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Green Buildings: What is the impact of construction with High Environmental Quality?

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1 Introduction – a definition of green building

We will start with a two part section. In the first part, we will precisely define what constitutes an 'impact', hence outlining the scope of the article. Then we will identify what a green building is, using definitions from different sources.

1.1 Definition of an impact

1.1.1 Flows

Various elements can be thought of as flowing into a building at any given moment. They are in constant movement in every building; entering, accumulating, modifying or being modified, and then passing out of the building in one form or another. How successfully these elements are controlled, moved, or otherwise manipulated are the determining factor of whether or not a building can be called successful.

Some of these flows are easily visualized because they are material: water, air, building elements, raw materials, etc. For example, a certain volume of water will enter a typical building each day through the water mains network. Some may be stored, to be used after certain modifications to its characteristics such as temperature and state (solid, liquid, or vapour) or even used to accumulate pollution. Ultimately, it will be released. This may occur through the sewage or ventilation system or even integrated into a product. This same type of *path* can be charted for every material flow.

Some other flows tend to be less easy to visualize because they do not consist of material elements going in and out. Energy is a typical example of this type of flow. It enters the building in different forms (electricity, fuel, sunlight, etc.), may be stored (as heat or cold for example) or transformed (electrical motors transforming electricity into mechanical and thermal energy). This energy too will be ultimately released into the surrounding environment in some form, usually as heat, chemical energy in exhaust gas, or as energy stored in products.

The last type of flow can be categorized as virtual, only because they do not have a material or an overtly predominant role in daily activities. Money, for example, will 'enter' the building at its construction, be partly stored as supporting facilities, but kept flowing in the operation and maintenance activities. Eventually it is released at the time of sale.

All of these flows are critically important, since, as noted in the GGHC[1] 'The construction and use of buildings in the U.S. consumes 3 billion tons of raw materials annually (40 per cent of raw stone, gravel, sand, and steel, 25 per cent of virgin wood, 40 per cent of energy resources, 75 per cent of PVC, 1 per cent of freshwater flows) and generates significant waste (25-40 per cent of municipal solid waste from construction and demolition alone), 50 per cent of CFCs, 30 per cent of CO_2 production, and substantial toxic emissions.'

The USGBC[2] notes that 'In the United States, buildings account for:

- 36 per cent of total energy use/65 per cent of electricity consumption
- 30 per cent of greenhouse gas emissions
- 30 per cent of raw materials use
- 30 per cent of waste output/136 million tons annually
- 12 per cent of potable water consumption'

A particular type of flow is in fact the people living or working in a building. They enter at some point in time, interact with this environment, and finally leave the building.

[1] GGHC: Green Guide for Health Care
[2] USGBC: United States Green Building Council

This representation of the flows that enter and exit a building throughout its whole life will help us define precisely what constitutes an impact.

1.1.2 IMPACTS

As seen above, a large number and series of flows are continuously running through buildings, and are modified as a result. Therefore, an impact can be defined as the difference in a given flow between its entrance and its exit. We should note that in this definition, not only the construction itself is considered, but everything that was modified as a result, when compared to the time when the building was not there.

As an example, the construction of a supermarket almost certainly creates new transportation flows, possibly modifying the entire transportation flow within a city. This will have to be considered an impact of any new construction.

In order to help classify the various types of impact, the CSTB[3] in France, has proposed the following classification, based on the receiviCEng typology:

- Impacts on environment
  - Planetary level
  - Regional level
  - Local level
- Impacts on user
  - Impacts on comfort
  - Impacts on health

In this classification system, the various impacts on environment are classified in regards to geographical importance, while the impacts on users are based on intensity.

1.2 Definition(s) of green building

'*We are the relations that we make with the external world.*' — A. Jacquard (French genetic engineer and philosopher).

As seen in the previous chapter, we can characterize the interactions a building is creating with its environment. The purpose of creating green buildings is to minimize the total number of impacts over the entire lifetime of the project. This is made quite clear in the following examples of definitions from several sources:

- 'Green building is a design and construction practice that promotes the economic health and well being of your family, the community, and the environment. A smart step toward personal economic rewards, green building also has positive social and environmental ramifications that assert your commitment to the future and the way we live for years to come'. (www.greenbuilding.com)
- Green or sustainable buildings are sensitive to:
  - Environment
  - Resource and energy consumption
  - Impact on people (quality and healthiness of work environment)
  - Financial impact (cost-effectiveness from a full financial cost-return perspective)

[3] CSTB: Centre Scientifique et Technique du Bâtiment

- The world at large (in the form of a broader set of issues typically the purview of government, such as groundwater recharge and global warming)

California's Executive Order D-16-00 established a concrete set of sustainable building objectives: 'to site, design, deconstruct, construct, renovate, operate, and maintain state buildings that are models of energy, water, and materials efficiency; while providing healthy, productive, and comfortable indoor environments and long-term benefits to Californians.' (Report to California's Sustainable Building Task Force)

- 'Green buildings are buildings that are environmentally responsible, profitable, and healthy places to live and work' (USGBC).

We can in fact make a direct comparison between these definitions and the definition of sustainable development proposed in the Brundtland Report (1987), which introduced it as a balance between social, economic, and environmental development. From this point of view, a building project acquires greenness by realizing a balance between social (user's health, social integration, transportation network, etc.), environmental (use of materials, energy consumption, etc.), and economic constraints (profitability, productivity, etc.). Included in the social aspect is the idea of good governance, providing a frame for the interactions between the organizational structures (administrations, project designers, etc.) and the end-users and stakeholders.

2 Impacts of building projects

The CSTB in France has proposed a synthetic and scaled classification of impacts. We will use this structure here to present a comprehensive view of possible impacts. The impacts are presented following a geographical structure, from the very local to the planetary level.

We will mention some of the specific solutions presently available for each of the impacts noted. These will be within the frame of green construction to adjust the impact level, and will quite often correspond to credits or prerequisites found in the LEED®[4] rating system. Since any single impact can be the subject for an extensive discussion, we have limited our discussion in order to provide the overall scope of the aspects implied in a project without going too deeply into detail. More in-depth information regarding each specific subject can be found in the accompanying bibliography.

While evaluating the extent of the various types of impact, one should always keep in mind the constant interactions between them. As an example, modifying interior lighting (impact on user) can often modify hydrothermal comfort (another albeit different impact on the user) and consumption of energy (regional and/or planetary impact). Such interactions abound for each impact discussed here, hence the necessity for a general, overall approach of the entire impact problem. It is our wish to simply open possible pathways for optimized choices.

2.1 Types of impact on users

2.1.1 Impact on comfort

User comfort can be modified by a significant number of factors related to the way the building behaves. These factors are listed below.

- Hydrothermal discomfort

Hydrothermal discomfort inside a building can be easily studied by considering the Fanger equation for comfort, which describes the six essential parameters related to human comfort: ambient temperature, radiant temperature, humidity, air velocity, clothing insulation, and

[4] LEED®: Leadership in Energy and Environmental Design

activity level. This equation is elucidated in detail in *Human Thermal Environment* (Parsons, 2002, Taylor & Francis Ltd).

Whereas activity level and clothing insulation depend only on the user's behaviour, the other four parameters are typically influenced by design and construction solutions. Discomfort can therefore be considered a consequence of inadequate consideration of these parameters or the unexpected movement of air, abnormal values of surface temperatures, air temperature, or relative humidity.

These parameters can be efficiently controlled passively (that is, without an active, energy consuming system) by using a bioclimatic approach in the building design. The particular problem of surface temperature can also be dealt with by a careful study of the effusion of materials. For example, the use of highly effusive materials such as smooth, hard, nonporous materials in rooms that need to feel cool and low effusion materials such as wood coverings in rooms like bathrooms intended to feel warmer, Special attention needs to be given window surface orientation to prevent overheating in the summer and excessive cooling in the winter. Solutions such as low-emission glass are often used.

At a second stage, an efficient active air management system can be integrated, like double flow ventilation systems with air quality monitoring. A heat exchanger will help save energy.

- Acoustic inconvenience

Acoustic inconvenience represents all aural sensations experienced by the user due to noise at all frequencies, levels, and dynamics. Such inconvenience can be experienced inside as well as near the building and is a result of the double influence of the building's operational use (equipment, activities, etc.) and its surrounding environment (road, air, or rail traffic, industries, etc.).

There are a large variety of solutions available ensure a high quality acoustic environment. However all have one thing in common in that they are much easier to employ and more cost-efficient if included during the initial design phase.

The best protection against external noise is the careful study of the site and its acoustic characteristics. The main sources of noise are often nearby rail traffic or motorways, airports, neighbouring buildings, etc. Noise levels within a building from external sources can be lowered by taking into account the prevailing winds. A preliminary study will help determine optimized orientations and may include using cushioning rooms such as storage or parking areas on the most exposed orientations.

Walls and windows will have to be chosen carefully, keeping in mind that massive elements absorb noises better. On traditional wall and window constructions, acoustic insulation capacity is sometimes mentioned in dB. The materials used in construction are also very important, since leakage or weaknesses are entry points for noise.

The relation between acoustic inconvenience and summer comfort also needs to be considered since opening a window is often the least expensive cooling system. An incorrect or incomplete study of noise problems can sometimes make cost efficient cooling impossible.

Equipment, in particular ventilation equipment which often function 24 hours a day, will have to be carefully chosen, taking into account the reverberation properties of the walls and wall coverings to be used. Openwork wood panels are often used to alleviate noise.

- Visual discomfort

Visual discomfort represents every problem experienced through seeing. This impact must be considered for the inside of the building (lack of or excessive light, colour schemes, etc.) as well as in the neighbouring environment (green spaces, landscape, etc.). It is influenced by both the operations being carried out in the building and its surroundings (views, access to sunlight, etc.).

The Heschong Mahone Group has extensively studied the influence of lighting and views in classrooms, retail stores, and offices for the California Energy Commission. They have proven that there is an important correlation between natural lighting and access to external views and the comfort and productivity of the occupants.

Lighting, space design, and simulations are efficient tools to optimize illumination on working or living places. Rooms and associated lighting (natural or artificial) should be designed with the end-user and intended use in mind (type of use, time of use, public versus private space, etc.). Adjustable, permanent, or temporary shading systems made from sustainable natural materials can often help in securing a properly adapted ambiance, while at the same time favourably impacting thermal comfort, particularly in the summer.

- Olfactory discomfort

Bad smells are a very common complaint and have to be considered inside the buildingas well as in its surrounding. They are created by the accumulated effects of a building's operation (bad ventilation, foul-smelling emissions from materials, equipment, activities, and even users themselves) and the surrounding environment (road or air traffic, factories with foul-smelling emissions, etc.).

There is little that can be done regarding external emission sources such as factories or road traffic apart from improving hermetic practices and efficient filtration of the intake air used for ventilation. The design and the construction of the workspaces can have a positive effect on emissions linked to interior activities. Likewise the regular maintenance and cleaning of the ventilation system is particularly important. Green buildings tend to maintain permanently high ventilation rates.

Finally, the initial choice of paints and coatings (wall, floors, etc.) with few or no VOC can greatly help in creating a comfortable olfactory atmosphere. A list of acceptable materials in the LEED® rating system is listed below:

Architectural Applications	VOC limit (g/l less water)	Specialty applications	VOC limit (g/l less water)
Indoor carpet adhesives	50	PVC welding	510
Carpet pad adhesives	50	CPVC welding	490
Wood flooring adhesives	100	ABS welding	325
Rubber floor adhesives	60	Plastic cement welding	250
Sub floor adhesives	50	Adhesive primer for plastic	550
Ceramic tile adhesives	65	Contact adhesive	80
VCT and asphalt adhesives	50	Special purpose contact adhesive	250
Drywall and panel adhesives	50	Structural wood member adhesive	140
Cove base adhesives	50	Sheet applied rubber lining operations	850
Multipurpose construction adhesives	70	Top and trim adhesive	250
Structural glazing adhesive	100		

Substrate Specific Applications	VOC limit (g/l less water)	Sealants	VOC limit (g/l less water)
Metal to metal	30	Architectural	250
Plastic foams	50	Non-membrane roof	300
Porous material (except wood)	50	Roadway	250
Wood	30	Single-ply roof membrane	450
Fibreglass	80	Other	420

Sealant primers	VOC limit (g/l less water)
Architectural non-porous	250
Architectural porous	775
Other	750

It is worth noting that very often, contractors or project leaders require much lower values for VOC content. This is especially the case with private organizations or individuals. This can be based on yet to be established EU norms for paints and coatings, or on strong political choices.

- Inconvenience due to wind

The immediate surroundings of the building can, in many cases, have hydrothermal and acoustic influences. The architect and designer must always take into account wind loads on the structure. They also need to be especially careful of local winds that are modified by already existing buildings, structures, or even roads.

A careful study of the surroundings and the prevailing winds can help design the building in a manner that uses the wind as a resource, for instance, by the installation of a wind powered generator.

- Psycho-sociological discomfort

This impact expresses the discomfort created by a psychological or functional imbalance, or a failure to adapt the operation to the appropriate social frame. This is a consequence of both the operation (external and internal architecture, quality of construction, conviviality of spaces, etc.) and the site (unfriendly site, difficult neighbourhood, distance to social and transport services, etc.).

The building and its site has an important psycho-sociological role. It has direct implications on the users' quality of life as a place where people will live, work, or have various social activities. The entire first chapter in the LEED® rating system deals with this matter as does this chapter. Although many factors are impossible to measure, some can be evaluated, and should be considered at the earliest possible phase in the project. It should be one of the initial considerations when choosing a site.

At this phase in the project, it will be important to go beyond just considerations of the professional environment. Planners must also consider issues such as connectivity (existing and future) of the site as well as basic services, day care, library, school, post office, market, theatre, etc. As an example, depending on the local politics, it may or may not be valuable to build a bank headquartering in a rural area. The basic question to be asked here is, 'How easy and pleasant will the organization of life around this intended building be?'

2.1.2 Impact on health

The impact on health has particularly heavy consequences for the users. This means that security and public health is very often a mandatory field of study.

- Sickness due to soil pollution

Polluted soil containing toxic products can have both a short and long-term influence on the building users' health. This can involve everything from the work environment to a children's playground.

Such pollution can be a consequence of history of the site and its environment (short or long distance accidental deposition of toxic elements such as occurred at Bhopal and Chernobyl). Depending on local regulations, the site may require remediation, decontamination, and certification before a new construction can take place.

It is also important to consider the possibility that a polluting activity will take place in the newly constructed building. Proper early planning can sometimes minimize this impact. One well-known example is InterfaceFLOR, a carpet manufacturer, which initiated a program in 1994, to modify the environmental impact of its waste. The site has since achieved a 63 per cent reduction in the amount of polluting waste it produced.

- Sickness due to water pollution

The influence of water quality on human health is unquestioned. The effects of water pollution on humans, animals, and plants range from the build-up of toxic heavy metals to allergic reactions, and bacterial and viral infections. Water pollution can originate at the local water distribution network or at the internal water network. One very well known example is the impact of lead pipes on tap water quality. In the past, lead has often been chosen for use in massive water pipes and mains because of its favourable physical qualities. It is now known that lead is a proven toxic substance. The World Health Organization has defined acceptable limits, and most water distribution networks in Europe using lead will be replaced by 2013.

- Sickness due to air pollution

Air quality has a strong influence upon human health, both inside and in the neighbourhood of the building. Like water, it can be responsible for a huge range of responses from simple headaches, allergies, and fatigue to fatal infections and cancers. Air quality depends on both the buildings operation (ventilation, materials and equipment, etc.) and the external environment (road and air traffic, airborne pollution from manufacturing, etc.).

Management of indoor air quality is a very important element in every environmental rating system, since, as WHO reports, 'Indoor air pollution causes 14 times more deaths than outdoor air pollution (2.8 million lives). The volatile organic compounds (including pesticides) found indoor are believed to cause 3,000 cases of cancer a year in the US.'

Bad indoor air quality is most often caused by three factors:

1. Bad outdoor air quality: road traffic, industrial production, etc. cause toxic pollutants that can, if not controlled, freely enter the building and accumulate. A common but effective solution is an efficient double flow air management system with filtering functions.
2. Indoor emission of pollutants: the use of glues, paints, and coating can cause both immediate and long-lasting emission of toxic products (Volatile Organic Compounds). An appropriate choice of building materials which might not need coatings (raw wood, stone, adobe, etc.), or coatings with low VOC ratings will dramatically reduce this kind of pollution. Monitoring of indoor air quality in terms of pollutants (CO, NOx, VOC, etc.) is also often used, especially in the early phases of occupancy, to avoid exposure. An example of acceptable levels of VOC (LEED® reference) is given above.

3. Human or process related emission of pollutants: the most common example is tobacco smoke. It is in fact mandatory for a LEED® building to be smoke-free, or to include strongly controlled smoking areas, including all external smoking areas taking into account distance, ventilation, sealing, etc.

- Sickness due to various types of radiation

Ionizing radiation and electromagnetic fields, both inside the building and in the surrounding neighbourhood, have a strong influence upon human health. There are two types of dangerous radiation commonly encountered:

1. Ionizing radiation: This type of radiation is emitted by radioactive elements. The most common source in buildings is radon, a natural radioactive element occurring as a gas seeping from the ground. It is a product of the decay of naturally occurring uranium. The greatest health risk exists when radon is allowed to accumulate in closed spaces because of poor ventilation. Measures to combat this accumulation include increased ventilation rates and construction over ventilated void spaces. On-site measures after construction can be realized in some cases. Some construction materials can also be naturally radioactive (stones, some colouring products, etc.). In most cases, they can be avoided by the right choice of building materials in the early phases of design and construction.

2. Non-ionizing radiation: Electromagnetic radiation can be caused by either direct or alternating current electric systems, and are a strongly suspected as the source of various health problems including cancer, metabolism disruption, stress, and headaches. This type of radiation can be caused by every type of electrical equipment (cables, screens, computers, lighting, etc.). The electric field, which is proportional to voltage and is created even with no electric consumption, can easily be avoided by proper design of the electric path and use of shielded cables where necessary. Magnetic fields, which are proportional to consumption, are not stopped by most common building materials, making the choice of appropriate low emission equipment and security distances the best practices and the most practical solutions.

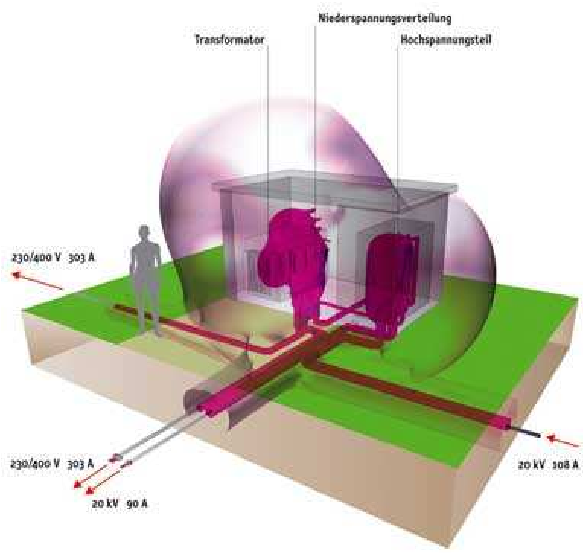

Figure 1: Distribution transformers, often integrated in building, emit strong electromagnetic fields (100 µT in the dark red area, 1 µT in the light red area).

- Illness due to noise and vibration

Noises and vibration, coming from both inside the building or from its local neighbourhood, have an influence on human health. These effects include, among others, cardiac problems, fatigue, irritability, stress, and digestive system disturbances. This impact can be caused by noise and vibration generated both by the operation itself and by the surrounding environment (road, rail or air traffic, structures, factories, etc.). Noise and vibration problems, already mentioned as affecting comfort, can have significant health consequences in some situations.

Specific effects of noise and vibration have been noted by Dr. Deoux in *Le guide de l'habitat sain*, 2002, Medieco Editions. These include, but are not limited to, the following impacts on health: unnecessary stress on the organism resulting in higher breathing and cardiac rates, disturbed sleep patterns, hearing loss and other ear damage, vision modification (including narrower field of vision, slower colour perception and impaired night vision), cognitive problems (especially slower learning in children), and social behaviour disturbances. Corrective measures are the same as for comfort.

- Sick building syndrome

This effect is the result of a combination of a variety of factors that can be traced back to the building's design, building materials, and the cumulative effects of low order characteristics on human health. These effects include among others excessive fatigue and allergies. In this syndrome, it is the building itself which causes the symptoms.

2.2 Impact on the local level

Since a building can have a significant impact upon the individual user, it has also clearly impacts on the local environment. Each of the impacts noted thus far merit further detailed review. The purpose of this paper however is to provide an overall view.

- Land occupation and depletion of plant covering

The primary impact of architecture choices, in the overall sense, includes the building's structure and the transportation and distribution organization. It concerns the occupied surface and the quality of the modified surface such as soil drying and the selection and modification of plant cover. A series of rule-of-the-thumb practices have been noted by some observers to lower the impact of construction. Observance of these rules results in reduced pressure on undeveloped land by avoiding previously unoccupied sites. They also encourage brownfield redevelopment and the increase of human density with its accompanying increase in efficiency. Observance of these rules also includes the promotion of a rehabilitation projects, instead of a new construction.

A low impact on plant covering has to be achieved during the construction process as well as the control of storm water and sedimentation. Absorbent soil covering and a minimum open space (recommended to be at least equal to the surface of the building area) should be a primary consideration in all building designs. It must always be remembered in the planning phase that waterproofing techniques and nonporous installations such as above and below ground parking lots and roads have a very high impact on the natural flow of water both above and below ground.

- Urban inconvenience (wind, shadow, noise, dust, smells, visual aspect, neighbourhood)

This impact expresses the influence of the construction operation on the local neighbourhood. It concerns the inconvenience caused for the neighbours, not the users (see paragraph 'impact on users'). There are several categories of urban inconvenience, including:

1. Modifications in natural wind patterns, created by the building or other installations (trees, etc.). This is especially sensitive in pedestrian areas.

High winds and turbulence created by the venturi effect of air moving down narrow or constricted channels between high buildings are common in large high-rise American cities. Common solutions include lower profile building and a move towards more organic urban structures.

2. Shadows created by buildings and other installations on the neighbourhood. Many urban regulations include a right to sunlight, and a new construction should not create any excessive sun depletion (extended or continuous shadows) for the neighbourhood. An accepted rule-of-the-thumb is to respect a distance of twice the height of the building between each building (whereas regulations may only impose a distance equal to the height). A computer simulation is often used in projects where this may be a critical factor.
3. Noise, created during both the construction phase and the operational phase (air conditioning, heat pumps, etc.). A variety of noise characteristics such as the decibel level, frequencies, and rhythm can be measured and considered, in order to propose adapted solutions. A common sense solution is to make a comprehensive noise survey of the neighbourhood before the construction process begins and to adapt working times where possible, to the area's normal working hours, school hours, etc. Very good levels around 75 dB(A) can be achieved with appropriate measures and equipment (sound insulation used on the equipment, shutters locked with nuts and keys instead of the traditional hammering on wing nuts, etc.).
4. Dust, created during the construction phase and operation. Dust particles can be mineral or organic, and have major consequences regarding respiratory health, discomfort, and general air-quality. A systematic cleaning of trucks, tires, and equipment before leaving the construction area, the choice of enclosed cab trucks and earth moving equipment, and aspiration devices can significantly reduce both health and nuisance effects on workers and the neighbourhood.
5. Smells
6. Visual modification of the site, an expression of the aesthetic integration of the operation in the neighbourhood. This is the 'visible tip of the iceberg', because everyone visiting the site or living in the area will judge the architectural quality of the project. This is one of the principal roles of the architect, but early surveys, consultation, and discussion with neighbours can greatly increase the acceptability of any project.
7. The neighbourhood can also generate a variety of types of discomfort not mentioned above, in particular those of psycho-sociological nature. For example, this can be the functional imbalance created in the area or insufficient respect for the existing social framework. Collective dwellings in an industrial area and excessive separation of social categories are two common classes of social integration problems.
8. Inconvenience for workers and maintenance agents (wind, noise, vibration, dust, air and soil pollution, smells, hydrothermal ambiance, etc.). This impact accumulates and compounds the influence of the operation on the comfort and health of the workmen during the construction phase and operation agents during the operational phase.
9. The best way to manage the construction process in a green manner is to have an initial agreement with every company involved. Project management should comprehensively explain and describe their interest in and commitment to green processes and how these processes differ with

the business as usual concept. Security and waste management are of particular importance here, and every specific solution (waste sorting, cleaning, recycling processes, etc.) has to be described in detail.

- Air pollution

This concerns all emissions into the surrounding atmosphere (dusts, gases, etc.) that can have an impact on human health and well-being. The use of uncontrolled and unmonitored incineration of waste on-site should be eliminated. Because this waste includes treated wood, plastics, paint, etc., it can be a primary source of air pollution and does not serve as an acceptable method of waste treatment.

- Phreatic table and water flow modification and water pollution

This impact is measured in terms of the presence of toxic compounds, bacteria and viruses, acidification, eutrophication, etc. and in the physical changes such as displacement, waterproofing, floods, drying, and temperature) caused by a project. Of particular importance is the treatment of effluents during construction and control of any integrated water treatment system during operation.

- Soil pollution

This is the influence of the production of toxic compounds by the construction and operation on the site itself and neighbouring surfaces. The influence of soil pollution on users is considered in the 'impacts on users' section. The use of any potentially polluting product should be carefully managed with the preference for low-impact, plant-based (as opposed to oil-based) products, recycling of oil and construction waste, etc.

2.3 Impact on regional level

Impact on the regional level includes all activities from the county or province, up to the country. These are often less visible to the general public, but involve public health problems and social costs. Because they are diffused throughout a large area, it is usually not possible to identify or even incriminate a single source. But every building makes a contribution to the cumulative result.

- Acid rain

Acid rain has caused and continues to lead to the depletion of certain forests and damage to buildings and other structures. It is the result of the deposition of acidic compounds in the atmosphere which are then delivered by rain. These compounds can be either acid from the emission of HCl, HF, etc. or become acid after combining with atmospheric water (SO_2, NOx, etc.). The production of these substances is very often a result of an industrial process, but SO_2 and NOx are also common by-products of combustions used in heating and transportation. Therefore, the choice of an appropriate heating energy and transportation organization (public network, localization, etc.) will be beneficial.

- Smog and other air pollution

This is the presence in the atmosphere of products that are harmful to living plants and animals. The principal chemical compounds are ozone, lead, H_2S, SO_2, NOx, and VOC while physical compounds are often organic or in the form of mineral dust. The causes of these problems and their solutions are very similar to those mentioned in the section on acid rain.

- Pollution from non-radioactive waste

This is waste which cannot presently be treated from a technical and economically efficient standpoint. This impact considers the pollution of air, water, and soil and the degradation of landscape generated by various types of waste (other than radioactive waste). This includes the waste that will be generated at the demolition of the building at some point in the future. This highlights the importance of the initial choices on materials and processes. A good example of appropriate planning and construction is the Ecover factory in Belgian. It's designed and choice of materials was conceived from the very beginning as making it 'possible to put the entire ultimate demolition residue into a coffee mill, and then spread it directly on the surrounding fields without any negative environmental effects'. This also includes all waste produced by the operation of the building (electronic equipment, furniture, etc.) and all in-house activities (paper, products, etc.).

- Pollution from radioactive waste

This impact includes the inconvenience created by the storage of radioactive waste. The number of building concerned with radioactive waste management is relatively limited, primarily involving the nuclear power industry, hospitals, and laboratories. But the special characteristics of these waste products make it absolutely critical to conduct a careful management of this waste at every stage. It is still quite common to have radioactive iodine effluents out of hospitals.

- Water pollution (other than waste)

This impact concerns surface and underground water, and deals with toxic compounds, acid, eutrophication, radioactive products, and bacteria and viruses. A green building will carefully consider all aspects of water demand and use, as well as disposal.

The initial category of measures to be applied to the water network of a building involves strict quality control of the installation and the avoidance of wasting water. This applies to such areas as leakage, foaming heads, and IR controls.

Another measure able to reduce the demand on the outside water sources is to utilize rainwater on the site, with storage and cleaning systems in house. This water can later be used for watering, cleaning, and even some industrial processes.

The last category of measures concerns on-site water treatment. This can be mandatory for certain factories, but more and more users are making the choice to have a higher treatment quality, ideally a macrophyte system, so that water leaves the facility as clean as or cleaner than it entered.

- Soil pollution (other than waste)

This impact concerns the presence of toxic materials in the ground. They can be introduced, as an example, from transportation or industrial activity.

- Ecosystem modification (climate, water flows, landscape, flora, and fauna)

This impact concerns all structural changes in the environment that were not mentioned in the previous discussion other than natural resources depletion. This involves regional climate modifications, surface water flows modifications (for example, a nuclear power plant will result in higher water temperatures down stream, a dam construction will modify the volume, speed, and flood risks, which can be a benefit or a drawback), underground water flow modifications (displacement, characteristics modifications, etc., which can occur when phreatic water is used directly), landscape modifications (redesign, desertification, etc.), and flora and fauna.

- Natural resources depletion (regional fuels, rare or non-renewable materials, water, natural spaces)

This impact is the expression of an imbalance between the use of natural resources (implying their destruction) and their creation. This is particularly concerned with those resources which are expected to be in short supply or even unavailable in the next century. We will only consider those natural resources typically used in a region. We will distinguish:

1. Regional fuel (wood, straw, peat, etc.). For example, a large heating plant switching to wood might modify the regional organization of forestry work.
2. Rare or non-renewable materials. For example, wood can be renewable, but it is not always renewed. This can apply to wood from forests which are not

environmentally managed, leading to resource depletion. Another example are certain types of gravel and clay.

3. Water (water intended for consumption is considered here, because its quality is threatened by pollution or drought). Rapid development of buildings with heavy water-consumption in cities like Dubai or on the coasts of Spain are examples of un-green processes that lead to regional water depletion. On the other hand, examples like the InterfaceFLOR factories 5, have reduced their water demand for global production by 81 per cent since 1994 are examples of green success.

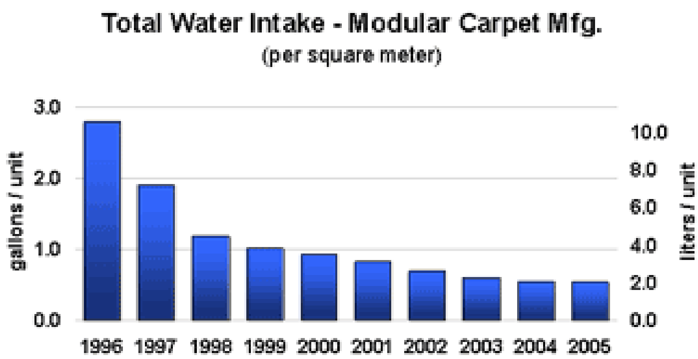

Figure 2: Evolution of total water intake for modular carpet manufacturing by InterfaceFLOR (source: www.interfacesustainability.com)

4. Natural spaces disappear because of human activity, especially during the construction of transportation infrastructure, an energy production factory, mining, and other large-scale projects. This includes natural landscapes utilized to harvest or mine materials used in construction processes. This is not principally on the neighbourhood or local scale, but rather is concerned with primary forests and mineral deposits. Over 80 per cent of primary forests have disappeared because of over-exploitation for Western construction needs.

2.4 Impact on a planetary level

Even larger in scope and consequences, impact at the planetary level constitutes an important, if not the most important challenge to our world. But here too, no single enterprise or country can be blamed or held entirely responsible. The reduction of this impact must be achieved through national and international agreements and regulation and, of course, a strong commitment from project leaders around the world.

- Greenhouse effect increase

The greenhouse effect is creating global planetary warming. It is caused by the emission of greenhouse gases into the atmosphere. A building can impact the greenhouse effect in

[5] INTERFACE is a major carpet manufacturer. More information on www.interfaceinc.com

many forms, the principal ones being those linked to energy consumption, on construction phase (material production, material transportation, construction machines, etc.), on operational phases (air conditioning, heating, user's transportation, etc.), and on the demolition phases (machines, recycling of energy and materials, waste treatment energy, etc.). In the USA, for instance, construction is estimated to use one third of the national energy supply and two thirds of the electricity generated. USGBC estimates that the construction business as responsible for 30 per cent of US greenhouse gas emissions.

In this context, every optional choice is an occasion to reduce this impact. Such tools as a life cycle analysis can greatly help in making correct environmental choices. The European Display Campaign[6] and CO_2 emission quotas are other tools to help set us on the right path.

- Ozone layer depletion

The protective ozone layer is damaged by CFC and HFC gases, which are today still massively used in air conditioning systems and heat pumps. The ozone layer is now stabilized as a consequence of the Montreal Agreement on CFC, but massive quantities of these products still exist and are in use. Even if HFCs, now used in cooling systems and heat pumps, are much better for the ozone layer that CFCs, they are not neutral. They are also very strong greenhouse gases. Therefore, any initial reduction in the volume used and replacement by better choices (no HFC in exchange loops) can only help in improving the situation.

- Natural resources depletion

It is now widely recognized that the time of wide and easy availability of fossil and fissile energy sources reserves has its end in sight. Few knowledgeable observers feel that reserves of oil, gas, and uranium will be abundant for longer than 50 years at today's consummation rates. The expected lifetime of modern buildings usually exceeds 30 years (the more or less standard amortization). This obviously makes energy choices and consumption levels a critical environmental and economic choice.

3 Why choose a green building process?

As seen in the previous sections, every construction project has an impact on a variety of levels. The intensity of these impacts defines how green the project will be. It is the responsibilities of the project's stakeholders to study these various impacts and then make appropriate choices according to given criteria.

The following section deals with this aspect of green project management. It defines who the stakeholders are and which criteria they can use in evaluating the different types of impact while leading a green building project.

We will first describe stakeholders, and the various motivation and evaluation criteria they may have when leading a construction project.

Secondly, we will determine how a green building project can increase the satisfaction level of the various stakeholders, by increasing the value (in its broadest sense).

3.1 Stakeholders

A theoretical listing of people and organizations with an implied interest in the building process will be provided, as well as a summary of their particular interests.

3.1.1 Owner

The owner of the building, who usually initiates the project, can be a private concern, a public organization, and even an individual in the case of residential dwellings. In most

[6] The Display Campaign is an initiative to promote display of energy performance certificates on public buildings, and is led by the Energie-Cités network. More information on www.euroace.org/display.htm

cases, the owners will seek to optimize their investment, which can take several different forms:

- Higher occupancy rate/higher loan
- Lower maintenance
- Better liquidity of the assets

In many cases, the owner will not be the same individual, concern, or organization as the user, and has a high sensitivity regarding the initial investment.

3.1.2 Project manager

The project manager organizes the realization of the project, often looking for an economical optimization of his or her interventions. This optimization, which may signify a high sensitivity on all efficiency and security aspects, also has benefit in terms of image and work of higher value (utilizing emerging technologies, for example).

3.1.3 Bank/Investor

The bank or investor seek to secure their investment, and will therefore be sensitive to the risk aspect of the project over its entire lifetime. There is also, in the case of pilot projects, the opportunity to develop new products. If a regulation on CO_2 exists, an investor can include a green project in the overall emission calculation, hence helping in reaching green objectives.

3.1.4 Insurance

An insurance company will seek projects with the lowest possible risks, both during the construction (warranty on construction quality, fewer accidents, etc.) and the subsequent operation (fewer accidents, fire risks, flood risks, pollution, etc.). Their influence on health costs and possible legal risks will also be considered. For example, in 2006 the Firemen's Fund Insurance in the USA is launching a first-of-its-kind green coverage, including rate credits and other incentives, for commercial building owners who re-build damaged properties using green and LEED® certified building practices.

3.1.5 Building company

The building company carrying out the construction process will be sensitive to the quality and reputation of the project, which can later be used as a reference. It will also be very sensitive to risk reduction and an improved reputation that can follow from a successful realization. Innovative or high quality aspects can also be of value.

3.1.6 User

The user will seek an optimized productivity of the installation. In the case of a residential project, this can mean a comfortable, healthy, and user-friendly building with reduced operational costs. In the case of professional or commercial use, reduced operation costs, good productivity of the activities being carried out, and a good image will be valued.

3.1.7 Administration

Everyone involved in administration, from the local residents block committee up to the UN, will have interest in maximizing the collective benefit. Unlike the position of other stakeholders, the role of administration is not focused on self benefit, and they will therefore put special effort into every reduction of health and environmental risks. This can apply in many fields, such as public health, resource management, transportation organization, and social organization.

3.2 How green buildings are a way to increase value

Although this view is slowly changing, it is still commonly assumed that a green building is more expensive than a building utilizing conventional construction materials and techniques. The chart below clearly shows in which areas a green process will add value to a project.

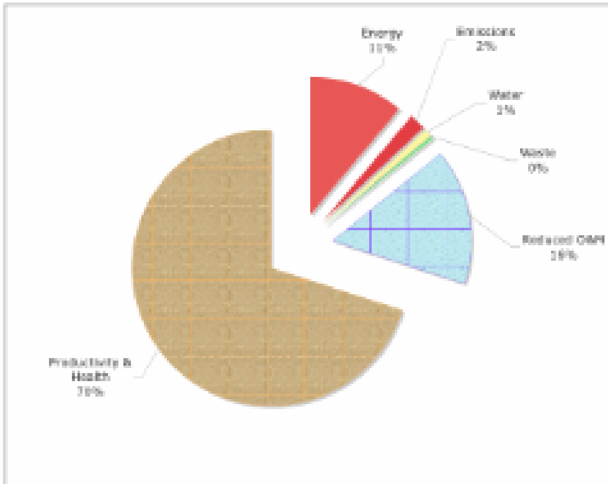

Figure 3: Percentage breakdown of green building financial benefits (LEED® Certified and Silver buildings). Source: Capital E analysis, mentioned in *The costs and financial benefits of green buildings*

3.2.1 Decreased operating costs

According to the Californian study, *The costs and financial benefits of green buildings,* 11 per cent of the financial benefits from green building are directly linked to a reduction in energy consumption, while 16 per cent directly linked to operations and maintenance costs. This same study notes that, over a period of 20 years, a benefit of 5.79 $/ft^2 solely from reduced electricity charges, based on the demand reduction and peak power reduction. In France, a study from ARENE[7] has shown a mean reduction in operating costs of approximately 2.50 €/m^2/year over a 10 year period.

This can only be realized by the early integration of an energy conscious approach to the project. The easiest way to do so is to integrate a bioclimatic approach, reducing the need for energy use for heating and lighting. Efficient equipment can also be implemented, and although the initial investment may be slightly higher, the return on investment is usually quick, based on the overall benefits analysis (cf. following paragraphs). This can be accomplished by utilizing green lighting, heating and ventilation systems, remote control systems, etc.

[7] ARENE is a French regional agency working as a resource and expertise centre for sustainable development. Find more information at www.areneidf.org

A study limited strictly to energy use conducted by USGBC on 22 LEED® buildings has shown the following benefits:

	Certified	Silver	Gold	Average
Energy efficiency (above standard code)	18%	30%	37%	28%
On-site renewable energy	0%	0%	4%	2%
Green power (grid power from renewable sources)	10%	0%	7%	6%
Total	28%	30%	48%	36%

Reduced energy use in green buildings compared to conventional buildings. Source: USGBC, Capital E Analysis, mentioned in *The costs and financial benefits of green buildings*

The initial design of the surroundings can also lead to important economies in the operation phase, by choosing materials with reduced care, plants with low maintenance requirements (watering, mowing, pesticides, etc.).

A key here is to think about services before thinking about equipment. A service such as providing light can be achieved with a variety of techniques, many of them being based on green solutions (natural lighting, reflectors, light ducts, etc.). This is quite a different concept from the usual approach to the problem, which is simply installing many powerful lighting sources.

A last point, often mentioned, but seldom with a verifiable citation, is that because of the generally more integrated design process, green buildings are assumed to have a longer operational life, making the investment more profitable.

3.2.2 Productivity increase and health cost reduction

A surprising result mentioned in *The costs and benefits of green buildings* report is the very important role of productivity increases as one of the benefits of a green building. In fact, they may represent up to 70 per cent of all financial benefits. The principal reason for this is the spread of costs for the company operating a building; the large majority of the cost goes to salaries of occupants. An example, based on data from RICS[8], is given below:

[8] RICS: The Royal Institution of Chartered Surveyors, a leading source of land, property, construction, and environmental knowledge. Find more information at www.rics.org

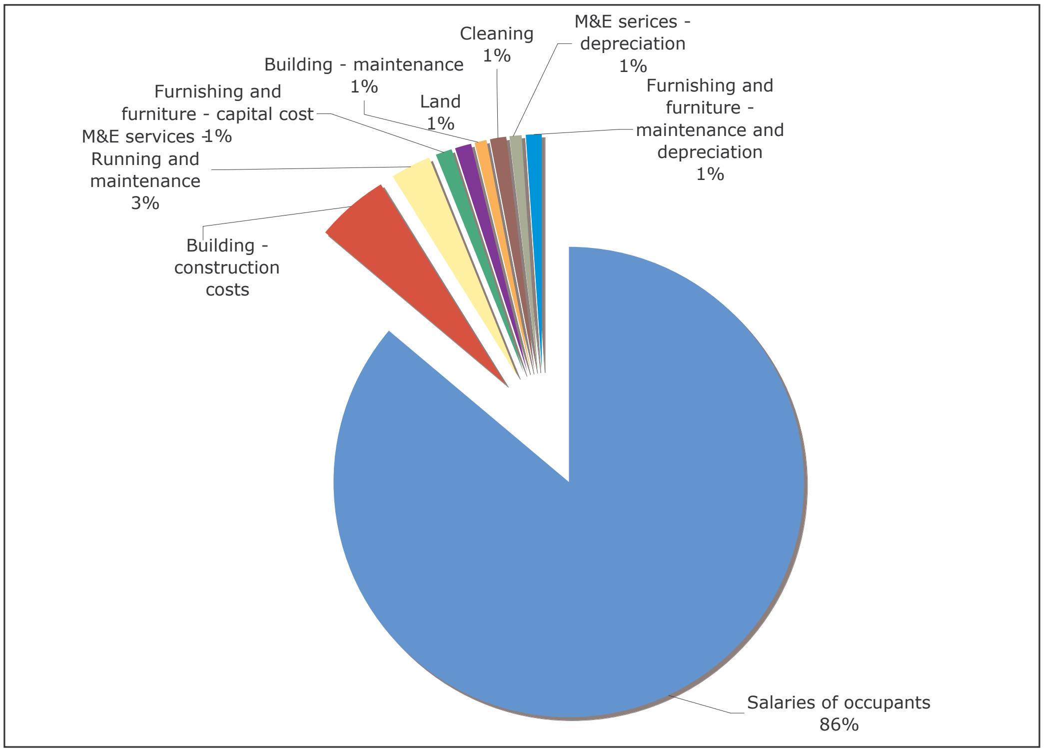

Figure 4: Comparison operating costs. Source:

The importance of productivity in the overall benefit is therefore 20 to sometimes 100 times the energy costs. This is summarized in the Californian study by the sentence: '*If green design measures can increase productivity by 1 per cent, this would, over time, have a fiscal impact roughly equal to reducing property costs by 10 per cent*'

In trying to measure the impact of green measures on productivity, several studies in different fields have come to similar conclusion:

- Students in green schools learn to read faster and have better results. The following result is mentioned in the Heschong Mahone Group study on *Windows and classrooms*: *'Data from California schools (which is considered the most detailed) shows with a 99 per cent statistical certainty that students with the most daylight progressed 20 per cent faster in mathematics and 26 per cent faster in reading than students with the least day lighting*.'
- Green supermarkets have higher sale efficiency. As demonstrated in the Heschong Mahone Group study *Daylight and retail sales* for the California Energy Commission, a verifiable increase in sales of 1 to 6 per cent by using appropriate day lighting is observed in supermarkets.
- Green hospitals, as mentioned in the *Green guide for health care*, have a shorter recovery time for patients.
- Green offices, as mentioned in the *Windows and offices* study, see a constant correlation between indoor air, lighting, and overall quality of the interior environment (light, view, noise, etc.) and worker's performance.
- Finally, a comfortable building is also a good tool for improving recruiting and loyalty as well as a proven method for reducing personnel turnover in a company.

3.2.3 Improvement of health and well-being

As we have seen above, the productivity of employees will, in general, be improved in green buildings. Another aspect of the increase in productivity is the reduction of absenteeism, in particular those absences due to health causes. The study *The costs and benefits of green building* notes that, based on results from William Fisk (*Health and productivity gains from better indoor environments),* there is a measurable benefit in the case of green building, which is achieved through prevention and use of healthy materials.

Source of productivity gain	Potential annual health benefits	Potential US annual savings or productivity gain (2002 dollars)
1) Reduced respiratory illness	Avoiding 16 to 37 million cases of common cold or influenza	$7-16 billion
2) Reduced allergies and asthma	8% to 23% decrease in symptoms in 52 million allergy sufferers and 16 million asthmatics	$1-5 billion
3) Reduced sick building syndrome symptoms	20% to 50% reduction in SBS health symptoms experienced frequently at work by ~15 million workers	$10-35 billion
4) Sub-total		$18-56 billion
5) Improved employee performance from changes in thermal environment and lighting	Not applicable	$25-180 billion
6) Total		$43-235 billion

Potential productivity gains from improvements in indoor environments

It is difficult to achieve precise and reliable information on materials which guarantee a healthy environment and improved employee health. This is the purpose of the current REACH program, which is expected to be fully operational by 2008. Nevertheless, most countries now require a Security Document for chemical products (coatings, paints, etc.), and many alternatives based on natural products have recently emerged.

3.2.4 Reduction of legal pursuit risks

Contractors and operating companies can often be held responsible for cases of sick building syndrome. The use of a green building approach can reduce this risk. The Rocky Mountain Institute notes that several insurance companies are currently considering offering reductions in premium and bonuses for buildings constructed according to green rules. The case of Firemen's Fund Insurance mentioned above is a significant example of this evolution.

The USGBC reports that, in Bloomquist v. Wapello (500 N.W.2d 1, Iowa, 1993), plaintiffs successfully sued employers and builders for creating an unsafe work environment due to inadequate ventilation and pesticide applications.

3.2.5 Value creation for current occupants

As mentioned earlier, individuals and companies renting a green building generally experience reduced operational costs. This is a significant financial advantage for renters, and makes the buildings more attractive. Another important consideration noted by the Federal Energy Management Program is that: 'On average, 44 percent of building occupants move internally within a given year.' The average cost of these moves is calculated to be approximately $2,500. This figure is generally less in green building, since they are designed from the outset to be more flexible than conventional structures.

3.2.6 Increase in market value

Even though companies tend today to disengage from fixed assets, they still represent a major part of capitalization. In France, real estate represents 16 per cent (110 billion €) of the capitalization of the CAC40 companies.

The asset's liquidity is therefore important. Given the aforementioned objectives and benefits of green building, the demand for durable buildings can be expected to increase, especially if a green label is attached to act as a guarantee of quality. An increase in the green building market can therefore be expected in upcoming years.

3.2.7 Availability of subventions

There are numerous financial and regulatory processes and incentives to promote green building processes which are not applicable to conventional construction. Depending on the project's category, substantial subventions can be obtained for green operations from European Union, national, regional, and local organizations and agencies.

3.2.8 Better image

It is quite common for a new construction project, whether residential or business related, to encounter adverse reactions from the neighbourhood. This is directly linked to the number of impacts listed in the local impacts section above.

Since the very basis of the green concept is a better integration of the building into its neighbourhood (environmental, social, and economical), the image and relation with the neighbouring communities is often much easier.

This can start with a clean construction process, creating less noise and dust, and continue right on up to a reorganized collective transportation system in which the building's operator takes part, including a locally planned social and economic integration any new activities.

On a larger scale, many companies in a variety of business areas (for example, Accor in hostelry, Ecover in home care products, Patagonia for sporting goods, etc.) use their green headquarters, local representation, or pilot factory as a showcase of their environmental conscientiousness.

3.2.9 Prediction of risks and performance

Since durable construction is usually associated with good engineering along with monitoring, a building's performance is more easily predictable, and problems can be detected faster. This leads to economies, both on the consumption of energy and the corresponding productivity increase. The overall intent of the activity is therefore maintained at an optimal level.

3.2.10 Creation of social value

There are multiple reasons why green buildings are a benefit for the community. First, a lower consumption of natural non-renewable resources makes these available for others, including future generations. On a global scale, this also helps reduce demand pressure for these resource markets. A transfer from non-renewable, internationally transported resources to locally produced resources also tends to strengthen the local economy and reduce the level of transportation with all of its attached costs and nuisances.

Another regional benefit is the increase in local employment, since many green techniques (solar panel installation, vegetal roofing, wood framing, etc.) require skilled labour. The potential in Europe has been assessed at several hundreds of thousands of new local jobs.

Finally, as already mentioned, bad indoor environmental quality is a massive source of public health problems. Some of these can be at least partly solved by a preventive approach like green construction. The potential benefits to the economy in France alone have been estimated by ARENE at 2.3 to 7 billions euros.

3.3 What is slowing down penetration of green construction?

As seen in the previous chapter, green building generally adds value to a construction project. Nevertheless, green building projects are not yet in the majority. Let us examine the reasons for this fact.

3.3.1 Perceived as more expensive

Very often, green buildings are perceived as 'normal buildings integrating clean technologies', which means the green aspect is often considered as a bonus. It is considered to be an added cost, which usually cannot be amortized or otherwise compensated for.

This phenomenon can be very real for two main reasons. The first situation where added costs appear massive is when the design process is not appropriately modified and is conducted as a conventional project with only a green option on some equipment added at the end. An integrated project management on the other hand, that takes green elements into account from the very beginning of the program, is a key element in the success of a green project. This is confirmed by all active players and studies. The study *Costs and benefits of green buildings* calls particular attention to the green cost premium that is added on initial investment for different LEED® projects.

Level of Green Standard	Average Green Cost Premium
Level 1 — Certified	0.66%
Level 2 — Silver	2.11%
Level 3 — Gold	1.82%
Level 4 — Platinum	6.50%
Average of 33 Buildings	**1.84%**

Level of green standard and average green cost premium

Surprisingly, in this study the gold quality level appears to be less expensive than silver level. One reason can be the limited number of projects that were studied. But it nevertheless shows that a gold level can be achieved without an excessively high premium. This aspect is also mentioned in the *Putting the dollars together* study (William Browning, Rocky Mountain Institute). This study explains that buildings targeted at '*20* to 40 per cent energy savings typically are slightly more expensive, because some higher cost components are incorporated, but not enough to downsize other pieces. Buildings targeting a 50 per cent savings are frequently cost neutral. The intriguing discovery is that buildings that target much higher savings of 75 to 90 per cent can sometimes cost less to build'.

Another common cause of the green cost premium is the fact that the specific techniques and skills that are used in green design and construction are not yet commonly known or widely available. This has two main consequences. The first one is that architects and craftsmen who have this valuable knowledge have costs in relation with the quality and rarity of this knowledge. It may also be more challenging even to find such qualified people in the local area. The associated green cost premium generally voids as soon as a whole system costing practice is set up which takes into account the associated benefits.

The second consequence, also mentioned in the *Costs and Benefits of green buildings*, is that individuals entering the green construction market without full knowledge or skills sometimes apply added costs because of insufficient optimization, or as a warranty. Nevertheless, it has been shown in this same study that the learning curve concerning green construction is quite steep, which leads to a quick decrease of the premium as time goes by and techniques become better known.

3.3.2 Compartmentalization of stakeholders

As discussed above, the economic advantages in building green is clear in an overall cost approach. But in the so-called real world, the investor or builder must generally support the added costs, while the end-user receives the benefits (reduction in operations and maintenance, image, etc.).

This is probably the reason why most green building projects are conceived and realized by organizations that are at the same time investors and users.

There are at least two types of measures to help push green project.

The first category of measures comes from public administration. They can take the form of financial help, by subventions (as found in Canada and Switzerland), or by tax incentives. Another possibility is regulation or administrative organization. The state of Massachusetts, as an example, does not accept any construction larger than 4,500 m^2 without a LEED® registration. Similarly, the city of Scottsdale, Arizona offers preferential conditions to environment-friendly projects.

In order to spread the initial green cost premium over time, administration can help in organizing low-rate loans when they are applied to green projects. This solution is becoming more widely available in France where the national agency ADEME is working together with a network of banks, in creating synergy in the promotion of green actions.

The second category of measures can come from private organizations. Banks, already mentioned, are now proposing more and more loans specifically adapted to green construction projects (solar heater, green buildings, etc.). The offer ranges from 0 per cent short term loans to cover the time until subvention are paid, to loan rates depending on environmental performance of the project.

Insurance companies, as already mentioned, are expected to engage in this special business sector, even though it represents only 1 to 2 per cent of the turnover, but 30 per cent of the claims, with high risks and costs. Since most benefits of green building are difficult to measure accurately, insurance companies are still quite reluctant. Nevertheless, some specific offers appear. As an example, an Energy-Saving Insurance (ESI) consists in coverage of the losses due to unachieved consumption reduction goals. The market of ESI is estimated at 1 billion $/year in premium income.

3.3.3 Systematic engineering

As already mentioned, what makes the green construction process different from conventional construction processes is the engineering of every single aspect of the project. In the individual technical areas, each operation is traditionally realized by a different building trade: electricians do all of the electrical work, carpenters take care of carpentry, etc.

But in green constructions, one should always keep in mind the constant interactions between impacts. As an example, modifying lighting (impact on user) might often modify hydrothermal comfort (impact on user) and consumption of energy (regional or planetary impact). Modifying an electrical path may alter electromagnetic fields (impact on user), impact thermal insulation (energy demand), and even waste production (using more or less electrical cable). Such interactions abound for every single impact listed in Section 2. Because green building demands such a systematic approach and more collaborative actions between the building trades, such projects usually demand a higher human and time investment at the beginning of the project, especially from the project initiator and the engineering departments, who have to check constantly for possible interactions in order to develop optimized solutions.

Although this higher initial investment has proven to be profitable, it is not yet common and generally accepted, and evidently causes a certain amount of suspicion towards green projects.

4 Conclusion

4.1 Certification

Many local or national institutions have put a variety of labels in place (LEED®, BREAM®, HQE®, Built Green, etc.) to help stakeholders in following the process, to help guarantee a given quality level, and to promote best practices. We will present two of them below with some details.

4.1.1 LEED®

Maybe the most famous and well-established worldwide is the LEED® (Leadership in Energy and Environmental Design) label. The United States Green Building Council (USGBC), a national non-profit entity, developed the Leadership in Energy and Environmental Design (LEED®), a Green Building Rating System used to rate new and existing commercial, institutional, and high-rise residential buildings according to their environmental attributes and sustainable features. The LEED® system utilizes a list of 34 potential performance-based credits worth up to 69 points, as well as seven prerequisite criteria, divided into six categories:

- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Innovation and Design Process

LEED® allows the project team to choose the most effective and appropriate sustainable building measures for a given location and/or project. These points are then tallied to determine the appropriate level of LEED® certification. A full description of the LEED® credits can be found on www.usgbc.org/leed/

Four levels of LEED® certification are possible depending on the number of criteria met. They indicate increasingly sustainable building practices:

- LEED® Certified 26-32 points
- LEED® Silver 33-38 points
- LEED® Gold 39-51 points
- LEED® Platinum 52+ points

There is a general perception that LEED® is becoming the standard for US green building design. As the industry magazine Health Facilities Management described in October 2002, 'LEED® has become the common benchmark for sustainability.' Although imperfect and still evolving, LEED® has rapidly become the largest and most widely recognized green building design and certification program in the US and probably in the world.

LEED® was first introduced through a Pilot Program, and twelve buildings received version 1.0 certification in March 2000. Version 2.0 was released shortly thereafter for use as a design and certification tool. At the end of 2000, about 8 million square feet of buildings were undergoing LEED® certification. By early 2003, this number had jumped to over 100 million square feet. As of December 2002, of all new construction projects in the United States, an estimated 3 per cent had applied for LEED® certification, including 4 per cent of schools, 16.5 per cent of government buildings and 1.1 per cent of commercial projects.

4.1.2 BREEAM®

BREEAM®, a label created and employed in Great Britain, assesses the performance of buildings in the following areas:

- Management: overall management policy, commissioning site management, and procedural issues
- Energy use: operational energy and carbon dioxide (CO_2) issues
- Health and well-being: indoor and external issues affecting health and well-being
- Pollution: air and water pollution issues
- Transport: transport-related CO_2 and location-related factors
- Land use: Greenfield and Brownfield sites
- Ecology: ecological value conservation and enhancement of the site
- Materials: environmental implication of building materials, including life-cycle impacts
- Water: consumption and distribution efficiency

Developers and designers are encouraged to consider these issues at the earliest opportunity to maximize their chances of achieving a high BREEAM® rating.

Credits are awarded in each area according to performance. A set of environmental weightings then enables the credits to be added together to produce a single overall score. The building is then rated on a scale of Pass, Good, Very Good or Excellent, and a certificate awarded that can be used for promotional purposes.

BREEAM® covers offices, homes, and industrial units, as well as schools and retail units. Other types of buildings can be covered with a previously discussed adaptation.

4.2 Future of green building

There are now few questions on the benefits of building in green when the problem is considered globally, both on the environmental and financial aspects. The reality is nevertheless still complicated when it comes to actually launching a green program, and some questions about the future of green building need to be fully addressed to assess the potential evolution of the business.

4.2.1 Labels or regulations?

Today, green building is on a strictly voluntary basis. The prevailing standard remains 'not so green' construction. We have seen that the penetration of the green building concept is slow, even with its proven individual and collective benefits.

It is therefore logical to ask how green construction should be encouraged. Many countries in Europe have agreed that a Factor 4 reduction of greenhouse gases before 2050 is necessary. This implies, as shown by NegaWatt[9], a systematic application of strict rules on each and every construction and retrofit action for the next 45 years, or the goal would be missed.

History tells us that it is not possible to achieve this level by simply relying on voluntary labelling or by encouraging the good intentions of individuals. Is the correct path then the mandatory application of strong green label rules, as is already the case in some American cities? Since a norm is always a balance between profitability of business and public security; it will therefore be necessary to establish the standard quite quickly.

4.2.2 Role of industry

Building industry players vary from one-person local business to massive international holdings, from the very alternative-minded to the strictly industrial, business oriented organizations. Nevertheless, most mention green building in their public relations communications, in more or less authentic tones (the brochure *'la construction durable'* ('sustainable construction'), published by Fedichem[10], is a good example).

Can the strong financial logic of the industrial world fit in a frame claiming local and low-impact solutions? As we have seen, green building is a great chance for businesses, in terms of image, in terms of markets, and in terms of its social role. Will the industry adapt to green building, or will green building have to be adapted? The frame will still ultimately be determined by the planetary environmental problems, among which global warming is now at the forefront creating pressure. Many insurance companies worldwide now consider the increase in natural disaster occurrences, and include this parameter in their models and calculation. Perhaps the change will be initiated, even mandated, by business interests from outside the construction world.

4.2.3 Training and information to the building's users

Technologies, construction techniques, and architecture can do a great deal to improve the efficiency of a building in terms of environmental aspects. But in the end, the education of the users and their capacity to use the building in the best way will weigh heavily in the final balance. This is the reason why some labelling organizations like LEED® include an education aspect, implying that every building, from large headquarters to individual lodgings, should be delivered or transmitted with appropriate information. This is especially important in the case of green buildings, which often include advanced or unfamiliar technologies. Green buildings will only reach their maximal green potential when they are in the hands of well-informed users.

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[9] NegaWatt is a French NGO developing energy saving prospective scenarios and corresponding political and regulatory measures. More information on www.negawatt.org

[10] Fedichem is the Belgian federation of chemical industries. More information at www.fedichem.be

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Building Green : www.buildinggreen.com

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Construction Durable: www.constructiondurable.com

International Energy Agency: www.iea.org

NegaWatt : www.negawatt.org

World Resources Institute: www.wri.org

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