the library itself unlike all the complementary services such as the cafeteria, exhibition hall and congress hall. Next the chosen shape and material should resolve one of crucial question of how to be modern and monumental at the same time. And, what is important, the building from the very beginning was formed to be energy saving one and the shape show it clearly. Part of the concept is as well the use of the area around the building - social space on the west and a green park on the east. Finally, the building was designed to include the interior and the graphic design following the concept “the technological schoolbook”, so a lot of things (for example installations) are knowingly shown for better understanding how the building was designed and functions.

The building has three underground and six aboveground floors.

Underground there is book storage, technology, supply and a parking lot. On the ground floor and the second floor there is the main entry to the library and all complementary facilities - conference hall, exhibition hall, cafeteria, bookshop and cloak room. All of them are around the entry hall which is the main place for meeting people not just from the library but from the whole university campus. That is the reason why the building has not one but four entrances to all sides. The idea was to give to the campus, not just a library, but a needed public place as well; where all the students could meet together. The entry hall doubles as a square for bad weather days (in summer the campus is empty). Additionally, there is a night study room on the ground floor so the building can provide the 24 hour service without needing to open all the building during the night. In the middle of the ground floor is the entrance to the library and first info desk. The visitors then follow up to the second floor and the atrium hall with the main desk. The atrium is naturally lit through the skylight and it is the main space of the whole building. Then the library floors follow from third to sixth. The setup is similar. On the north side of the floor there is the administration section. In the public part there are the study places and study rooms of different sizes next to the façade, followed by book shelves in the darker part of the floor and finally an info desk and other study places around the atrium with natural light. This plot mirrors not just the natural light level in different parts but also helps to distribute the warm gain from the sun and to differentiate acoustic demands. For administration the open space-system is used. Each floor is a little different but the main orientation points remain. More differences are found in the last floor where two open atriums give the chance to read under the sky, and is also where individual study rooms for rent are located.

In construction of the building many interesting technological solutions were used. Some of them help the flexibility, the others help save on energy demands.

The construction itself used columns in a 15 meter grid with, in both directions, pre-stress concrete slabs. The statics deflation diagram for floor slabs pre-stressing was used for designing the floor, so you can imagine how the strength in the construction goes.

The concrete corn activation system is used for the heating and cooling. There are plastic pipes directly in construction slabs with a medium whose temperature is changing according to demands during the year. This system perfectly suits the open space of the library. In addition, there is an easy system for pre-cooling the building during summer nights just by natural ventilation via opening windows.

The main facade is divided into glass and blind parts on the surface in a ratio near to 50/50% in order to optimize the amount of heat energy.

Recuperation of air and sun blinds are standard solutions, here thanks to an external double façade, wherein the sun blinds are sheltered from the wind.

For the surface of the ground floor an asphalt-based floor covering material (bitu-terrazzo) was used. It significantly reduces noise levels in the building. The fire prevention system is an automatic water mist-spraying fire extinguishing system which is more property/asset-protective, plus it does not require a large-capacity storage vessel.

The roof is covered with extensive green to create the fifth façade of the building for views from surrounding higher buildings. It also slows down draining in case of heavy rain.

The interior is very open and friendly to express the openness and friendliness of the contemporary institution. The main elements are the power-colored floor and the orientation of all lighting which point to the very middle point of the building. In every room you are sure about your position. Some furniture was developed especially for the library to give visitors a free-minded feeling. They are movable so the students can build their own constellations from them. The main principle of interior design is about collaboration and reciprocal influence.

The important parts of the interior are the graphic design, which follows the technical schoolbook concept, and the art. We invited an art curator with the group PAS (production of contemporary activities) to prepare an art scheme for whole building. From the big scheme only the central artwork remains because of the lack of money. There was an international competition for this job and the famous artist Dan Perjovschi won. So now you can see an elaboration of his ideas from MoMa in New York.

The National Technical Library will be ceremonially opened on September 9(th), 2009. Library users will have access to over 1,200 seats in study areas and 300 seats in relaxation areas. It is estimated that the library stores about 1.2 million volumes. There will also be an exhibition hall, a conference hall with 200 seats, a cafe with 150 seats, WiFi internet access throughout the building, parking for 300 cars and stands for 200 bicycles. It is expected that the new library will draw up to 900,000 visitors every year.

Figure 12 Images of NTK. [12]

5. CLIMATE ANALYSIS BY VASARI / GREEN BUILDING STUDIO (AUTODESK):

Good sustainable building design starts with understanding a building site's climate. The data and visualization tools available within BIM tools can help you better understand how to consider factors like temperature, humidity, wind conditions, and sky conditions in your design.

Autodesk Revit, Vasari, and Green Building Studio each have tools for climate analysis.

Vasari:

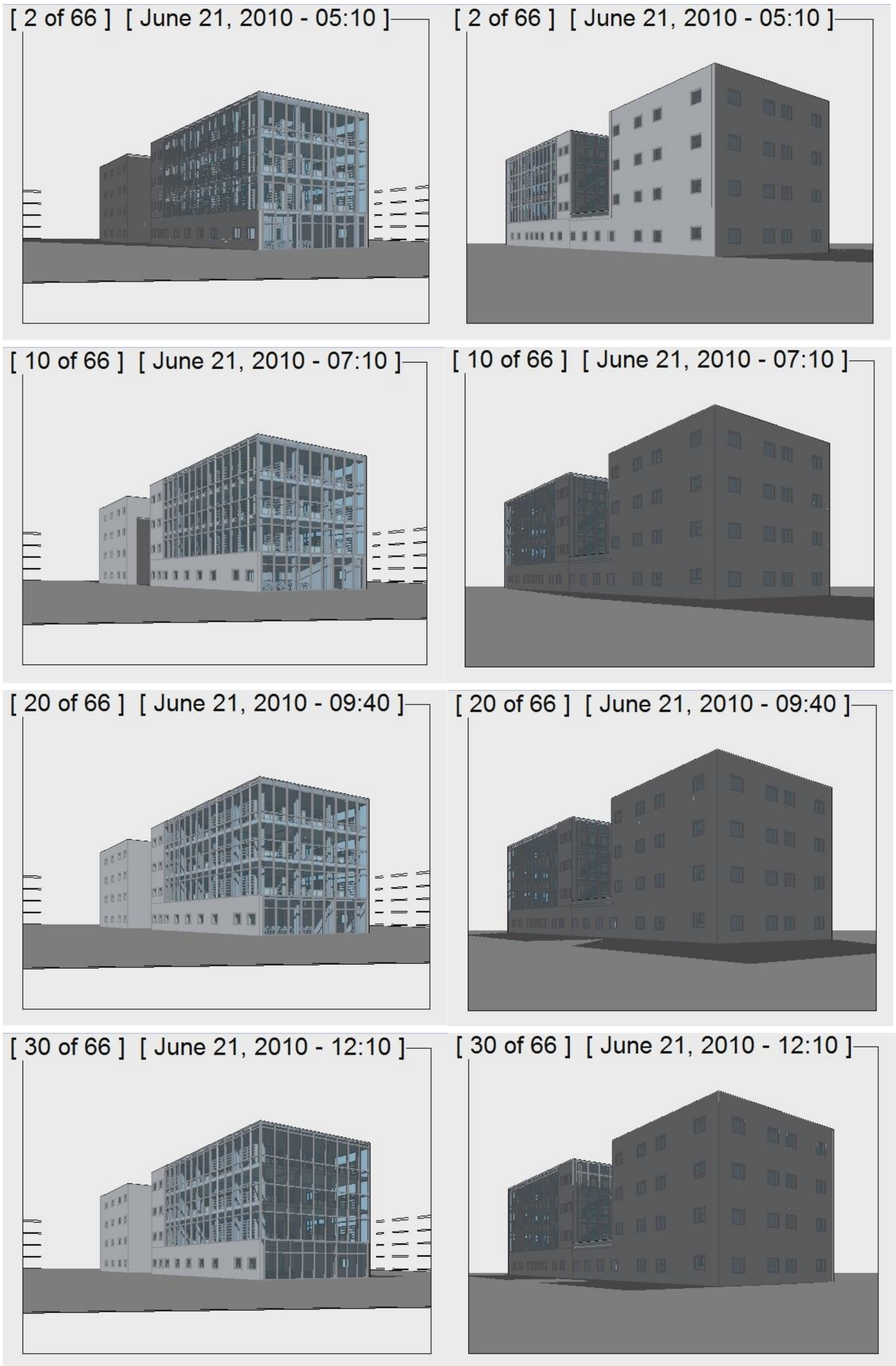
- **Sun path:** Control the sun's path and visualize site-specific shadows.
- **Solar Radiation:** Quantify the incident solar radiation striking the building surfaces.
- **Wind data:** See the wind rose diagram for the project location showing wind direction, frequency and speed.
- **External wind simulations:** Simulate the airflow (wind speed and pressure) on the site and around your proposed design with basic CFD.
- **Conceptual energy analysis:** Quick feedback on the expected energy use of your proposed designs and compare the effectiveness of building form, orientation and envelope design options.

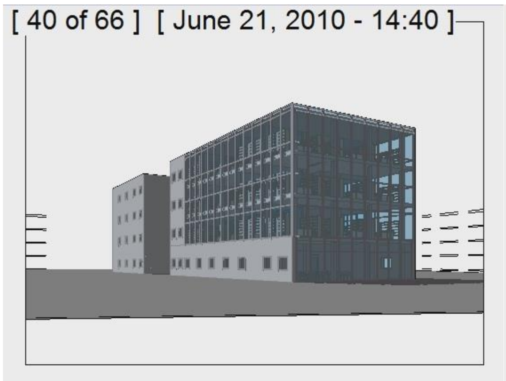
Green Building Studio:

- **Whole building energy analysis:** Energy use and carbon dioxide (CO_2) emissions, including regional electric grid carbon emissions by fuel type.
- **Water Use Analysis:** Estimate water use based on building type and number of occupants, and evaluate the effectiveness of alternative measures to reduce water use.
- **Renewable Energy Sources:** Identify and size options for onsite renewable solar and wind energy sources.
- **LEED Daylighting Credits:** Calculate each room's daylighting factor and identify ways to earn LEED daylighting credits.

- Sun Path:

Summer:

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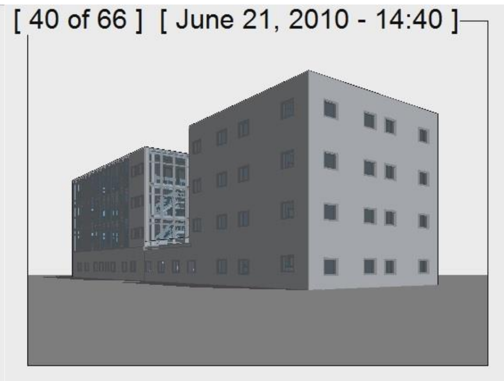
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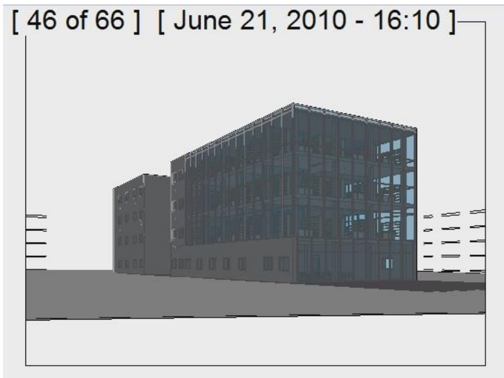
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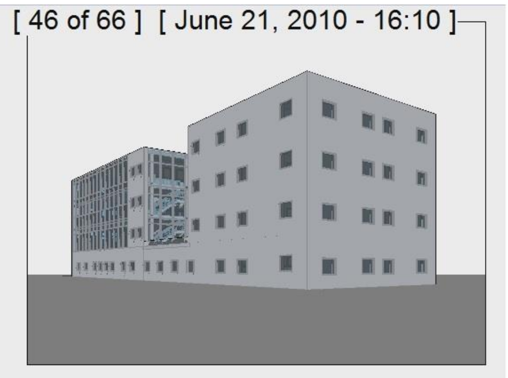
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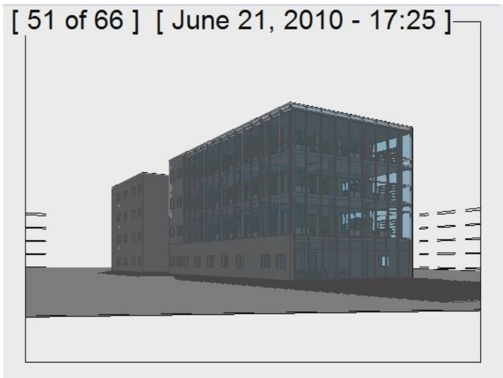
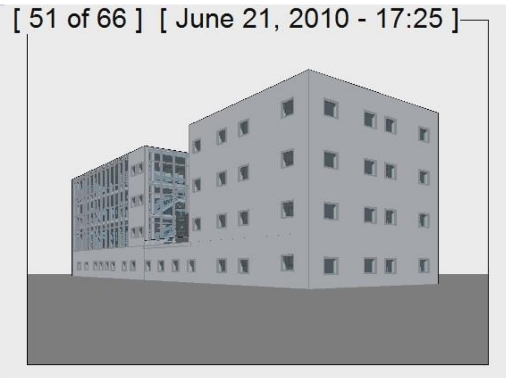
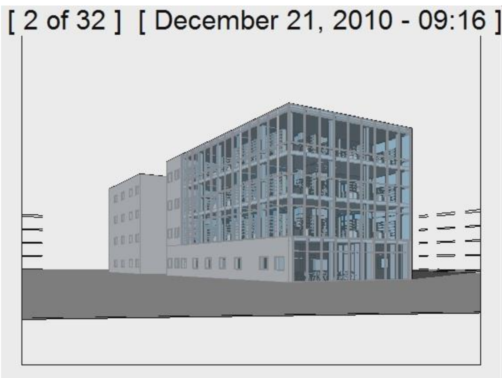
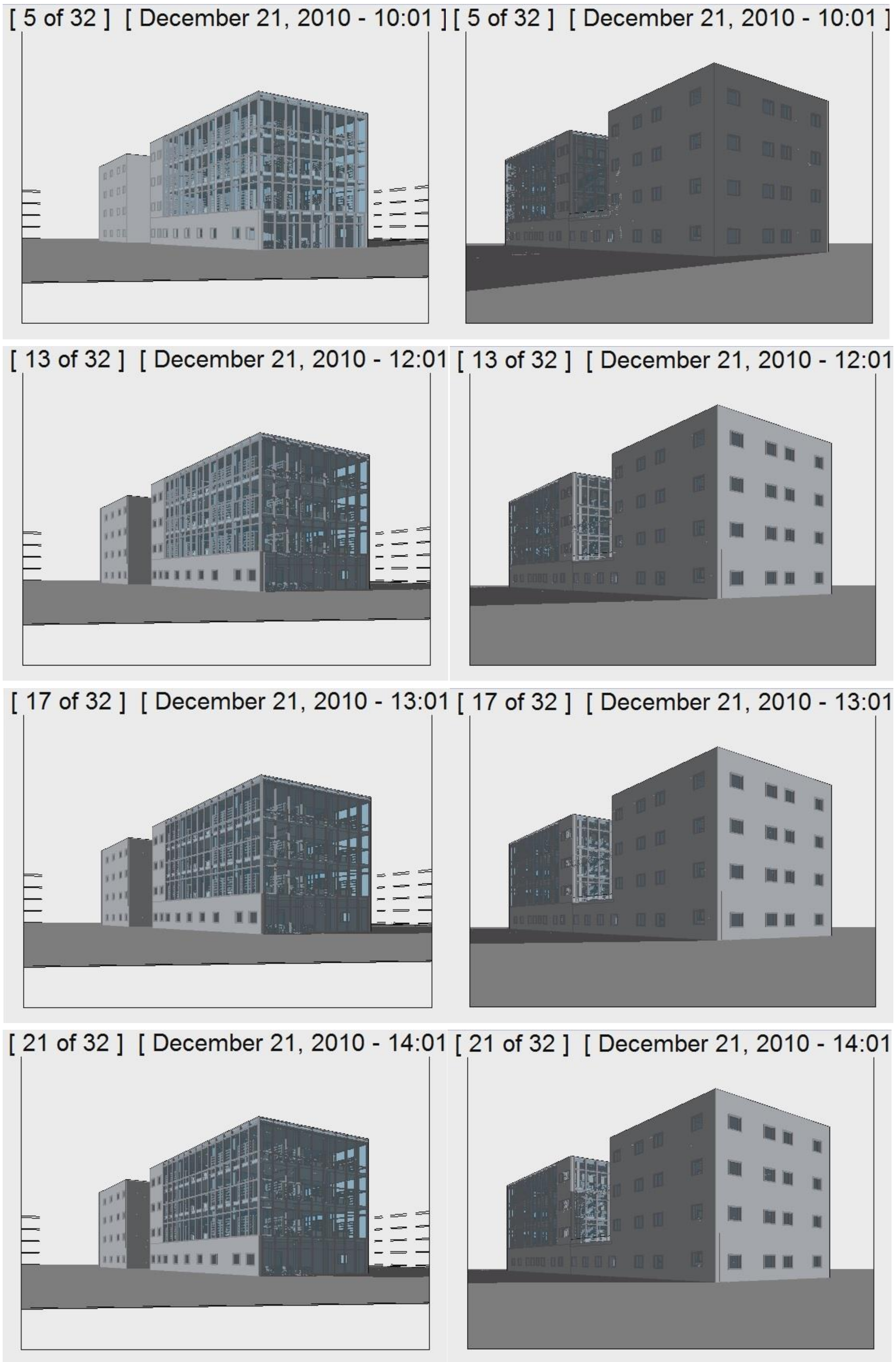
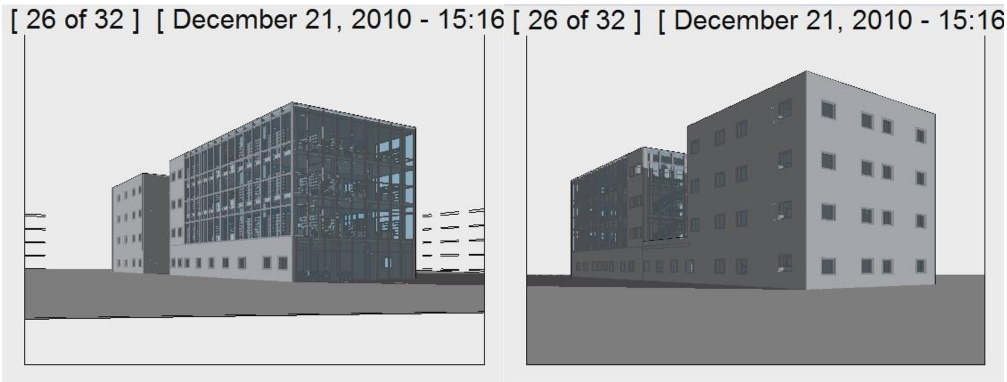

[51 of 66] [June 21, 2010 - 17:25]

[51 of 66] [June 21, 2010 - 17:25]

Winter:


[2 of 32] [December 21, 2010 - 09:16]

[2 of 32] [December 21, 2010 - 09:16]

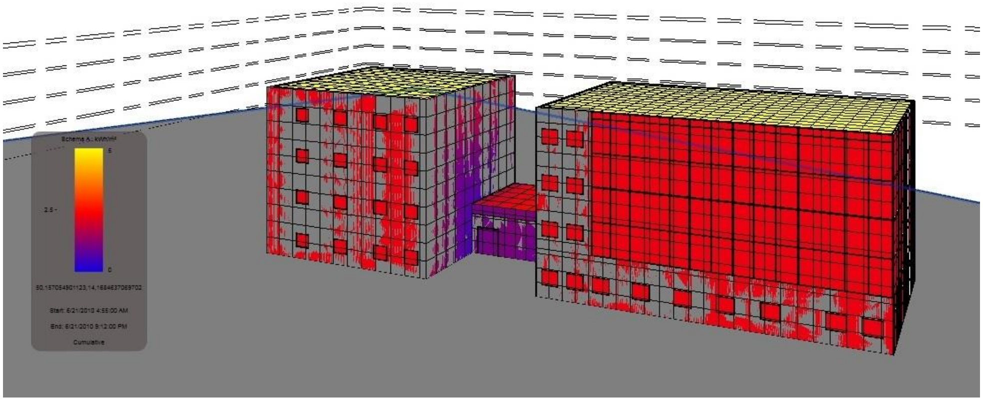

[5 of 32] [December 21, 2010 - 10:01]
[5 of 32] [December 21, 2010 - 10:01]
[13 of 32] [December 21, 2010 - 12:01
[13 of 32] [December 21, 2010 - 12:01
[17 of 32] [December 21, 2010 - 13:01
[17 of 32] [December 21, 2010 - 13:01
[21 of 32] [December 21, 2010 - 14:01
[21 of 32] [December 21, 2010 - 14:01



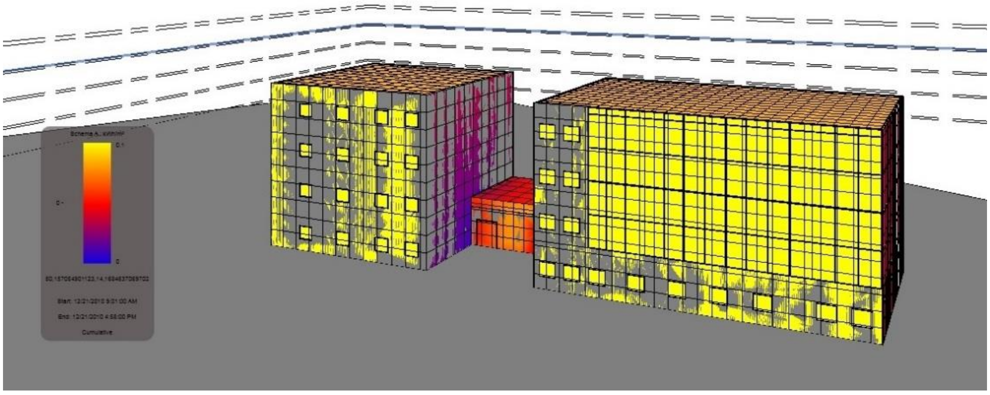
With the use of the sun-path diagram you can see where the sun will rise and set at different times of the year and its altitude angle (Height in the sky) in any time of day.

- Solar Radiation:

  Summer



Winter



As shown in the study, the main facade receives both summer and winter enough solar radiation.

This can be to harness that energy and accumulate, with photovoltaic cells as Genyo building.

Also to avoid heating in the interior, especially in the glass part, you can raise these three options:

- Blinds using regulate automatically via a sensor light inside the building.
- Planting deciduous trees.
- Using cantilever as parasol.

Although we should clarify that the last two options could degrade the performance of photovoltaic system.

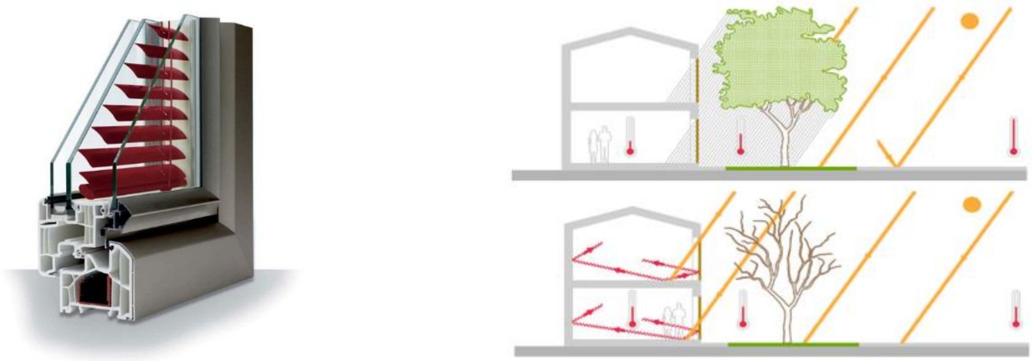
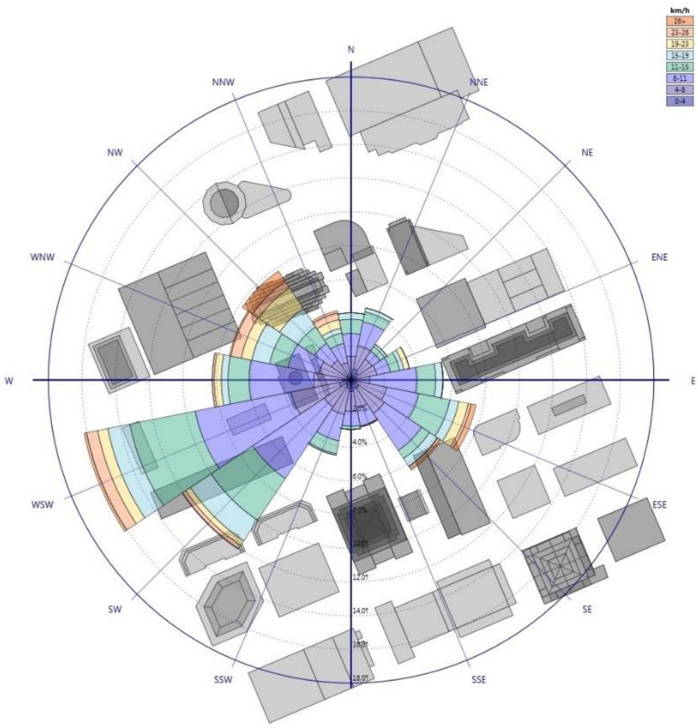


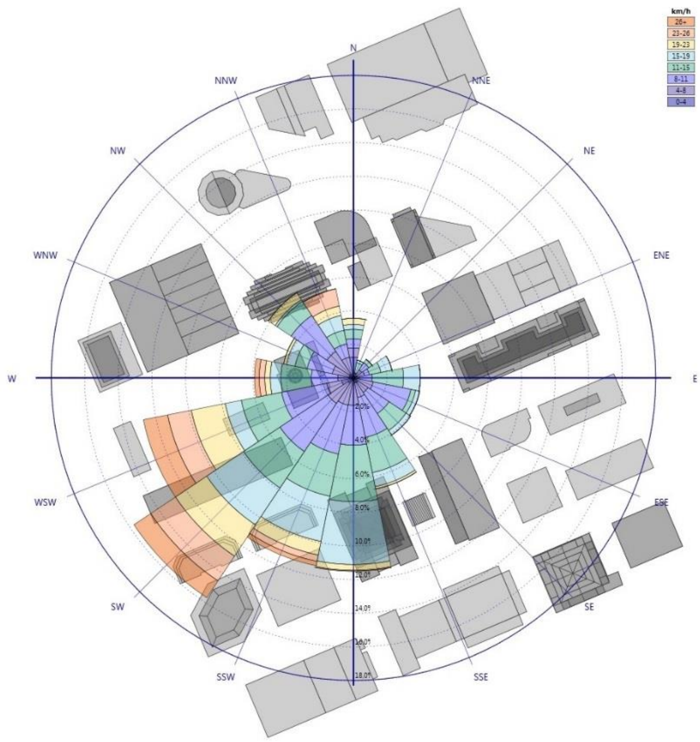
FIGURE 13 Images solar radiation. [6]

- Climate analysis (Wind):

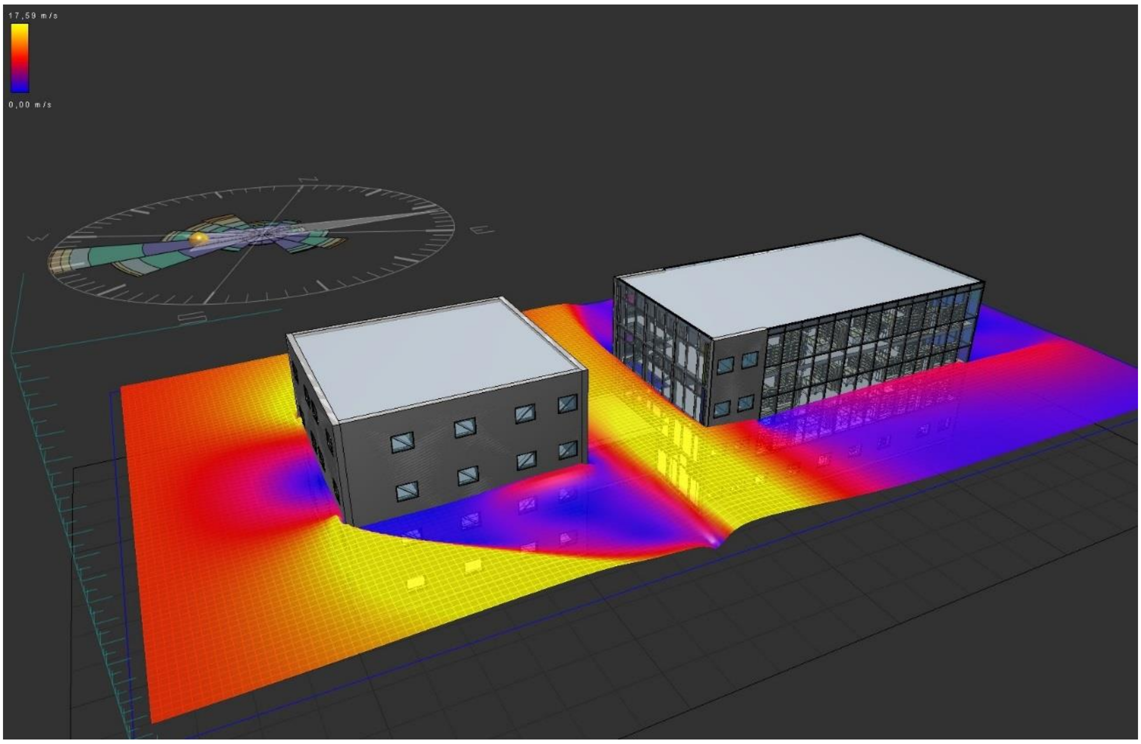
Wind rose summer

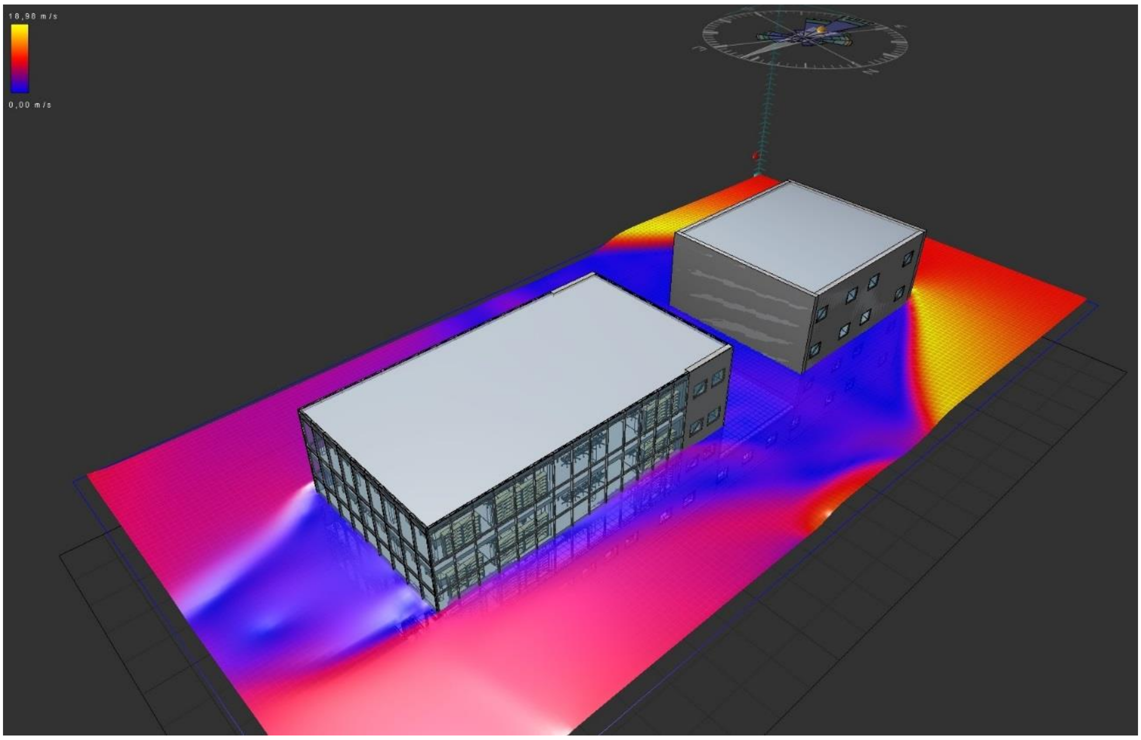


Wind rose winter

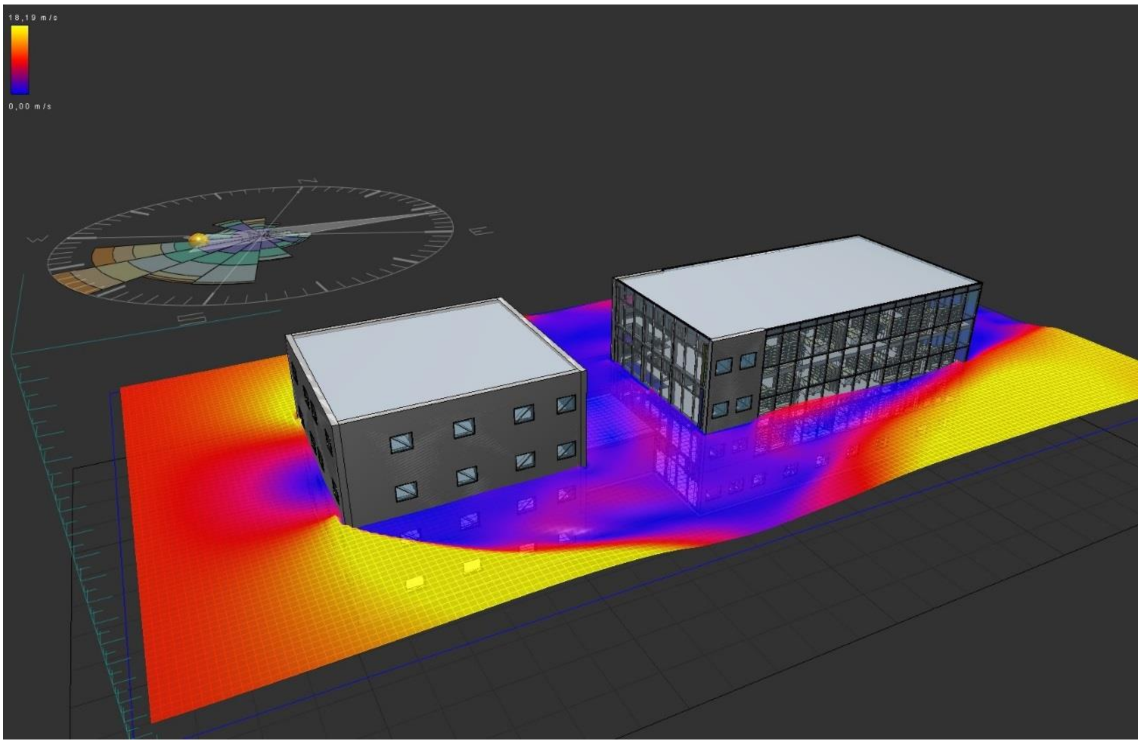


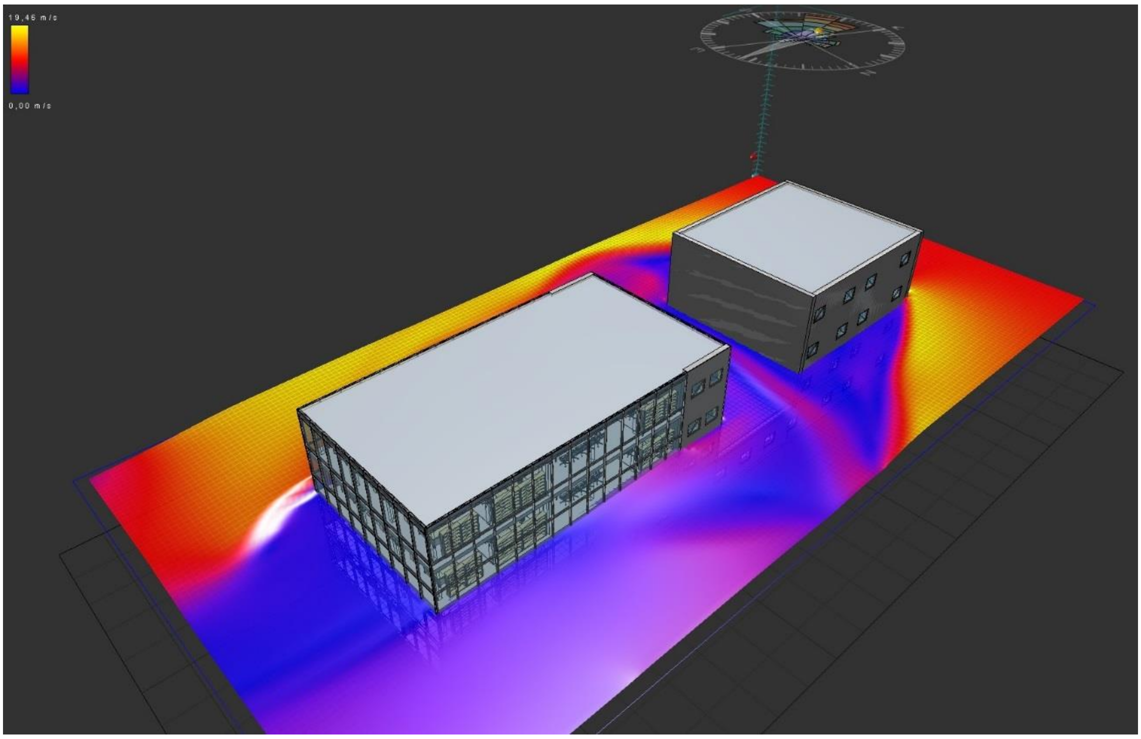
Wind tunnel summer





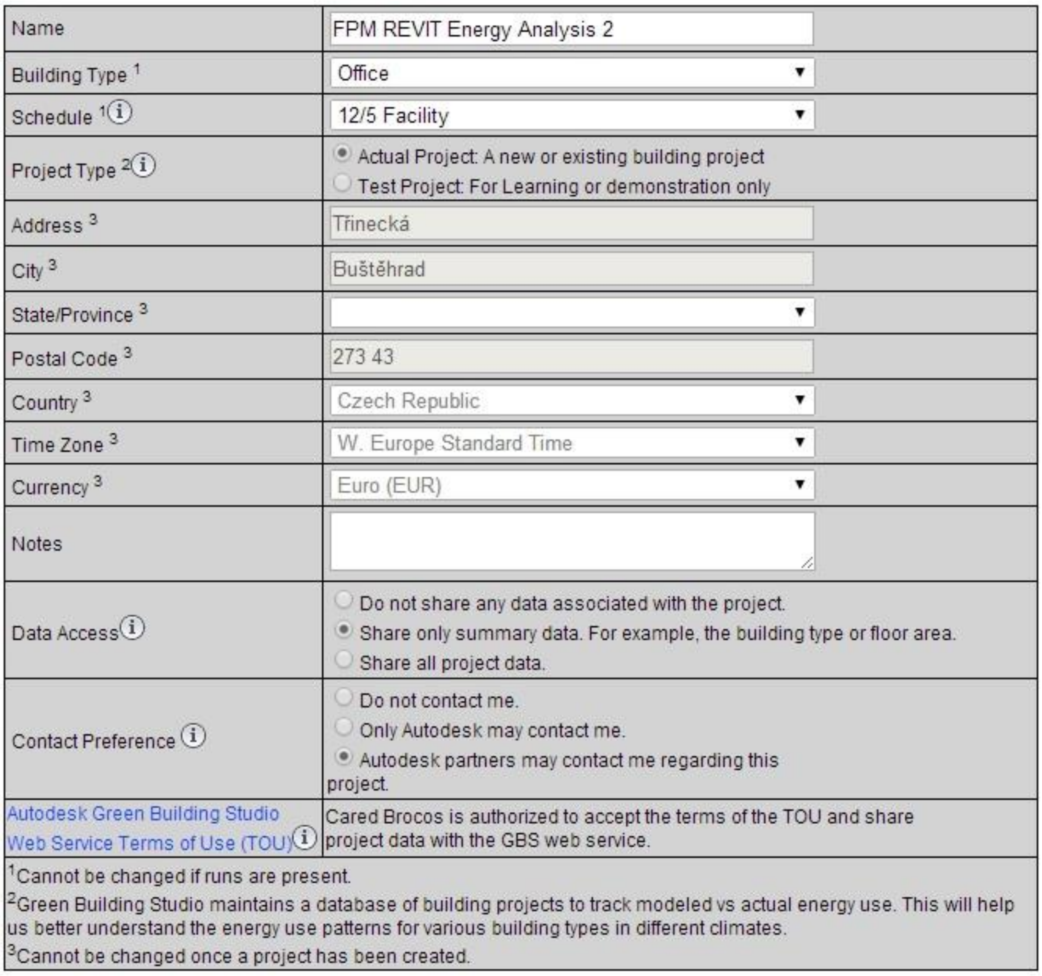
Wind tunnel winter





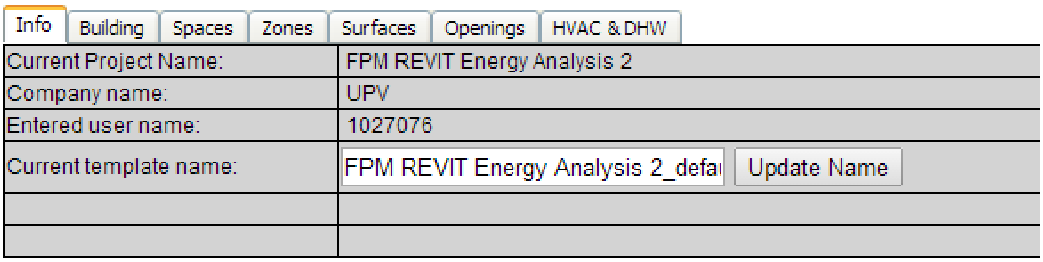
5.1. OFFICE STUDIO:

Project details and defaults:



Name	FPM REVIT Energy Analysis 2
Building Type [1]	Office
Schedule [1]	12/5 Facility
Project Type [2]	Actual Project: A new or existing building project Test Project: For Learning or demonstration only
Address [3]	Třinecká
City [3]	Buštěhrad
State/Province [3]	
Postal Code [3]	273 43
Country [3]	Czech Republic
Time Zone [3]	W. Europe Standard Time
Currency [3]	Euro (EUR)
Notes	
Data Access	Do not share any data associated with the project. Share only summary data. For example, the building type or floor area. Share all project data.
Contact Preference	Do not contact me. Only Autodesk may contact me. Autodesk partners may contact me regarding this project.
Autodesk Green Building Studio Web Service Terms of Use (TOU)	Cared Brocos is authorized to accept the terms of the TOU and share project data with the GBS web service.

[1]Cannot be changed if runs are present.
[2]Green Building Studio maintains a database of building projects to track modeled vs actual energy use. This will help us better understand the energy use patterns for various building types in different climates.
[3]Cannot be changed once a project has been created.



Info | Building | Spaces | Zones | Surfaces | Openings | HVAC & DHW

Current Project Name:	FPM REVIT Energy Analysis 2
Company name:	UPV
Entered user name:	1027076
Current template name:	FPM REVIT Energy Analysis 2_defa Update Name

AUTODESK.

FPM REVIT

FPM REVIT Energy Analysis office

Analyzed at 6/10/2014 11:02:12 AM

Energy Analysis Result

Building Performance Factors

Location:	50,157054901123,14,1684637069702
Weather Station:	161987
Outdoor Temperature:	Max: 33°C/Min: -16°C
Floor Area:	1,608 m²
Exterior Wall Area:	696 m²
Average Lighting Power:	10.87 W / m²
People:	43 people
Exterior Window Ratio:	1.29
Electrical Cost:	$0.15 / kWh
Fuel Cost:	$1.33 / Therm

Energy Use Intensity

Electricity EUI:	136 kWh / sm / yr
Fuel EUI:	1,271 MJ / sm / yr
Total EUI:	1,761 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	6,566,052 kWh
Life Cycle Fuel Use:	61,342,802 MJ
Life Cycle Energy Cost:	$791,527

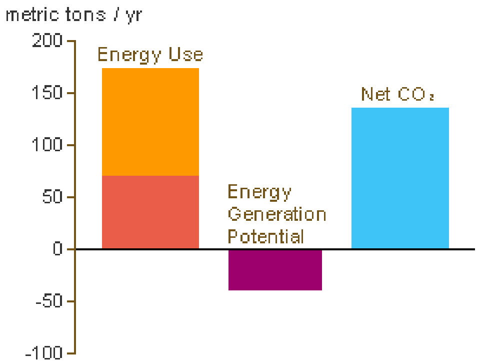
*30-year life and 6.1% discount rate for costs

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	38,795 kWh / yr
Roof Mounted PV System (Medium efficiency):	77,590 kWh / yr
Roof Mounted PV System (High efficiency):	116,385 kWh / yr
Single 15' Wind Turbine Potential:	1,259 kWh / yr

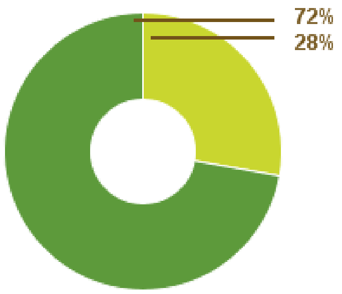
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

Annual Carbon Emissions



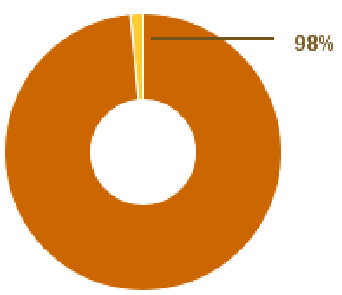
	(metric tons / yr)
Electricity Consumption	71
Fuel Consumption	101
Roof PV Potential (High Efficiency)	-37
Single 15' Wind Turbine Potential	0
Net CO_2	135

Annual Energy Use/Cost



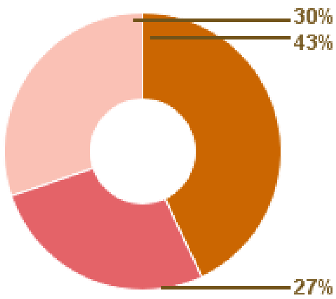
Electricity	28%	$32,327	218,868	kWh
Fuel	72%	$25,788	2,044,760	MJ
		$58,115		

Energy Use: Fuel



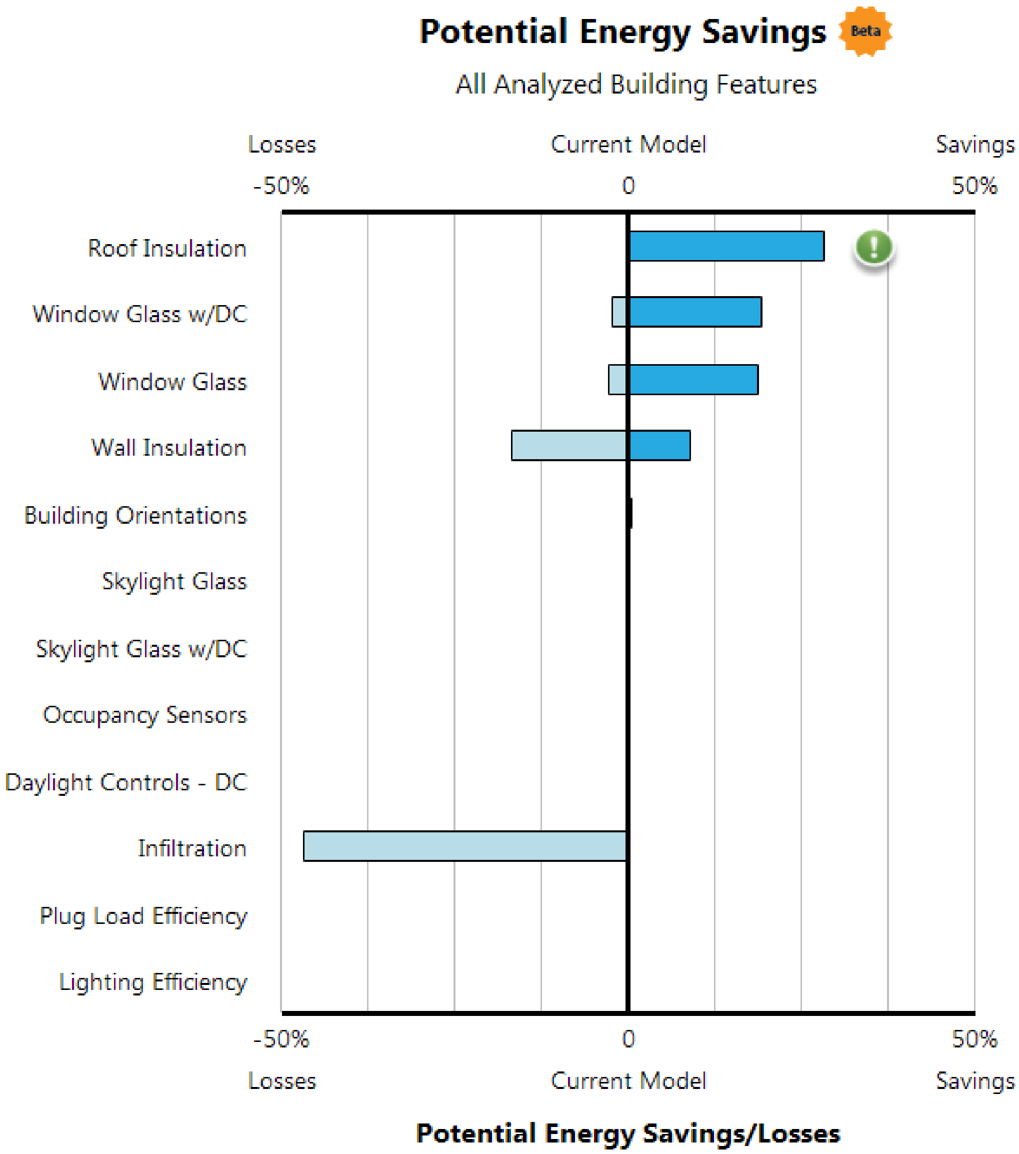
			(MJ)
HVAC	98%	$25,406	2,014,460
Domestic Hot Water	2%	$382	30,299
		$25,788	2,044,759

Energy Use: Electricity

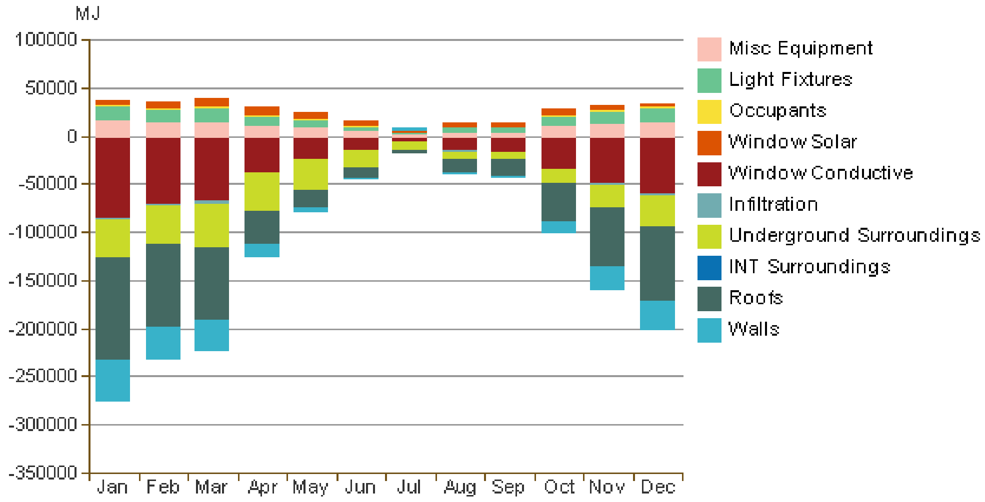


			(kWh)
HVAC	43%	$13,756	93,138
Lighting	27%	$8,577	58,076
Misc Equipment	30%	$9,663	65,427
		$31,996	216,641

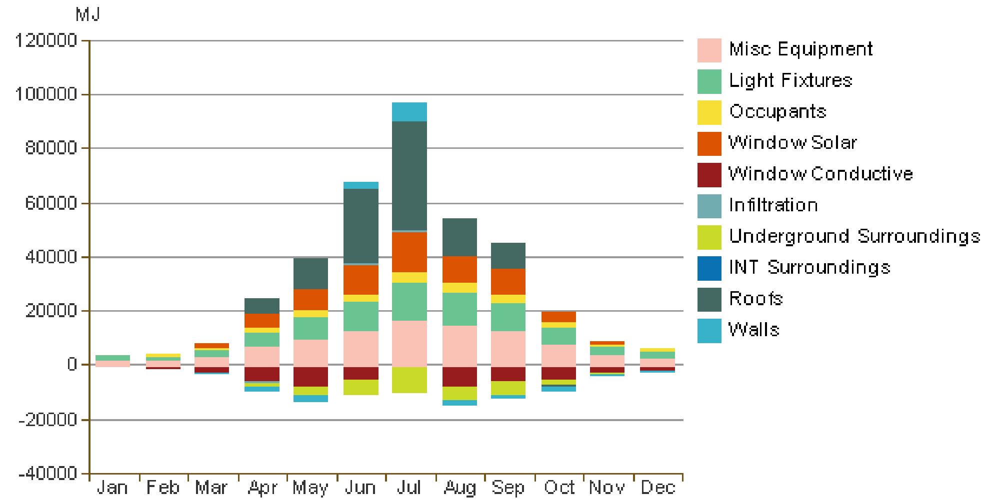
Potential Energy Savings



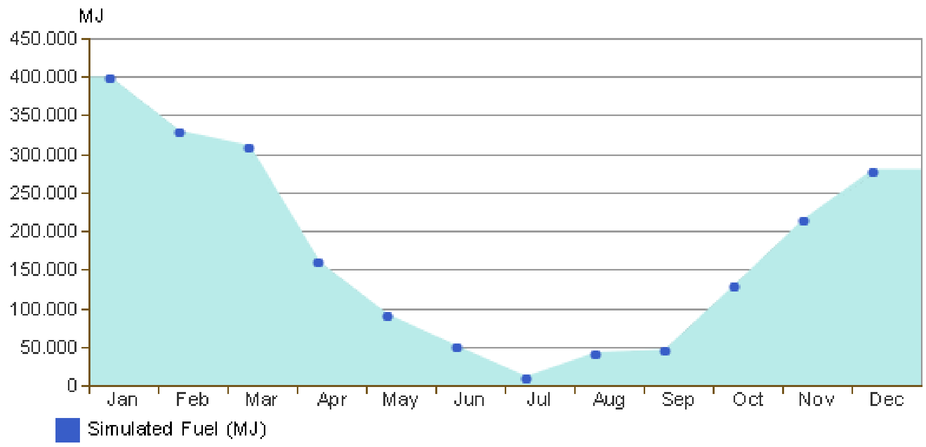
Monthly Heating Load



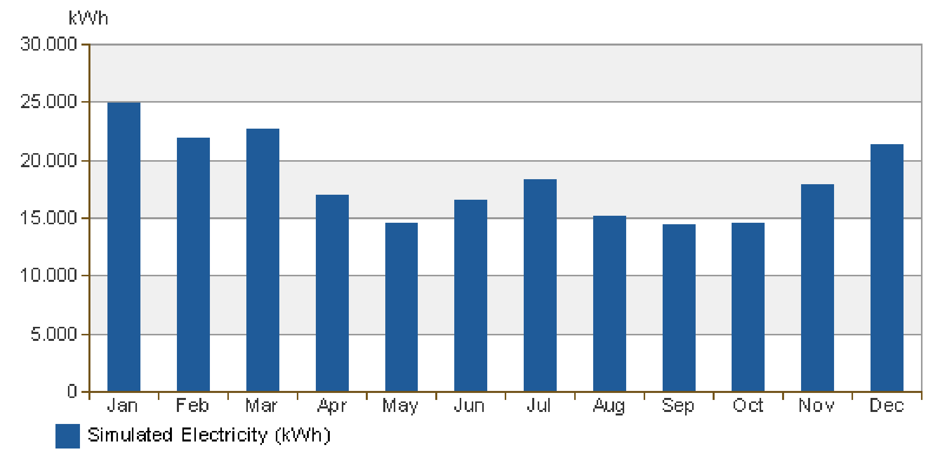
Monthly Cooling Load



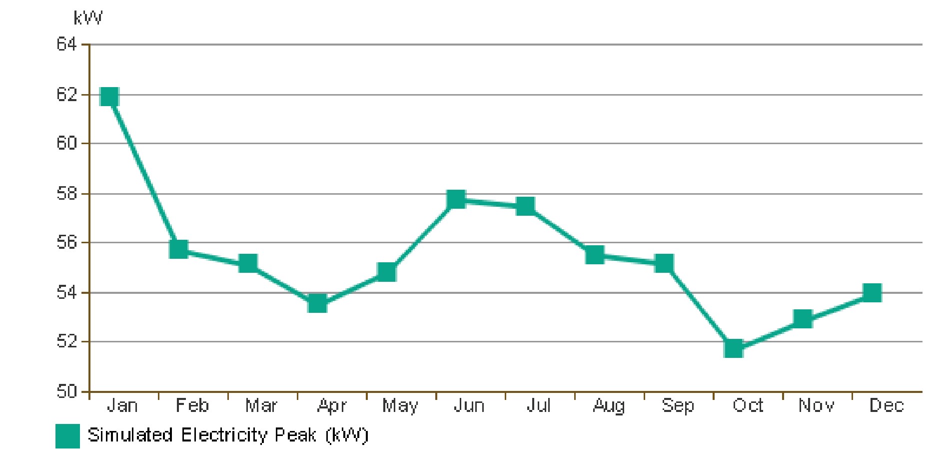
Monthly Fuel Consumption



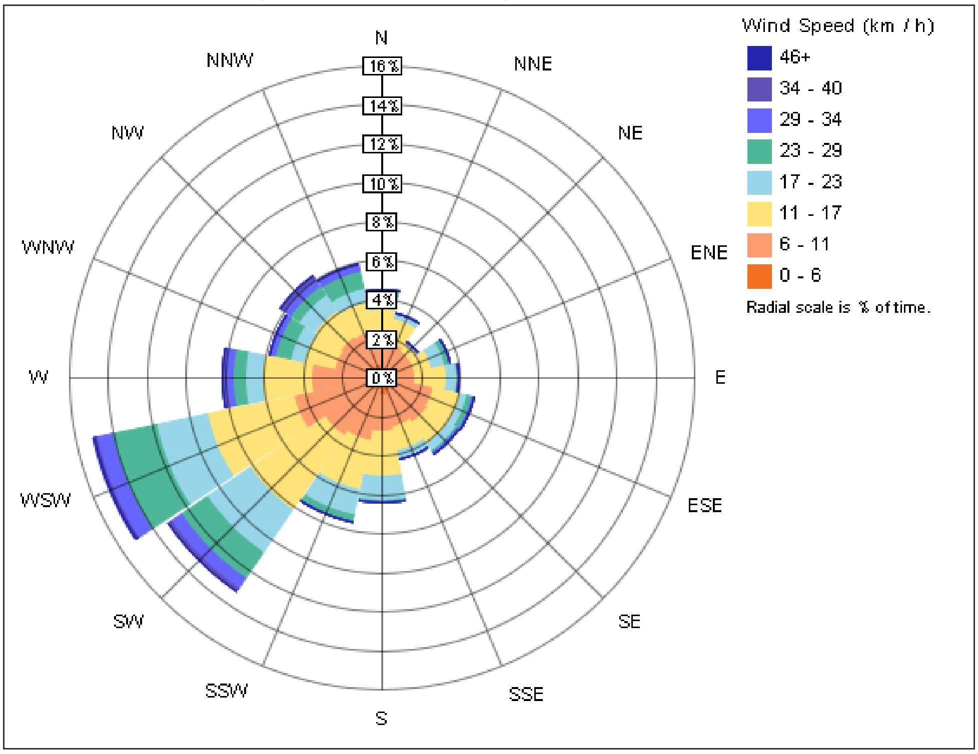
Monthly Electricity Consumption



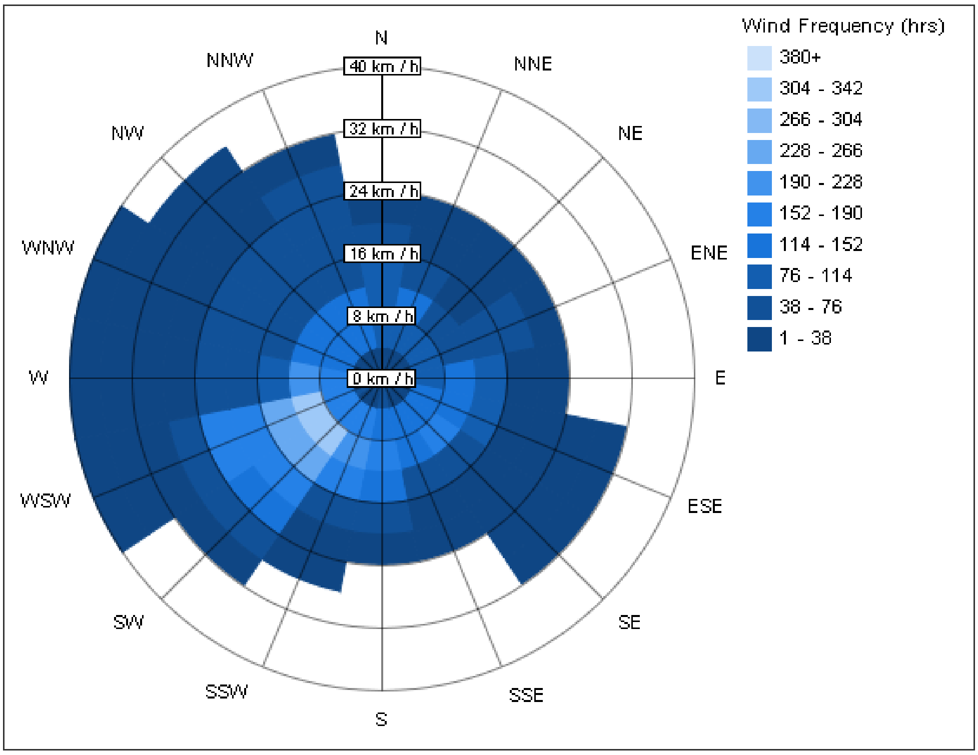
Monthly Peak Demand



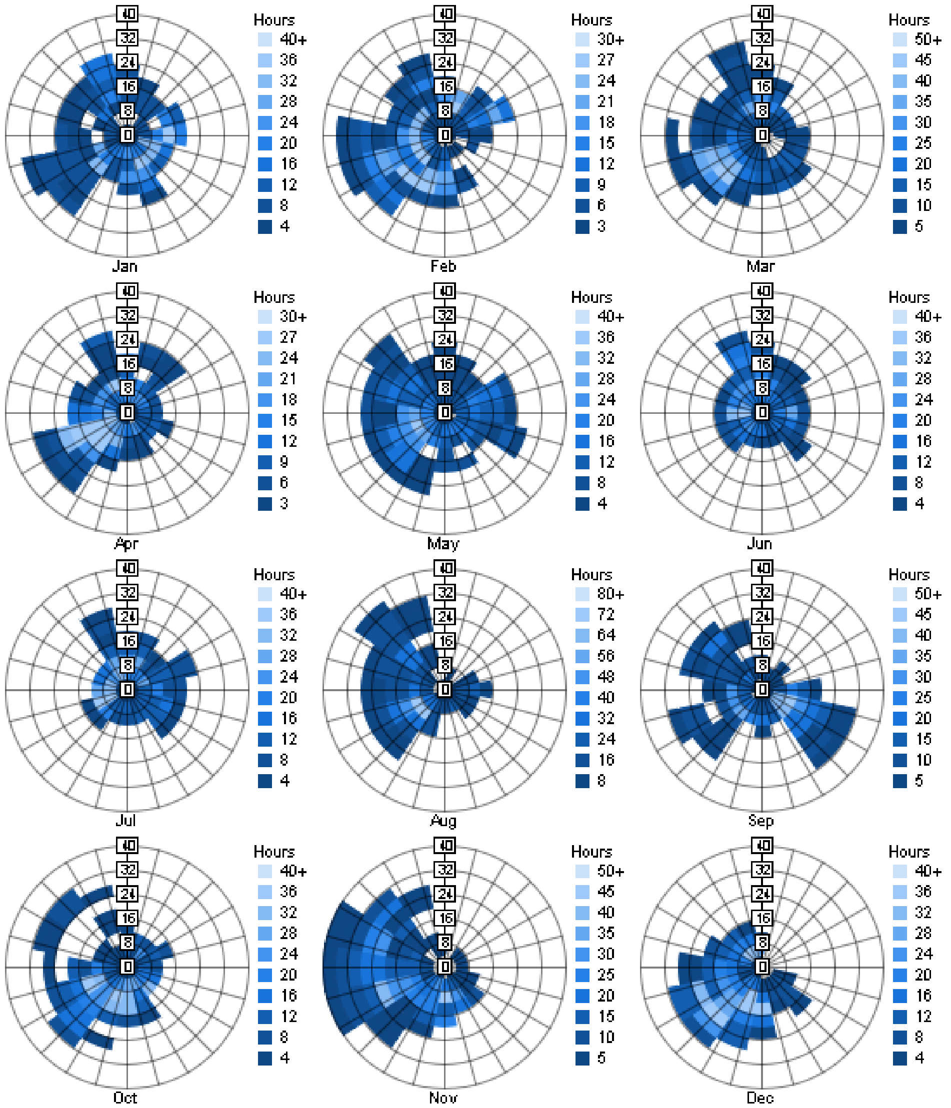
Annual Wind Rose (Speed Distribution)



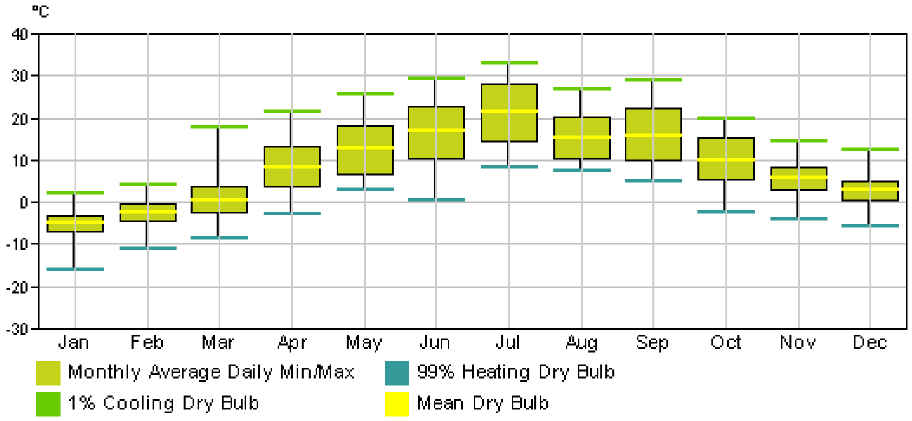
Annual Wind Rose (Frequency Distribution)



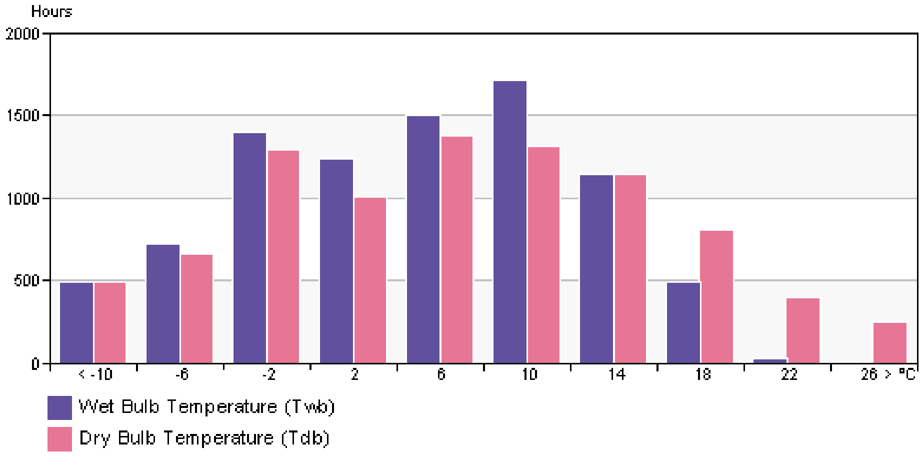
Monthly Wind Roses



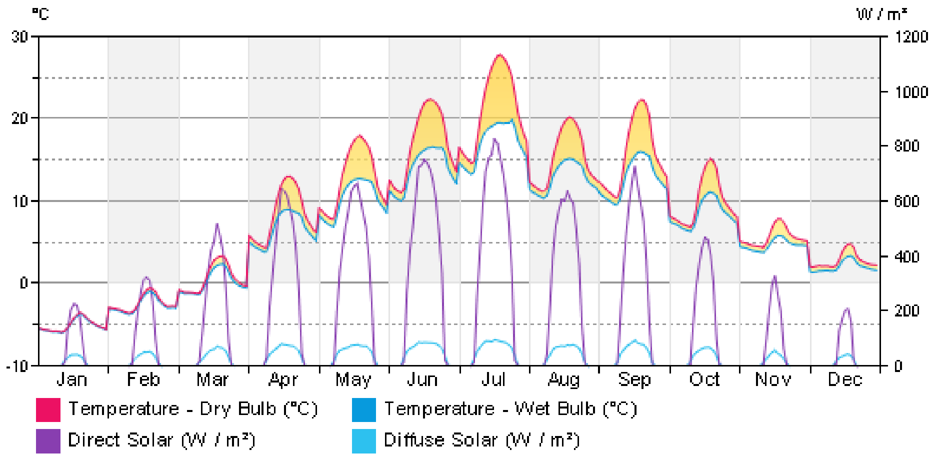
Monthly Design Data



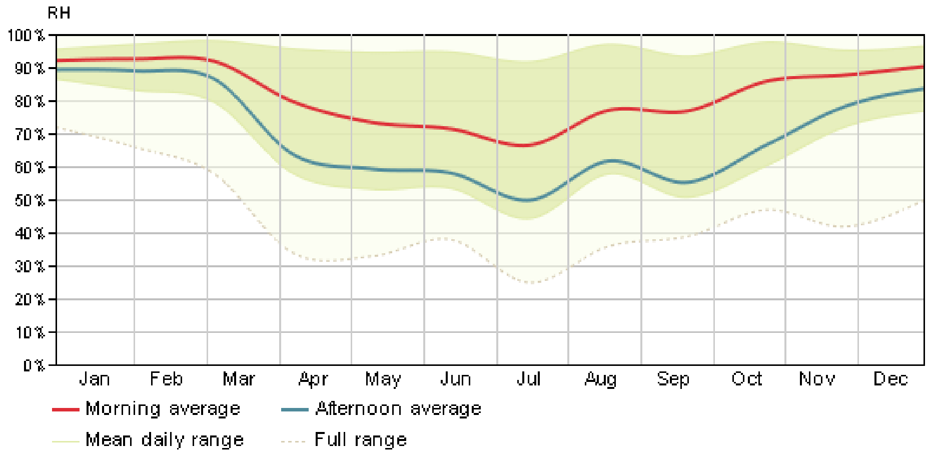
Annual Temperature Bins



Diurnal Weather Averages



Humidity



Energy Analysis Data

LEED, Photovoltaic, Wind energy and Natural ventilation potential results:

LEED Water Efficiency (more details)

	L / yr	$ / yr
Indoor:	1,329,184	$1,798
Outdoor:	1,063,385	$730
Total	**2,392,569**	**$2,528**

Photovoltaic Potential (more details)

Annual Energy Savings:	89,495 kWh
Total Installed Panel Cost:	$742,749
Nominal Rated Power:	93 kW
Total Panel Area:	672 m²
Maximum Payback Period:	38 years @ $0.15 / kWh

Wind Energy Potential

Annual Electric Generation:	1,259 kWh

Natural Ventilation Potential

Total Hours Mechanical Cooling Required:	4,497 Hours
Possible Natural Ventilation Hours:	642 Hours
Possible Annual Electric Energy Savings:	14,772 kWh
Possible Annual Electric Cost Savings:	$2,182
Net Hours Mechanical Cooling Required:	3,855 Hours

Building details and assumptions:

Building Summary - Quick Stats

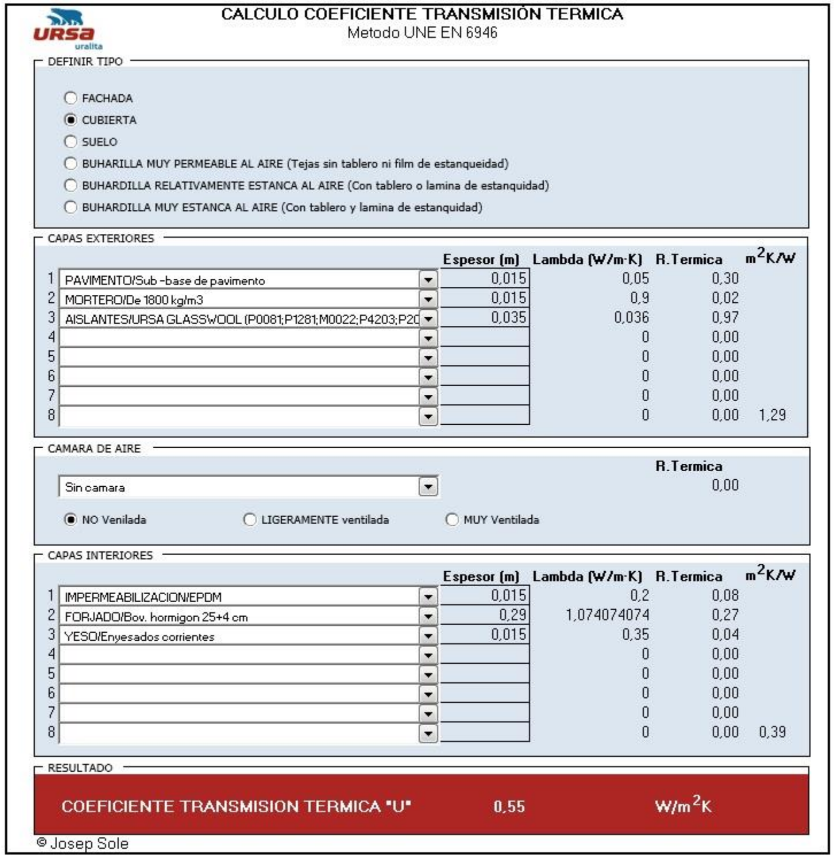
Number of People:	43 people ⬇
Average Lighting Power Density:	10.85 W / m² ⬇
Average Equipment Power Density:	11.00 W / m²
Specific Fan Flow:	6.3 LPerSec / m²
Specific Fan Power:	1.833 W / LPerSec
Specific Cooling:	8 m² / kW
Specific Heating:	6 m² / kW
Total Fan Flow:	10,150 LPerSec
Total Cooling Capacity:	212 kW
Total Heating Capacity:	270 kW

⬆ higher than typical value
⬇ lower than typical value

Base Run Construction		
Roofs	ASHRF28 U-Value: N/A	480 m²
Exterior Walls	ASHWL-66 U-Value: N/A	696 m²
	R11.4 8in CMU Wall U-Value: 0.46	599 m²
Interior Walls	R0 Metal Frame Wall U-Value: 2.35	2,077 m²
Interior Floors	Interior 4in Slab Floor U-Value: 4.18	1,180 m²
Slabs On Grade	SGFLR U-Value: N/A	429 m²
Nonsliding Doors	R2 Default Door (97 doors) U-Value: 2.39	161 m²
Fixed Windows	North Facing Windows: DGL-R-I (104 windows) U-Value: 2.92 W / (m²-K), SHGC: 0.13 , Vlt: 0.07	137 m²
	North Facing Windows: SGLI (21 windows) U-Value: 3.69 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	135 m²
	Non-North Facing Windows: DGL-R-I (256 windows) U-Value: 2.92 W / (m²-K), SHGC: 0.13 , Vlt: 0.07	343 m²
	Non-North Facing Windows: SGLI (18 windows) U-Value: 3.69 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	164 m²
Operable Windows	North Facing Windows: DGL-R-I (33 windows) U-Value: 2.92 W / (m²-K), SHGC: 0.13 , Vlt: 0.07	44 m²
	Non-North Facing Windows: DGL-R-I (48 windows) U-Value: 2.92 W / (m²-K), SHGC: 0.13 , Vlt: 0.07	61 m²

<u>U-value:</u> With the website of a Spanish company building materials *URSA*, heat transfer coefficients of roofs, slabs and exterior walls was calculated. [13]

– Roof:



CALCULO COEFICIENTE TRANSMISIÓN TERMICA
Metodo UNE EN 6946

DEFINIR TIPO

- ○ FACHADA
- ◉ CUBIERTA
- ○ SUELO
- ○ BUHARILLA MUY PERMEABLE AL AIRE (Tejas sin tablero ni film de estanqueidad)
- ○ BUHARDILLA RELATIVAMENTE ESTANCA AL AIRE (Con tablero o lamina de estanquidad)
- ○ BUHARDILLA MUY ESTANCA AL AIRE (Con tablero y lamina de estanquidad)

CAPAS EXTERIORES

		Espesor (m)	Lambda (W/m·K)	R.Termica	m²K/W
1	PAVIMENTO/Sub-base de pavimento	0,015	0,05	0,30	
2	MORTERO/De 1800 kg/m3	0,015	0,9	0,02	
3	AISLANTES/URSA GLASSWOOL (P0081;P1281;M0022;P4203;P20	0,035	0,036	0,97	
4			0	0,00	
5			0	0,00	
6			0	0,00	
7			0	0,00	
8			0	0,00	1,29

CAMARA DE AIRE

Sin camara — R.Termica 0,00

◉ NO Venilada ○ LIGERAMENTE ventilada ○ MUY Ventilada

CAPAS INTERIORES

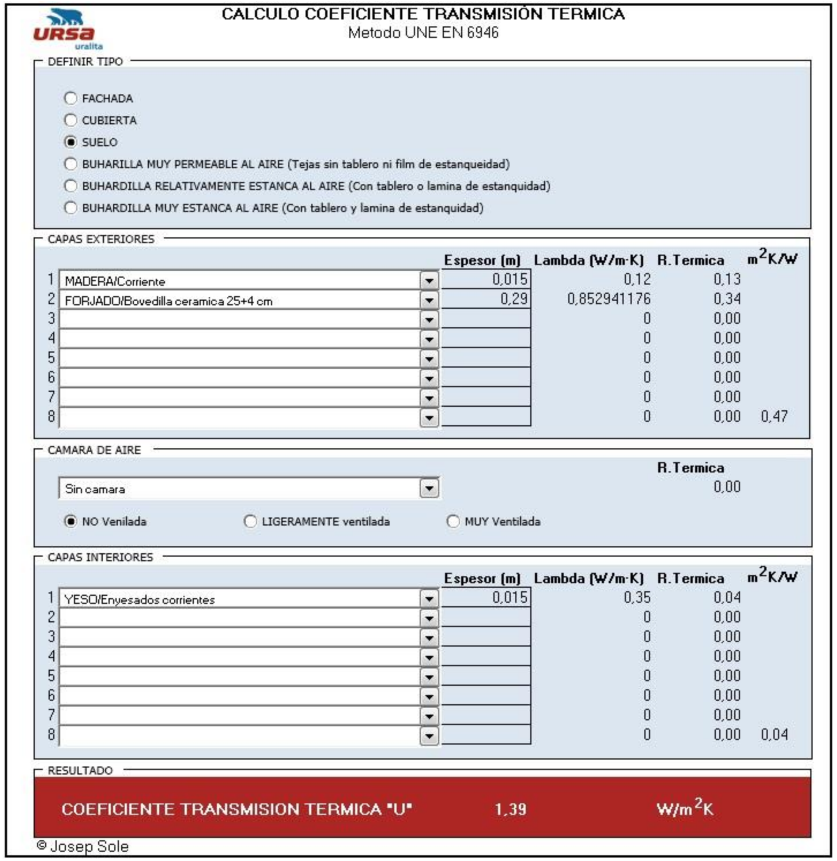
		Espesor (m)	Lambda (W/m·K)	R.Termica	m²K/W
1	IMPERMEABILIZACION/EPDM	0,015	0,2	0,08	
2	FORJADO/Bov. hormigon 25+4 cm	0,29	1,074074074	0,27	
3	YESO/Enyesados corrientes	0,015	0,35	0,04	
4			0	0,00	
5			0	0,00	
6			0	0,00	
7			0	0,00	
8			0	0,00	0,39

RESULTADO

COEFICIENTE TRANSMISION TERMICA "U" 0,55 W/m²K

© Josep Sole

– Slabs:



CALCULO COEFICIENTE TRANSMISIÓN TERMICA
Metodo UNE EN 6946

DEFINIR TIPO

- ○ FACHADA
- ○ CUBIERTA
- ◉ SUELO
- ○ BUHARILLA MUY PERMEABLE AL AIRE (Tejas sin tablero ni film de estanqueidad)
- ○ BUHARDILLA RELATIVAMENTE ESTANCA AL AIRE (Con tablero o lamina de estanquidad)
- ○ BUHARDILLA MUY ESTANCA AL AIRE (Con tablero y lamina de estanquidad)

CAPAS EXTERIORES

		Espesor (m)	Lambda (W/m·K)	R.Termica	m²K/W
1	MADERA/Corriente	0,015	0,12	0,13	
2	FORJADO/Bovedilla ceramica 25+4 cm	0,29	0,852941176	0,34	
3			0	0,00	
4			0	0,00	
5			0	0,00	
6			0	0,00	
7			0	0,00	
8			0	0,00	0,47

CAMARA DE AIRE

Sin camara — R.Termica 0,00

◉ NO Venilada ○ LIGERAMENTE ventilada ○ MUY Ventilada

CAPAS INTERIORES

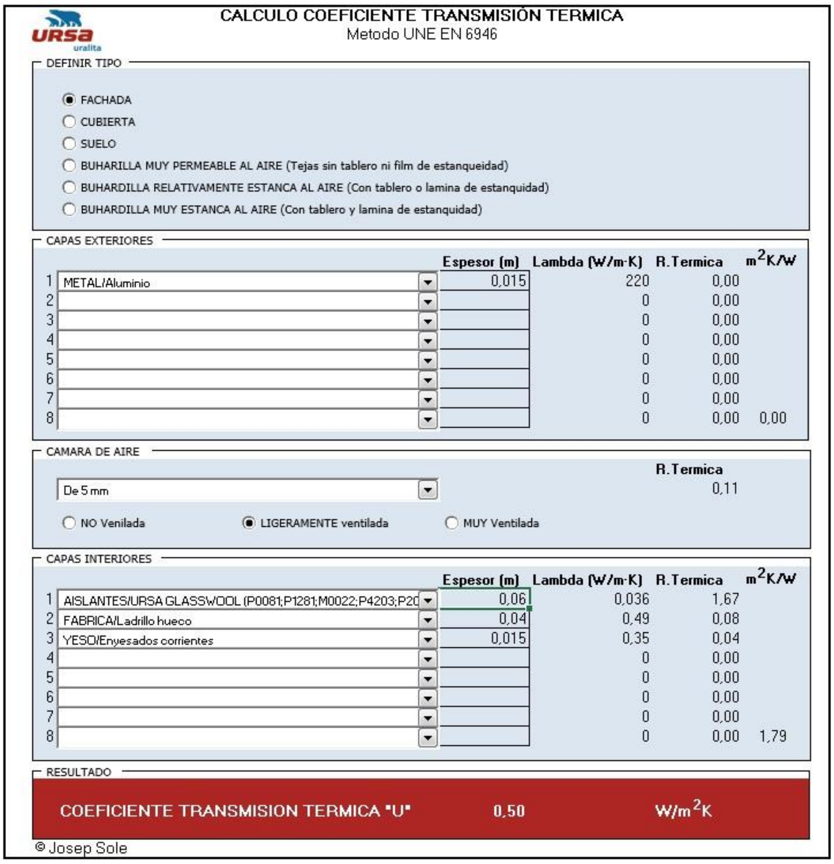
		Espesor (m)	Lambda (W/m·K)	R.Termica	m²K/W
1	YESO/Enyesados corrientes	0,015	0,35	0,04	
2			0	0,00	
3			0	0,00	
4			0	0,00	
5			0	0,00	
6			0	0,00	
7			0	0,00	
8			0	0,00	0,04

RESULTADO

COEFICIENTE TRANSMISION TERMICA "U" 1,39 W/m²K

© Josep Sole

– Exterior wall (office):



CALCULO COEFICIENTE TRANSMISIÓN TERMICA
Metodo UNE EN 6946

DEFINIR TIPO

- (•) FACHADA
- ( ) CUBIERTA
- ( ) SUELO
- ( ) BUHARILLA MUY PERMEABLE AL AIRE (Tejas sin tablero ni film de estanqueidad)
- ( ) BUHARDILLA RELATIVAMENTE ESTANCA AL AIRE (Con tablero o lamina de estanquidad)
- ( ) BUHARDILLA MUY ESTANCA AL AIRE (Con tablero y lamina de estanquidad)

CAPAS EXTERIORES

		Espesor (m)	Lambda (W/m·K)	R.Termica	m^2K/W
1	METAL/Aluminio	0,015	220	0,00	
2			0	0,00	
3			0	0,00	
4			0	0,00	
5			0	0,00	
6			0	0,00	
7			0	0,00	
8			0	0,00	0,00

CAMARA DE AIRE

De 5 mm — R.Termica 0,11

( ) NO Venilada (•) LIGERAMENTE ventilada ( ) MUY Ventilada

CAPAS INTERIORES

		Espesor (m)	Lambda (W/m·K)	R.Termica	m^2K/W
1	AISLANTES/URSA GLASSWOOL (P0081;P1281;M0022;P4203;P20	0,06	0,036	1,67	
2	FABRICA/Ladrillo hueco	0,04	0,49	0,08	
3	YESO/Enyesados corrientes	0,015	0,35	0,04	
4			0	0,00	
5			0	0,00	
6			0	0,00	
7			0	0,00	
8			0	0,00	1,79

RESULTADO

COEFICIENTE TRANSMISION TERMICA "U" 0,50 W/m^2K

© Josep Sole

5.2. DORMITORY STUDIO:

Project details and defaults:

Name	FPM REVIT Energy Analysis dormitory
Building Type [1]	Dormitory
Schedule [1] ⓘ	Default
Project Type [2] ⓘ	○ Actual Project: A new or existing building project ● Test Project: For Learning or demonstration only
Address [3]	
City [3]	BuÅ¡tÄ›hrad
State/Province [3]	
Postal Code [3]	273 43
Country [3]	Czech Republic
Time Zone [3]	Dateline Standard Time
Currency [3]	US Dollar (USD)
Notes	
Data Access ⓘ	● Do not share any data associated with the project. ○ Share only summary data. For example, the building type or floor area. ○ Share all project data.
Contact Preference ⓘ	● Do not contact me. ○ Only Autodesk may contact me. ○ Autodesk partners may contact me regarding this project.
Autodesk Green Building Studio Web Service Terms of Use (TOU) ⓘ	Cared Brocos is authorized to accept the terms of the TOU and share project data with the GBS web service.

[1]Cannot be changed if runs are present.
[2]Green Building Studio maintains a database of building projects to track modeled vs actual energy use. This will help us better understand the energy use patterns for various building types in different climates.
[3]Cannot be changed once a project has been created.

Info | Building | Spaces | Zones | Surfaces | Openings | HVAC & DHW

Current Project Name:	FPM REVIT Energy Analysis dormitory
Company name:	UPV
Entered user name:	1027076
Current template name:	FPM REVIT Energy Analysis dormitc [Update Name]

AUTODESK.

FPM REVIT Energy Analysis dormitory

FPM REVIT Energy Analysis dormitory

Analyzed at 6/10/2014 12:07:27 PM

Energy Analysis Result

Building Performance Factors

Location:	50,157054901123,14,1684637069702
Weather Station:	161987
Outdoor Temperature:	Max: 33°C/Min: -16°C
Floor Area:	1,608 m²
Exterior Wall Area:	696 m²
Average Lighting Power:	10.87 W / m²
People:	123 people
Exterior Window Ratio:	1.29
Electrical Cost:	$0.15 / kWh
Fuel Cost:	$1.33 / Therm

Energy Use Intensity

Electricity EUI:	147 kWh / sm / yr
Fuel EUI:	2,100 MJ / sm / yr
Total EUI:	2,628 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	7,069,332 kWh
Life Cycle Fuel Use:	101,332,924 MJ
Life Cycle Energy Cost:	$1,054,249

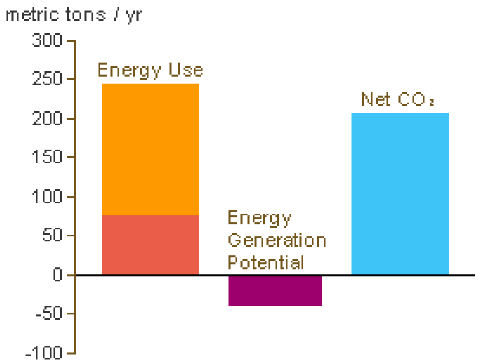
*30-year life and 6.1% discount rate for costs

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	38,795 kWh / yr
Roof Mounted PV System (Medium efficiency):	77,590 kWh / yr
Roof Mounted PV System (High efficiency):	116,385 kWh / yr
Single 15' Wind Turbine Potential:	1,259 kWh / yr

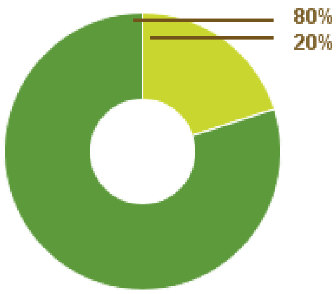
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

Annual Carbon Emissions



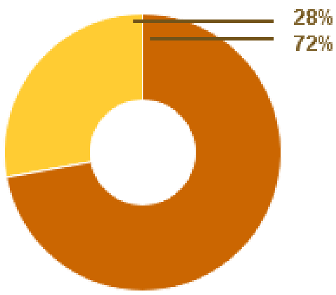
	(metric tons / yr)
Electricity Consumption	76
Fuel Consumption	168
Roof PV Potential (High Efficiency)	-37
Single 15' Wind Turbine Potential	0
Net CO_2	207

Annual Energy Use/Cost



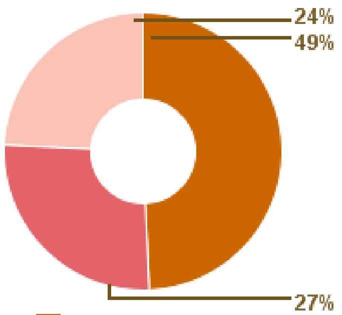
Electricity	20%	$34,805	235,644	kWh
Fuel	80%	$42,600	3,377,764	MJ
		$77,404		

Energy Use: Fuel



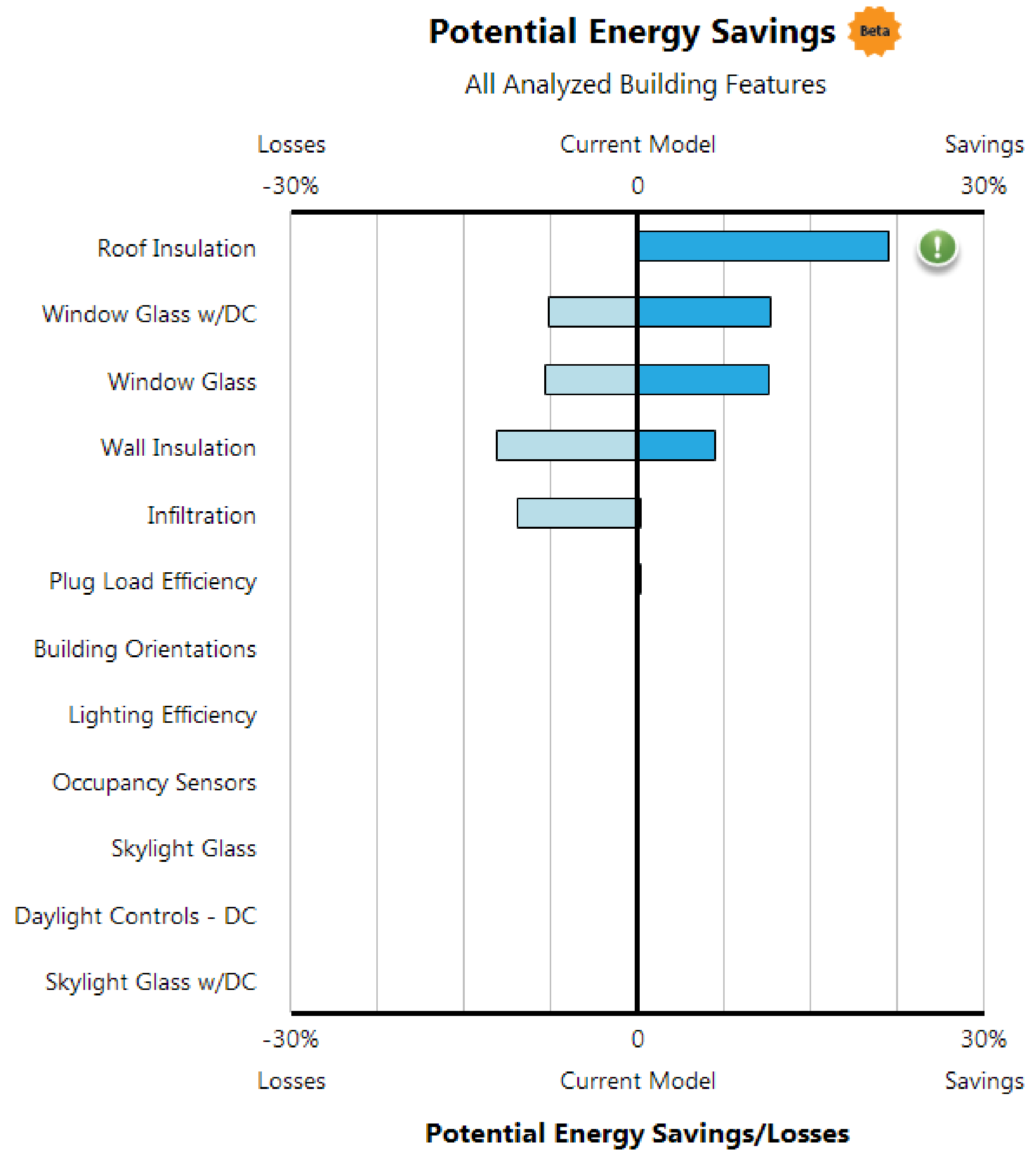
			(MJ)
HVAC	72%	$30,727	2,436,377
Domestic Hot Water	28%	$11,872	941,388
		$42,599	3,377,765

Energy Use: Electricity

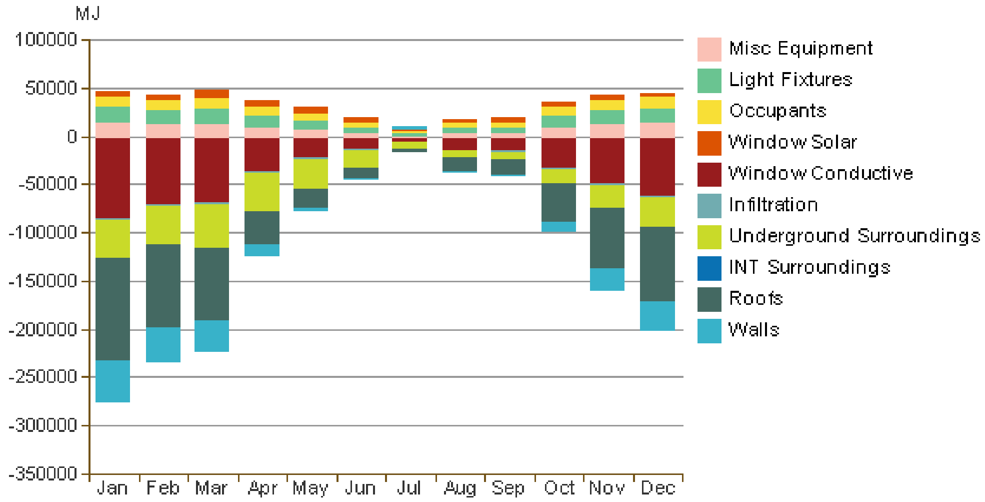


			(kWh)
HVAC	49%	$17,152	116,128
Lighting	27%	$9,207	62,336
Misc Equipment	24%	$8,445	57,179
		$34,804	235,643

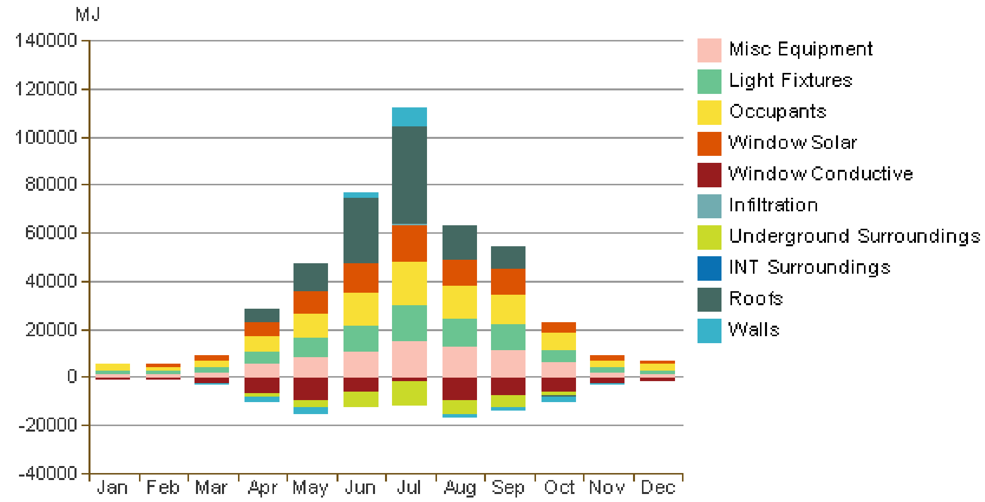
Potential Energy Savings



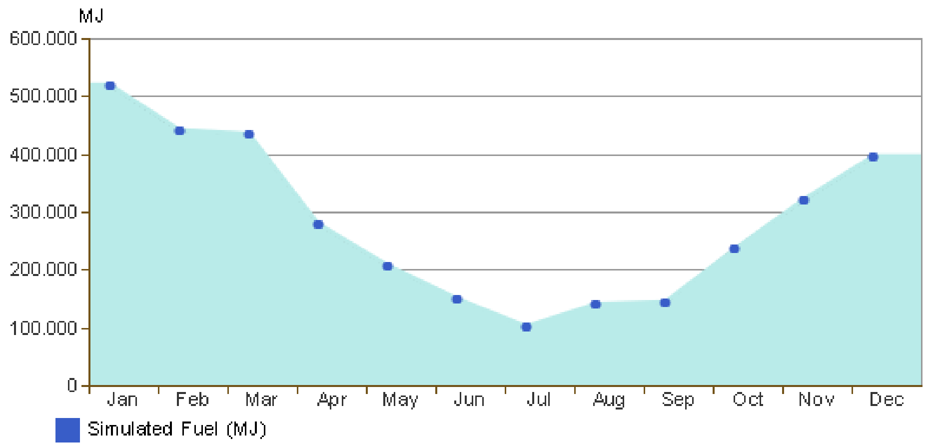
Monthly Heating Load



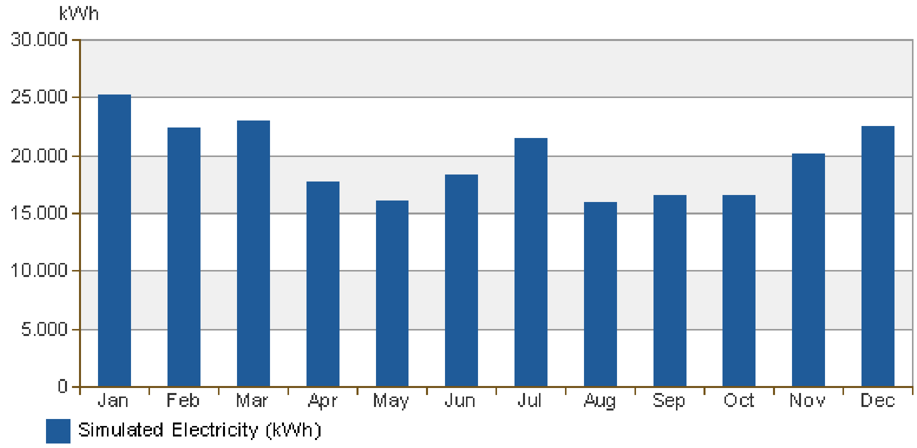
Monthly Cooling Load



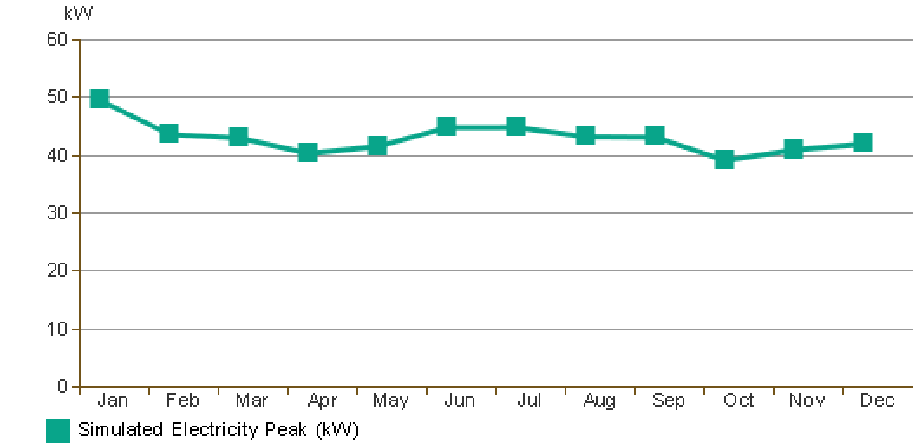
Monthly Fuel Consumption



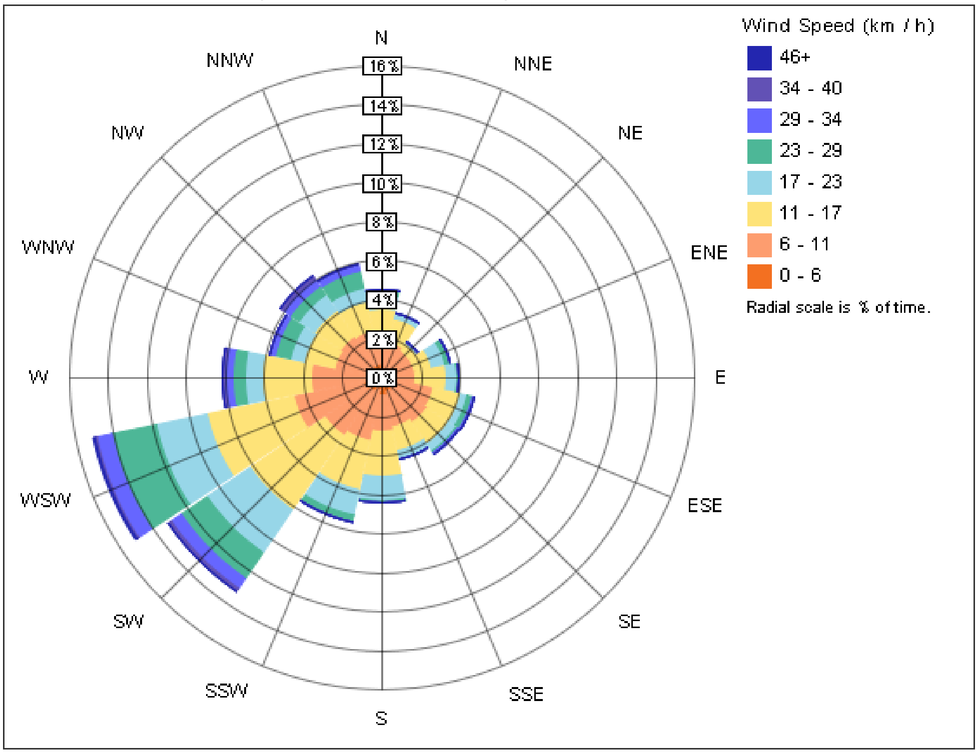
Monthly Electricity Consumption



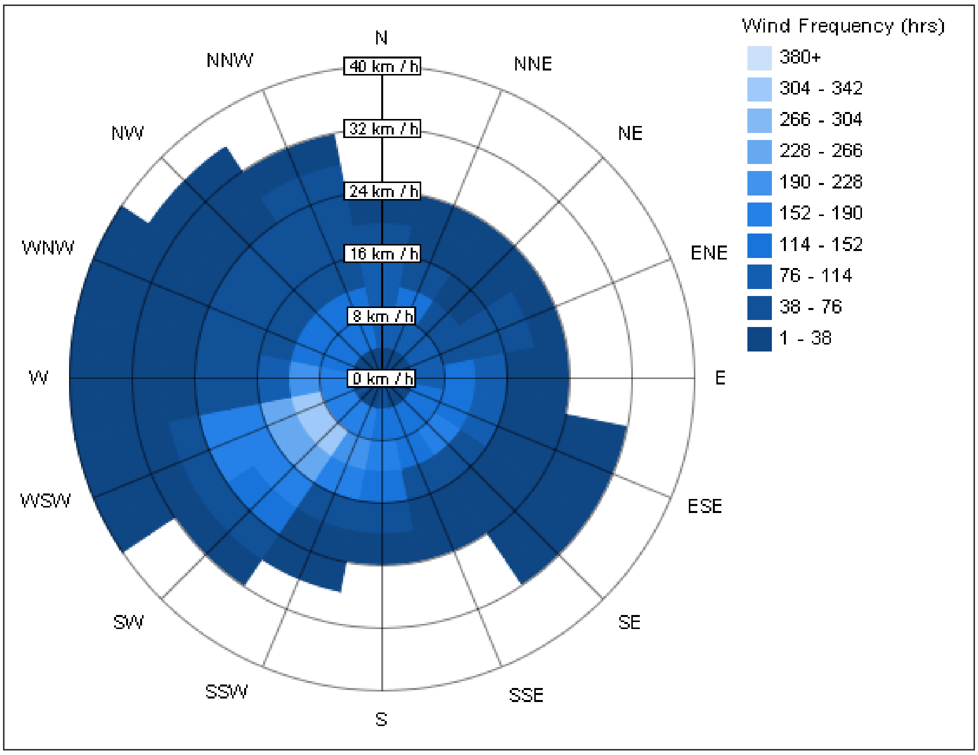
Monthly Peak Demand



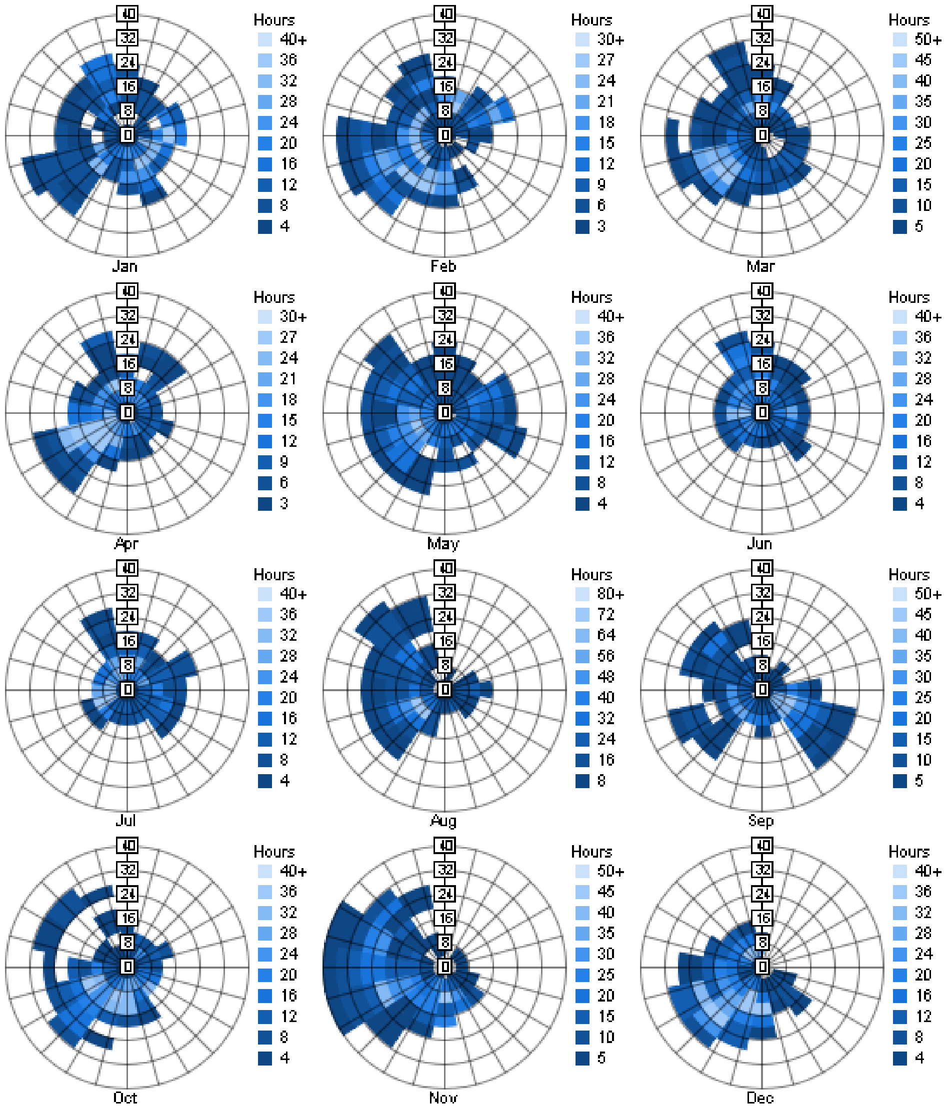
Annual Wind Rose (Speed Distribution)



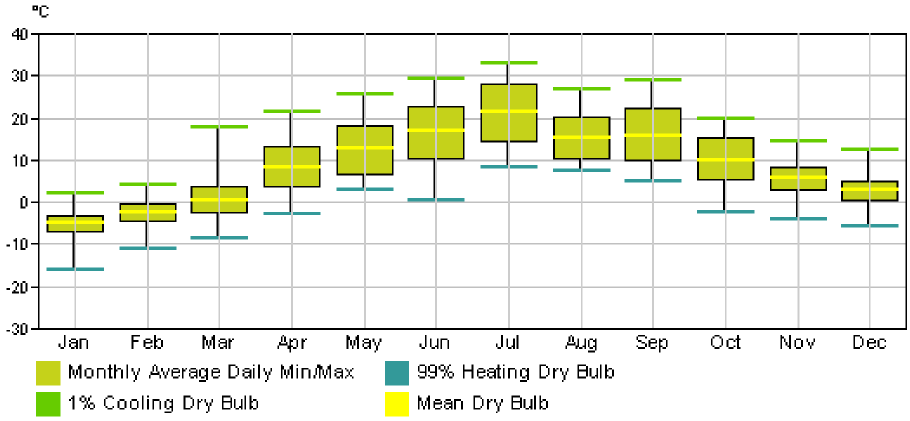
Annual Wind Rose (Frequency Distribution)



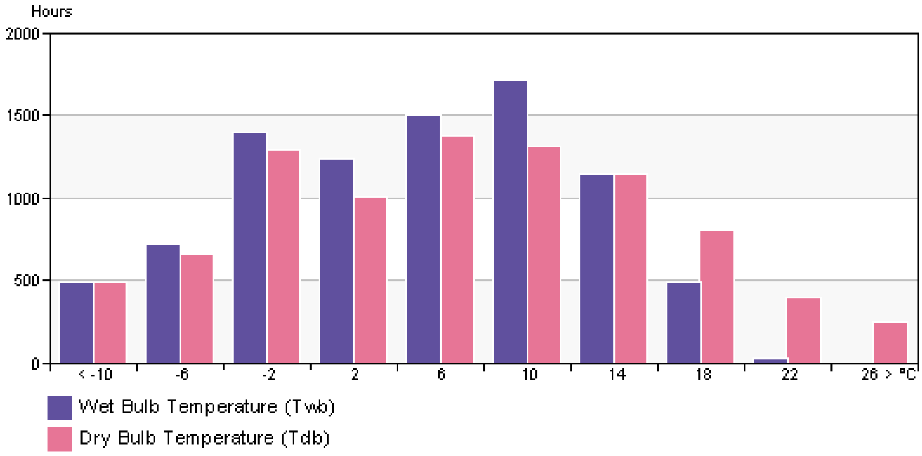
Monthly Wind Roses



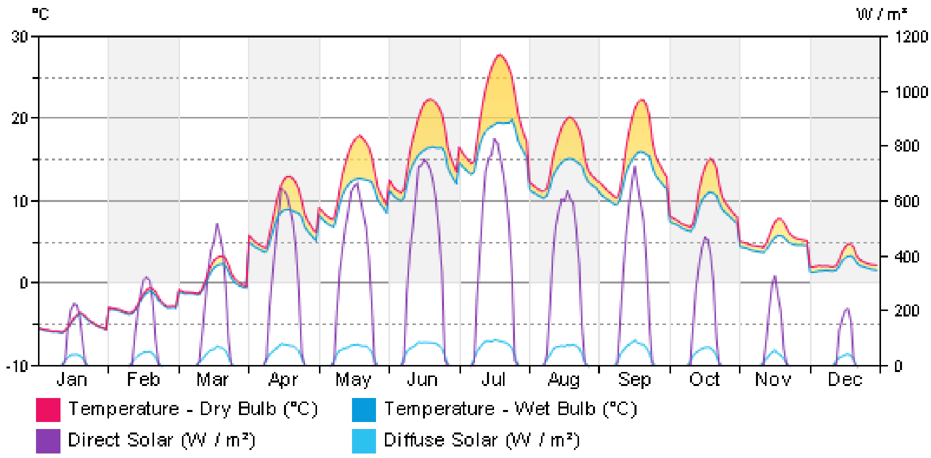
Monthly Design Data



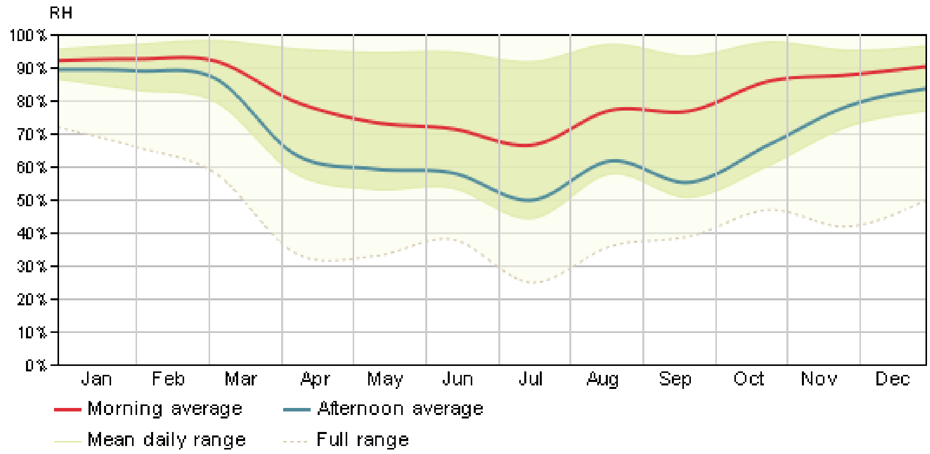
Annual Temperature Bins



Diurnal Weather Averages



Humidity



Energy Analysis Data

LEED, Photovoltaic, Wind energy and Natural ventilation potential results:

LEED Water Efficiency (more details)

	L / yr	$ / yr
Indoor:	12,440,040	$19,646
Outdoor:	444,056	$305
Total	**12,884,096**	**$19,951**

Photovoltaic Potential (more details)

Annual Energy Savings:	89,495 kWh
Total Installed Panel Cost:	$742,749
Nominal Rated Power:	93 kW
Total Panel Area:	672 m²
Maximum Payback Period:	38 years @ $0.15 / kWh

Wind Energy Potential

Annual Electric Generation:	1,259 kWh

Natural Ventilation Potential

Total Hours Mechanical Cooling Required:	5,651 Hours
Possible Natural Ventilation Hours:	871 Hours
Possible Annual Electric Energy Savings:	18,883 kWh
Possible Annual Electric Cost Savings:	$2,789
Net Hours Mechanical Cooling Required:	4,780 Hours

Building details and assumptions:

Building Summary - Quick Stats

Number of People:	123 people
Average Lighting Power Density:	10.85 W / m² ⬇
Average Equipment Power Density:	8.21 W / m²
Specific Fan Flow:	6.1 LPerSec / m²
Specific Fan Power:	1.833 W / LPerSec
Specific Cooling:	8 m² / kW
Specific Heating:	6 m² / kW
Total Fan Flow:	9,827 LPerSec
Total Cooling Capacity:	206 kW
Total Heating Capacity:	262 kW

⬆ higher than typical value
⬇ lower than typical value

Base Run Construction		
Roofs	ASHRF28 U-Value: N/A ⓘ	480 m²
Exterior Walls	ASHWL-66 U-Value: N/A ⓘ	696 m²
	R13.3 8in Concrete U-Value: 0.42 ⓘ	599 m²
Interior Walls	R0 Metal Frame Wall U-Value: 2.35 ⓘ	2,077 m²
Interior Floors	R0 Wood Frame Floor U-Value: 1.16 ⓘ	1,180 m²
Slabs On Grade	SGFLR U-Value: N/A ⓘ	429 m²
Nonsliding Doors	R2 Default Door (97 doors) U-Value: 2.39 ⓘ	161 m²
Fixed Windows	North Facing Windows: DGL-R-I (104 windows) U-Value: 2.92 W / (m²-K), SHGC: 0.13 , Vlt: 0.07	137 m²
	North Facing Windows: SGLI (21 windows) U-Value: 3.69 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	135 m²
	Non-North Facing Windows: DGL-R-I (256 windows) U-Value: 2.92 W / (m²-K), SHGC: 0.13 , Vlt: 0.07	343 m²
	Non-North Facing Windows: SGLI (18 windows) U-Value: 3.69 W / (m²-K), SHGC: 0.86 , Vlt: 0.90	164 m²
Operable Windows	North Facing Windows: DGL-R-I (33 windows) U-Value: 2.92 W / (m²-K), SHGC: 0.13 , Vlt: 0.07	44 m²
	Non-North Facing Windows: DGL-R-I (48 windows) U-Value: 2.92 W / (m²-K), SHGC: 0.13 , Vlt: 0.07	61 m²

U-value: The coefficients of the slab and the roof are the same, computed in the previous study. Only the exterior wall varies.

– Exterior wall (dormitory):

CALCULO COEFICIENTE TRANSMISIÓN TERMICA
Metodo UNE EN 6946

DEFINIR TIPO

- (•) FACHADA
- ( ) CUBIERTA
- ( ) SUELO
- ( ) BUHARILLA MUY PERMEABLE AL AIRE (Tejas sin tablero ni film de estanqueidad)
- ( ) BUHARDILLA RELATIVAMENTE ESTANCA AL AIRE (Con tablero o lamina de estanquidad)
- ( ) BUHARDILLA MUY ESTANCA AL AIRE (Con tablero y lamina de estanquidad)

CAPAS EXTERIORES

		Espesor (m)	Lambda (W/m·K)	R.Termica	m^2K/W
1	YESO/Enyesados corrientes	0,015	0,35	0,04	
2	FABRICA/Ladrillo hueco	0,115	0,49	0,23	
3	YESO/Enyesados corrientes	0,015	0,35	0,04	
4			0	0,00	
5			0	0,00	
6			0	0,00	
7			0	0,00	
8			0	0,00	0,32

CAMARA DE AIRE

De 5 mm — R.Termica 0,11

(•) NO Venilada ( ) LIGERAMENTE ventilada ( ) MUY Ventilada

CAPAS INTERIORES

		Espesor (m)	Lambda (W/m·K)	R.Termica	m^2K/W
1	AISLANTES/URSA GLASSWOOL (P0081;P1281;M0022;P4203;P20	0,035	0,036	0,97	
2	FABRICA/Ladrillo hueco	0,04	0,49	0,08	
3	YESO/Enyesados corrientes	0,015	0,35	0,04	
4			0	0,00	
5			0	0,00	
6			0	0,00	
7			0	0,00	
8			0	0,00	1,10

RESULTADO

COEFICIENTE TRANSMISION TERMICA "U" 0,59 W/m^2K

As shown in the study of the building, what is most striking is the lack of effectiveness of thermal insulation.

Remember that it is located in Prague, so the thickness of the insulation that is commonly used in Spain, especially Valencia, is much better.

So you should switch to one that better conserve the heat inside. The problem for the thermal requirements of the building does not have an ecological isolation is complying with the requirements.

CONCLUSION

As previously seen, it is of vital importance to take into account several parameters when deciding which type of insulating material better fits to our projects. Depending on the climate area, the type and orientation of the building, the application on which the insulation is to be used and some properties such a fire resistance, water behavior or mechanical stability, we will decide to use one type of insulation or another. The thermal performance of the insulation materials is one of the important properties to take into consideration since we can reduce the energy consumption of the building by selecting materials that can achieve a high R-value per inch due to their low thermal conductivity.

By studying, investigating and applying new insulation materials, we can reduce the total fossil fuel consumed by buildings (40% in the European Union) and thus, the amount of greenhouse gases, closing the gap every time more, to achieve net-zero energy buildings.

The model, the model has shortcomings in thermal insulation, you should use one even better with the demands of the building there is no thermal insulation is organic and environmentally friendly.

For the rest, it has enough space around it, so no problem in topic of solar radiation, and energy harvesting.

Although the budget initially increases considerably (materials, systems, constructively and skilled labor) medium to long term cost savings and in turn will help to reduce CO_2 values are noticed.

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[4] Construmática (Webpage)

[6] Google imagen

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[7] Google Maps

[8]

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[10]

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