Coping with CO_2 emissions: educational resources on the web concerning low-energy buildings

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Abstract

This paper presents informative and educational websites that may be used for teaching units about energy saving, in the household and in the construction of buildings. Such teaching tools are downloadable for free and consist of text, videos, images, drawings and interactive animations. All the teaching tools presented are in English, they may be used with the method that the teacher feels more appropriate.

Several websites presented deal with solar heat gain, insulation and thermal storage in passive houses. Shape and orientation of the building, and their influence on energetic performances are analyzed too. The energy used for the construction of buildings and possibilities for its reduction are also discussed.

In addition, the manuscript presents some educational resources that deal with earthquake resistant buildings and selecting safe places to built houses.

Among the subjects dealt with in the paper there is the very positive influence, perhaps unexpected, which plants surrounding a home may have when properly selected and located.

Key words: buildings, global warming, passive, save energy, Teaching tools.

二氧化碳排放量的調適：有關低耗能建築的網路教學資源

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摘要

本文介紹了知識性與教育性網站以提供教學單位有關家庭住宅與建築施工上節能減碳的資訊。此類教學工具可以免費下載，包括文稿、視頻、相片、圖像及互動式動畫。所有教學工具皆以英文呈現，可讓老師使用上更覺貼切。

一些網站專門針對被動式節能屋之太陽能擷取、絕緣性及儲熱性等作介紹。房屋的形狀和方位以及對熱能呈現的影響也有分析，樓房建築的能源使用及其節能減碳的可能性也做探討。

之外，本文也針對建築物防震及如何選擇安全地點蓋房子等介紹一些教學資源。本文所提的議題有絕對的影響，或許住家周邊的植物無法預料，也要好好選擇和栽植。

關鍵字：建築物、全球暖化、被動式、節能、教學工具

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Introduction

According to a document of the United Nations, "At the very heart of the response to climate change is the need to reduce emissions" (1>Towards a Climate Agreement). The same document provides also information about the disastrous consequences of climate change (1>The Science)

As it can be seen in Figure 1, according to the International Energy Agency, in 2005, 29% of the world-wide energy consumption was used for the household (2). This manuscript is intended to present informative and educational websites that may help in teaching how energy and emissions can be saved in the household and in the construction of buildings.

A reading entitled "Heating, Cooling, and Lighting as Form-Givers in Architecture", can stimulate the interest of the students, while introducing some concepts on low-energy buildings. A main aim of traditional architecture was to provide the maximum possible thermal comfort and natural lighting with minimal use of appliances. The architectonic differences between different geographic areas were, at least partially, dictated by the necessity to respond to different climates.

In hot and dry climates for instance, given the high intensity of solar light, small windows are sufficient for indoor lightning. Limited size of the windows and considerable thickness of the walls, avoid an excessive diurnal heat gain. In these areas buildings are very close to each other for mutual shading, and the streets are narrow. In this way they remain for much of the time in shadow.

In humid warm climates the temperatures are less high, but the high humidity rate creates discomfort; in these cases ventilation can provide better conditions for the occupants. Therefore, wide windows and buildings apart from each other are preferred, and if possible the roads are oriented so as to take advantage of prevailing breezes.

Shutters and large overhangs protect the home's interior from solar rays and rain when necessary (3>Surface area to_vol_ratio, Reference no 2 / 3>street width and orientation).

A website deals with the great historic tradition for solar utilization in the buildings of Arizona. Here, among the earliest buildings that utilized the solar energy there are the cliff dwellings, shown in the first drawing (4>Technology & Science>Solar Architecture>Solar Building Design in Arizona). Many of them, facing south, are heated by the low sun in winter, and then shaded by the cave roof from the high summer sun.

Aims of the teaching unit

This paper, based exclusively on quoted documents, presents online educational resources that could motivate and facilitate learning about how low-energy and low-emissions buildings can be comfortable and safe at the same time.

Materials and methods

The educational resources cited, available on line and downloadable for free, consist of text, videos, images, drawings and interactive animations that may help

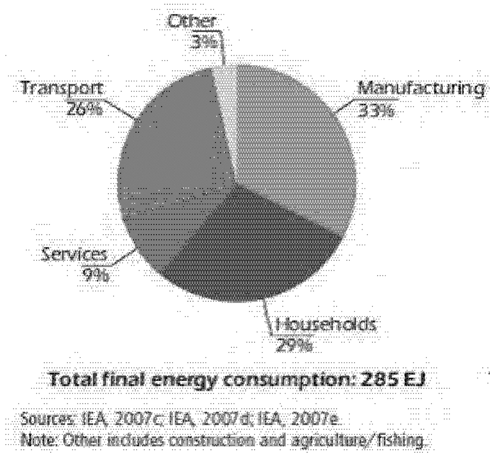

Figure 1 Shares of Global Final Energy Consumption by sector, 2005 (Source: IEA, 2008.Worldwide Trends in Energy Use and Efficency)

students to learn this subject. Some of these websites are from the southern hemisphere and need to be interpreted accordingly, for example, as far as the orientation of buildings is concerned.

These resources are all in English and can be used with the method that the teacher feels more appropriate. Their use is open to teachers of all disciplines, of course, depending on whether such colleagues have an interest in it. In some situations, for instance, the study of science and the English language has proceeded in parallel when such teaching tools were used for reading exercises. The subject is very complex and this manuscript is just an introduction to a more complete study.

Discussion

Notoriously, because of the "Heat Island Effect" a metropolitan area is hotter even by 1-6°C than its surrounding rural or forestal areas. After sunset, when the heat stored in the urban infrastructures is being slowly released, such temperature difference can reach even 12°C (5 / 6). In vegetated areas some solar energy is reflected back in the atmosphere, some is absorbed by the leaves for photosyntesis, while evapotranspiration uses the heat of the air to evaporate the water.

Deciduous trees or vines grown on trellises, extending along the southeast to southwest edge of a home, may shade the house from the summer sun and cool the air at the same time. In winter, after the loss of leaves, the solar radiation heats and creates light for the building (6 pag. 3-4-5 / 7 fig. 3). Planting should not obstruct the prevailing summer breezes, rather if possible, deflect them toward the openings (8>passive design>passive cooling / 8>passive design>shading).

Evergreen plants properly placed or geographical features may act as windbreaks, thus protecting the building from prevailing cold winter winds and reducing heat losses. In several US States such techniques reduce by 10 to 30% energy consumption for heating and by 30 to 50% that for cooling. Text, images as it can be seen in Figures 2~3 (7 / 9), and a video with text (10>Energy Efficient Home Landscapes) help us to learn about this subject. The plants surrounding a house, if properly managed, may produce firewood, fruit, benefits for environment and wildlife. Windbreaks can be designed so as to manage snow drifting, minimizing its accumulation around buildings and on the roads, thus reducing labor and energy expenditure for its removal. Advantages and possible disadvantages concerning windbreaks are discussed in three documents (7 / 11>Chapter 6: Windbreaks / 12). For a more complete information, two websites provide useful tips in order to plant trees in such a way that will prevent mutual damage between plants and buildings (13/ 14). Furthermore, some landscaping tips may help to conciliate the presence of plants with fire safety in rural or urban fringe areas (15 / 16).

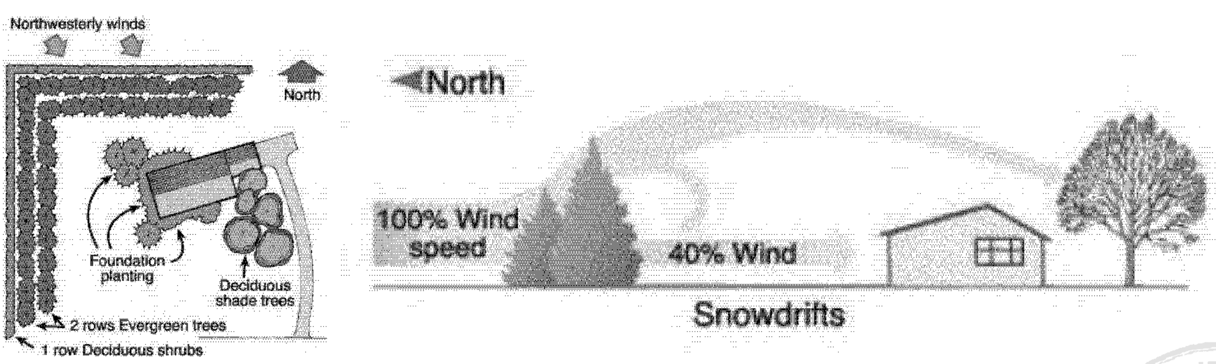

Figure 2-3 A typical plan for windbreaks (left) and a 20-foot-tall evergreen creates a windbreak on the northern exposure (right) (Source: University of Missouri Extension, 2007)

Some documents provide information about materials that can be used for thermal insulation of buildings, techniques for the installation, and related benefits (8>Design>Insulation / 17 / 18). Some materials have a very high recycled material content, such as cellulose and mineral wool (17>Insulation materials). Thermal insulation of a building and other improvements allow us to reduce energy losses, as shown in a document that also provides tips for building, renovating, buying or renting a home (19). Some animations show the ways that heat is transferred in our environment (20 / 21>Heat Transfer Conduction, Convection , Radiation). A document deals with the concepts of heat and temperature (22>Motion of Gas Molecules, Heat, and Temperature / Changes of Phase, Heat, and Temperature).

The passive houses use winter solar light to the greatest possible extent for heating the house (23>Passive Solar Homes Design, Direct Gain, Indirect gain, Isolated Gain (Sunspaces)/Window). Small windows on the north side of such houses reduce heat loss, whereas large openings on the south facade maximize the entry of solar radiation (23>Energy-Efficent Home Design>Windows, doors and skylights>Energy-Efficent Windows / 23>Passive Solar Home Design / 23>Tips: Passive Solar Heating and Cooling). This allows the heating of tile floors and concrete slabs, masonry walls and partitions; such materials have a high heat capacity and constitute the thermal storage mass (8>Design>Thermal mass / 4>Technology & Science>Solar Architecture>Passive Solar Design, Tables 1-4-5-6-7).

In winter, thanks to the solar heat stored inside the building and to the thermal insulation, the house can remain warm during the night. In summer the nocturnal ventilation of the building dissipates the heat stored in the thermal mass, and the following day, thanks to the thermal insulation, the temperature remains comfortable. Obviously, the shutters are of the utmost importance for limiting unwanted heat transmission, particularly during winter nights and sunny summer days. Absence of carpets on the floor, and thermal insulation installed externally to the building make the transfer of solar heat easier in the thermal mass during winter days, and the night cooling in summer (3>thermal mass).

Notoriously, in desert climates high daytime temperatures are followed by nights below freezing. Here, walls with a heavy thermal mass and some ability to resist the heat flow, allow the temperature of their internal surface to fluctuate with a delay of 10-12 hours, compared to the external one. This is the time it takes for heat waves to pass through such walls. This entails that the low night time temperatures reach the internal surfaces of the home in the middle of the day, thus keeping the rooms cool. Similarly, the high external temperatures of the day reach the internal surfaces in the night, thus warming the home (3>time lag). In very hot or very cold areas, walls with a heavy thermal mass prove detrimental since their temperature would be always out of the comfort range, thus entailing for the occupants undesirable radiant gains or losses.

Notoriously, in seismic areas, buildings should follow stringent rules for the safety of people. According to a manual of the World Housing Encyclopedia, size and number of openings should be limited, since if excessive, they could weaken the building (24>Tutorials>Stone Masonry>Stone, pag. 40). Furthermore, according to "IAEE Guidelines for Earthquake Resistant Non-Engineered Construction", the size of the openings in opposite walls should be similar, and symmetry is also desirable (25>Manuals>IAEE English>Chapter 3 p. 3-4). The solar radiation hitting the south facade can be collected by a Trombe wall, instead of a wall with wide and numerous openings (3>trombe wall). Such a Trombe wall is made of materials that have a high thermal storage capacity, placed behind a glazing and with an airspace between them. In winter, the solar radiation heats the wall and the air in the airspace. The heat stored in the wall is slowly released into the adjacent rooms by convection and radiation, while the warmed air flows from the airspace to the room through the upper vents (26). The cooler air of the room flows into the airspace through the lower vents, thus contributing to a continuous natural thermal circulation.

The above mentioned vents can be kept closed when it is cold outside, so as to avoid the inverse circulation of the air that would decrease temperature. In summer, the air heated in the airspace flows outside through exhaust vents located at the top of the glazing, thus creating an induced ventilation (26).

The amount of solar radiation intercepted by a surface hit by light is determined by the angle of incidence, as shown in Figure 4 (4>Technology & Science>Solar Architecture>Passive Solar Heating and Cooling Manual). The more the light is deviated from the perpendicular position, the more the radiation density is reduced. For a better utilisation of solar radiation all the year round, the longest axis of the building should be east-west oriented. This entails that in winter, when most of the solar radiation strikes the building from the southern quadrants, the larger wall facing south is well exposed to the rays. In summer such orientation exposes the smaller east and west facades, respectively in the morning and afternoon, when they are struck nearly perpendicularly by the sun.

A table provides interesting data about heat gain concerning east and west facades of a bulding located at the latitude of New Delhi, during the days June 21st and December 21st. Significant solar gains can be observed in the morning on east walls and in the afternoon on west walls, when they are hit nearly perpendicularly by the radiation (3>building orientation). In summer, the sun is high and the angle of incidence of the rays hitting the south facade is broad, hence the density of the radiation striking there is low, as shown by the red line in the first graphic (3>building orientation). Furthermore, a large roof overhang may shade most of the south facade when the sun is high, and then leave it well exposed to the low winter sun (27 first figure). On the southern facade of a high rise building, the terraces may have a similar function (author's note).

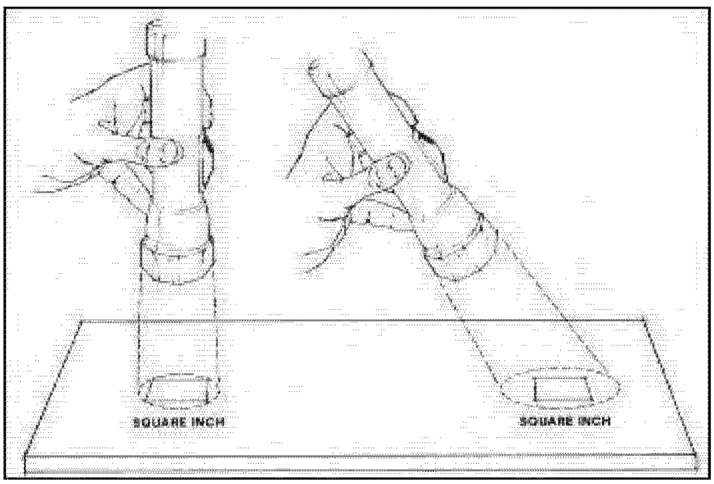

Figure 4 These illustrations demonstrate how energy density is determined by the angle of incidence. The amount of light emitted by the flashlight is the same in both illustrations but it is spread over a larger area (right) when the light is tilted away from its original perpendicular position (left) (Source: Arizona Solar Center)

An applet gives a visual illustration about how the sun interacts with buildings along its apparent path in the sky. The applet allows us to observe, among other things, the solar position, the angles of solar height and azimuth, the shadows that are created. Date, time, latitude and longitude for any point of our planet can be interactively modified (28>Solar Position and the Sun-Path).

A document deals with absorption, reflection and transmission for a single sheet of ordinary glass (Stephenson D. G., 1963). A figure shows that, for instance, during the summer solstice at Ottawa, the transmission of the incident radiation has a maximum noon value of 70% (29 fig. 1). Such value increases to 85% at equinoxes and to 87% at the winter solstice, depending on the smaller incidence angles of the rays striking the glass. The document deals also with an experiment about the control of unwanted solar heat gain through the windows, by tilting the glass. Interestingly, compared to a vertical window, the trasmission of solar rays is significantly reduced in summer, but not in winter (29 fig. 2).

An ample document provides information about energy performances of windows and glazing technologies (30). Window energy efficiency is analyzed according to its potential for the radiation of heat into the house and from the inside toward the outside, air leakage and non-solar heat conduction through glass and frame. Low-emissivity coatings deposited on the panes of glass reduce the trasmission of infrared radiation. When such coatings are applied to the outside pane of glass they keep the sun's heat out of the house, whereas, applied to the inside pane of glass the indoor heat is kept inside the house. Low-emissivity coatings can reduce visible light transmission; among them, the spectrally selective ones are of a special type that allows the full amount of visible light to be transmitted (31). Double or triple glazed windows may have gas fills between the panes of glass; some inert gases, like argon or kripton, have a higher resistance to heat flow than air.

Notoriously, the form of the building influences its performances, and not only from the thermal point of view. The surface of the envelope of a building that has a regular and compact shape is smaller, compared to one with equal volume, whose shape is complex or lengthened. This entails a smaller total area of external walls, roof and pavement involved in heat transfer, hence lower heat loss in winter and reduced thermal gain in summer (3>Clear Home>interactive>design matrix>planform/3> Surfaceareato_vol_ratio). Such smaller surface of the envelope allows also a lesser use of materials for the construction and hence a lower embedded energy. Furthermore, regular, symmetrical and not excessively long in relation to width, buildings are less exposed to torsions during earthquakes (25>Manuals>IAEE English>Chapter 3 p.3-4 / 24>Tutorials>Confined Masonry>Seismic Design... p. 29-30). Page 31 provides an important tip "Never weaken the wall breaking it to place electrical conduit or accessories" (24> Tutorials>Confined Masonry>House Design, Construction, and Maintenance).

Radiant temperatures of indoor building surfaces, air temperature, velocity of air movement and humidity rate determine the thermal comfort for the occupants of a building (32 fig. 1.3 and fig. 1.4). An easy-to-use thermal comfort calculator allows us to study how the above mentioned factors interact (33). The thermal insulation of buildings entails, besides a low heat transfer velocity, also a very small difference between the temperature of indoor air and that of internal surfaces of walls and windows. This reduces the transfer of radiant heat between people and the internal structures of the building, thus playing an important role in the comfort both in summer and winter. As a further benefit, insulation may keep temperature of ceilings and walls above the dewpoint thus preventing condensation and consequent damage to health and building structures (17 / 34). Thermal infrared images show the different heat losses occurring from an old building, an adjacent building that is not heated and from a passive house (35). Infrared images of a well insulated window allow us to observe that the temperature of the glass internal surface is 17°C whereas temperature outside is –5°C (36 fig. 3). From the same infrared image it can also be observed that even the temperature of the internal surface of the wall is quite high, hence close to the temperature of the indoor air. The figures 4 and 5 of the same document show internal surface temperatures in houses whose thermal insulation is poor. In passive houses thermal stratification of the air is imperceptible, as shown in the image (36 fig. 2). A graph shows that the entire section of a brick wall stays warm even at low outside temperatures (37).

Indoor air in buildings may contain, among other things, humidity, moulds, carbon monoxyde and volatile organic compounds including the formaldehyde outgassed from pressed wood products (38>Take a Tour of the IAQ House / 34). Through such interactive images we can also observe that radon can be present, particularly in basements. According to the World Health Organisation, this radioactive gas that exhales from the ground, with different intensities according to locations, is globally the second leading cause of lung cancer after smoking (39 / 40). Air change in buildings is important for the comfort of the occupants (38>Frequent Questions / 38>Basic Information), and contributes to prevent the so called "Sick Building Syndrome" (38>A-Z Index). Frequent opening of windows may provide adequate air change, but if outdoor temperatures are extremely low or high, thermal comfort can be reduced.

The passive houses have a continuous air change, keeping the windows closed and consuming a very limited amount of energy (41). In winter, the cold external air enters into the building flowing through an air-to-air heat exchanger that works on the counterflow principle. Here it recovers the heat of an equal amount of stale air that is flowing out. Thanks to such preheating, 75 to 95% of the temperature difference is recovered and the air may flow into the rooms without cooling them excessively. The fan that expels the formerly mentioned stale air, thus creating at the same time a suction that draws external air, takes much less energy than that recovered through the thermal exchange (40). Often in summer, opening the windows to catch the prevailing breezes that mitigate the heat may be desirable. Some drawings, as it can be seen in Figure 5, show the effect of wingwalls on air circulation in buildings (42 pag. 4-9 and pag. 4-10).

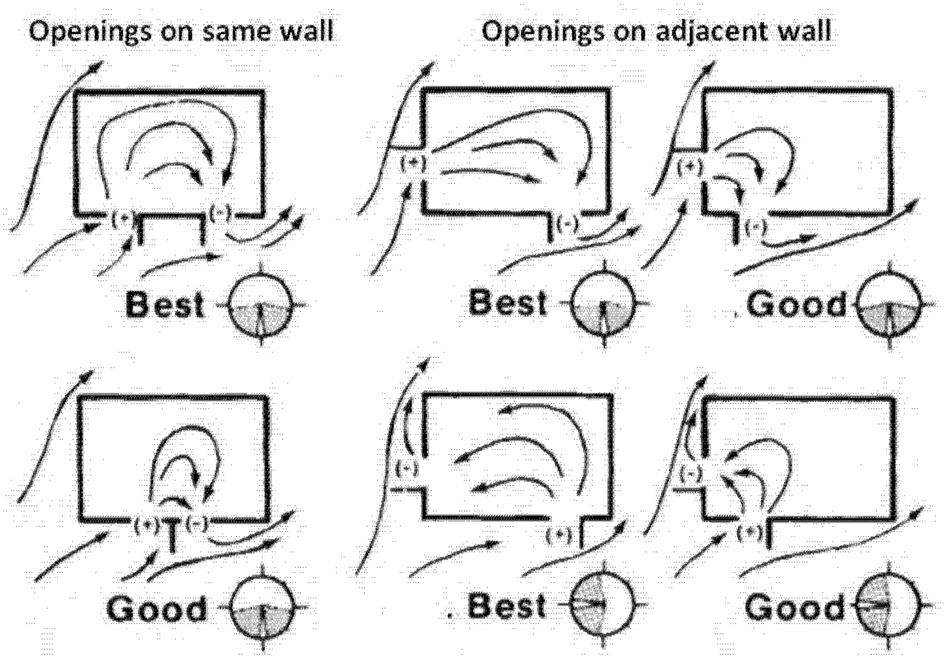

Figure 5 The healthy examples of wing walls on air circulation in buildings (Source: Adapted from FSEC)

A research has been carried out in a building office in Southern Portugal (J. Correia-Da-Silva, 2006). Here in summer, an intense air change is necessary, also for removing the heat created by overcrowding. Furthermore, a precooling of the air entering the building is desirable because of high outdoor temperatures (43). In this building a solar chimney expels stale air (43 fig. 1), and at the same time external air is cooled and attracted into the building without energy consumption. The peculiarity of such a solar chimney is a vertical trasparent surface facing south. The air that is inside the chimney, struck and heated by the solar rays, flows constantly out because of the lowered specific weight. This creates a suction at the chimney's base and as a consequence, if the windows are kept closed, outside air enters into the building through the above mentioned buried pipes. A few meters below ground, the underground temperature is close to the mean annual temperature of the site, hence the passage in the buried pipes has the effect of cooling the entering hot outdoor air.

A document explains how an ordinary house can be improved step by step to become a passive house. Three figures in the document show the improvements starting from a conventional construction, the cost of each, and the energy savings produced by each change (44). In the passive houses the energy use for heating and air conditioning is low, and consequently the related equipment can be downsized (27 / 3>thermal mass).

The design of low-energy buildings may take into consideration, besides the energy used by the occupants, also that used for construction, maintenance, repair and demolition of the house. As it can be seen in Figure 6, some documents provide, among many other things, information about the energy necessary for producing some building materials (45 page 150 / 46>embodied energy / operating energy / durability / 8>Materials>Embodied energy). The assessment of the embodied energy of a building is not easy and often the data cannot be directly compared. Such data are influenced, e.g. by the distance to which the materials are transported, the amount of recycled products that are or not employed and the efficency of the manufacturing process. The calculation can even consider the energy used for the transport of the workers to the job place, and that used to construct and maintain the machines that produce the materials.

The last mentioned website provides also guidelines for reducing the embodied energy of buildings. The most important factor is the construction of houses that are durable and originally designed for easy adaptability to the needs of the occupants that may change with the time. According to Jong Jim Kim and Brenda Rigdon (1998), the principles of life cycle design provide important guidelines for selecting building materials. Dwellings with an open plan and partitioning that is easily recycled allow a prolonged use of the building, and people may benefit from the energy embodied in it over a long lifespan (47 / 48>Waste Prevention / 48>Construction and Demolition Recycling / 48>Architectural Reuse / 48>Design for Materials Recovery). Resistance to natural disaster can also extend useful life of the buildings, as well as protecting the occupants, that is of the utmost importance. An animation, a text by Prof. Loren A. Raymond and a guide provide much information about selecting safe places to build houses (49>How will 3 buildings.... / 50 / 51).

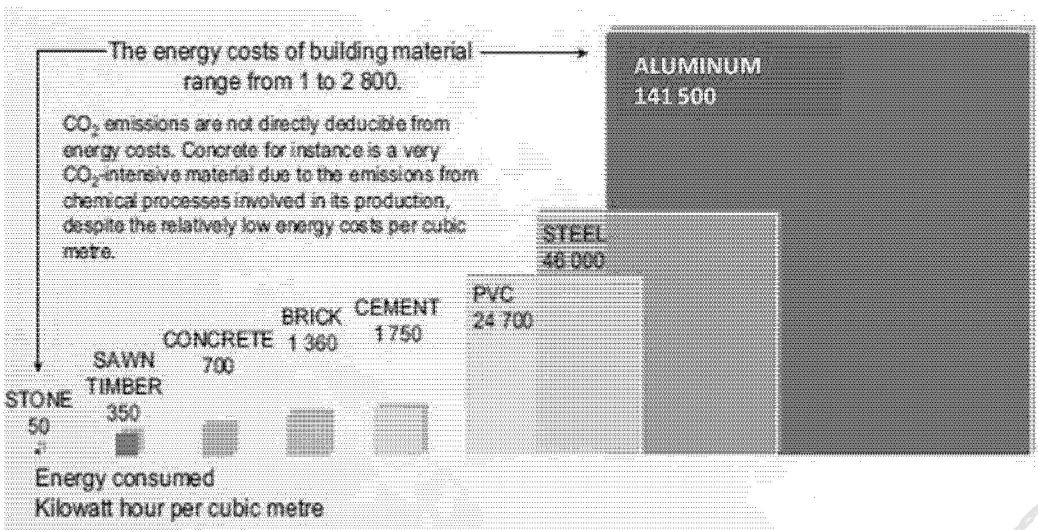

Figure 6 Energy cost of various construction materials (Source: UNEP/Kit the Habit, 2008)

Some materials are recyclable, such as steel that is easily recovered by magnets from demolition debris. Glass is recyclable too, but its separation from demolition debris is not always easy. Plastic is recyclable, but it is not so when integrated into other components and the separation is difficult or even impossible. Large amounts of electricity are required for aluminium manufacturing from bauxite ore; its recycling requires much less energy, but only 15% of its scrap is recovered from demolition debris. In the past highly engineered products difficult to recycle, such as for example the composites, partially substituted natural materials formerly used for constructions.

Two papers, by C. Van Rossem, Naoko Tojo, Thomas Lindhqvist (2006) and Gary A. Davis, Catherine A. Wilt (1997) deal with the principles of Extended Producer Responsibility. According to such principles, industries could be held responsible for collecting and disposing of their products, when these products arrive at the end of their life (52 / 53). Such "Extended Producer Responsibility" principles are promoting the design for easy recovery, disassembly and recycling of materials. Catharina Thormark (2001), provides guidelines that deal with design for reuse and recycling (54 Table 7-1). The content of an EPA document entitled "Waste - Resource Conservation - Reduce, Reuse, Recycle - Construction and Demolition Materials" is summarized by its title (55). An information sheet deals with possibilities and benefits of using recycled industrial materials in buildings. It also invites the readers to consult state and local environmental agencies to determine the approved uses of such industrial materials (55>Using Recycled Industrial Materials in Buildings)

Light appliances and home electronics can play an important role in energy saving. A website provides, among other things, the wattage of various household appliances, the formula for calculating their energy consumption, and tips for energy-efficent computer use (23>Energy-Efficent Home Design>Appliances and Home Electronics>Estimating Appliances and Home Electronics Energy Use / 23>Tips: Home Office and Electronics>Energy-Efficent Computer Use).

A website deals with efficient electric and electronic appliances (56>FAQs>Heating and Cooling / 56>Find ENERGY STAR Products). An animation deals with energy and money saving (56>Launch Energy Star@Home).

An educational document for kids provides information about energy efficiency and renewable energy (57 / 57>Kids - be an Energy Star).

The website of Arizona Solar Center provides information about solar cookers, including safety tips for their use (4>Technology & Science>Solar for Consumers>Solar Cooking>All about Solar Cookers).

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