

Zero Carbon Buildings: Implementation Strategies Utilized in Europe and the United States

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With today's emphasis on sustainable construction, there are many products and techniques that lead to better energy efficiencies as they relate to building construction. The term zero carbon building is used not only to describe a building's use of energy from fossil fuel sources, but also the emissions generated during construction to produce and transport building materials to the site. The strategies utilized to achieve a zero carbon project vary depending on the type and location of the project. This paper will discuss the strategies used to achieve a zero carbon project in Europe and the United States through a literary review and professional interviews with builders in the United States, England, Spain, Italy, Germany, Austria, the Czech Republic and France.

Key Words: Zero Carbon Buildings, Implementation Strategies, Carbon Neutral Buildings, Sustainable Construction

Introduction

The idea that many human activities contribute to greenhouse gas emissions is not surprising to anyone. There is no doubt that recent generations are creating more harmful emissions and degrading the environment than ever before (Reid, 2012). What some may not know is what these harmful emissions actually are and where they all come from. Greenhouse gas emissions are those emissions that allow sunlight to enter the atmosphere more freely and contribute to the greenhouse effect (REI, 2012). These emissions, or GHG's, come from a variety of sources such as combustible engines and aerosol cans. The reduction of ozone, caused by greenhouse gases released into the atmosphere, is known to cause increased rates of skin cancer, eye cataracts, and reduction in human immunity to disease (Watts, 2012).

This paper will discuss the strategies used to achieve a zero carbon project during its useful life, or the operational carbon. One question is why would a company spend so much extra time, money, and technology to achieve a zero carbon construction project? Other than the fact that it can be beneficial to the environment, both the United States and Europe have developed standards and regulations suggesting that zero carbon buildings will soon be required by law. Strategies will have to be developed to make zero carbon buildings affordable and profitable for all parties. The benefits, setbacks, and pitfalls of utilizing zero carbon in the construction industry need to be evaluated. The goal of this paper is to enlighten the reader on the strategies that construction companies, engineers, owners, and architects are using in the design and construction of zero carbon buildings.

What many may not know is that more than 50% of greenhouse gas emissions come from constructed buildings and the construction processes taken to achieve a completed building (WSP, 2012). This is an overwhelmingly exceeding number compared to the other sources of GHG's. The term sustainable development is generally defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). In the construction industry this means designing, constructing and managing buildings in such a way that reduces their impacts to a minimal level. This problem of climate change has attracted the attention of contractors, architects, and engineers across the globe, and there is finally a solution.

The idea of an environmentally friendly construction project has been around for decades (Birk, 2007). An environmentally conscious project may be discussed by using terms such as LEED, Green-Building, or Sustainability. All of these terms have the same goal to improve the performance of a building across five key areas of environmental and human health: energy efficiency, indoor environmental quality, materials selection, sustainable site development, and water savings (Rouse, 2010). These steps make it possible to have a construction project that is less detrimental to the environment as have been projects in the past. Recently "less detrimental" and LEED Certified has been insufficient; the new goal is to achieve a project that is helpful and advantageous to the environment. A new phrase has been introduced into the construction industry, zero-carbon buildings. The term zero carbon, or carbon neutral, was first coined by The CarbonNeutral Company in 1998 (CarbonNeutral Company, 2012). After taking into account emissions from space heating, insulation, building orientation, ventilation, hot water, fixed lighting, expected energy use, source(s) of energy, and materials used, a project is defined as zero carbon if the building will have net zero carbon emissions over the course of any given year (BSRIA, 2009).

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change. A major feature of the Protocol is that it sets binding targets for thirty seven industrialized countries for reducing GHG emissions. The initial steps to recognize a carbon market were implemented by the Kyoto Protocol in 1997 and were entered into force in 2005 (Battle McCarthy, 2001). The Kyoto Protocol has led to 95% GHG reduction in developed countries and 50-75% reduction in developing countries, making it the most important and influential piece of environmental legislation ever adopted (Watts, 2012). The general need to achieve a carbon neutral and environmentally responsible building can be broken down into five reasons. The reasons are: the need to comply with environmental regulation and legislation, increasing energy prices and the future prospect of fossil fuel shortages, the opportunity to reduce overhead and improve operational efficiency, brand enhancement via improvement of corporate environmental credentials, and consumer pressure (Watts, 2012).

A carbon footprint of a building can be defined as the carbon dioxide emissions resulting from construction materials, construction activities, lifespan operation and eventual demolition. A carbon footprint can be divided into embodied carbon and operational carbon. Embodied carbon is the total carbon emissions created in relation to construction materials and activities, and operational carbon denotes the emissions associated with heating and electrical consumption of a building during its operational lifespan. A building's total lifetime carbon footprint typically is comprised of around 20% embodied carbon and 80% operational carbon. However, embodied carbon is becoming an increasingly important part of a building's total lifetime carbon footprint as buildings become increasingly energy efficient during their operational lifetime (Bartoe, 2012).

During construction there is a spike in carbon emissions and afterwards it levels out. Although the operational carbon would not seem as daunting as the embodied carbon, it is actually 50-60% more. An important part of constructing a zero carbon building is allowing the project to have an on-site source of renewable energy. If the buildings' energy use does not exceed the amount of energy created on-site, there is a net zero energy use (Zero Carbon Building, 2012). Carbon neutral building technology is always growing and expanding with new products and procedures that we can use to benefit our environment by equaling or producing more carbon emissions than we create. By utilizing these materials and methods, we may be able to develop a building that can potentially sustain itself and even be beneficial to the environment and its community (Carbon Neutral Building, 2012).

There are many presumptions of how to achieve a zero-carbon building, but there is no set standard. Most of the zero-carbon projects in existence today are lower height, fewer use buildings. The tallest net zero carbon building in the United States is planned to start in the third quarter of 2012 and be completed sometime in the end of 2013; this building is the Oregon Sustainability Center in Portland, Oregon. The center will consist of a basement and approximately eight above ground levels (Oregon Sustainability Center, 2011). It is not out of the ordinary that there are no high-rise environmentally friendly construction projects. This is because the steps necessary to achieve zero carbon emissions for this type of building are so drastic, expensive, and inconvenient. The most daunting task to overcome when developing a strategy for a large scale carbon neutral project is to find a way to overcome the immense cost that such a project would require (TCPA, 2012). Some of the steps that may be taken when considering carbon neutral construction are: using energy efficient appliances, using green energy sources (solar, wind, and biomass energy) that must be on-site, using recycled and reusable building products, positioning the building to achieve maximum energy consumption, and by using locally available materials to name a few (Zero Carbon Building, 2012). All of these are relatively simple to do when constructing a house, but not feasible when considering a sixty floor high-rise office building. Such inconvenient strategies would hinder construction, affect surrounding buildings, or just not be possible at all. There is a different set of strategies for different projects to achieve the same goal of zero carbon construction.

Methodology

In person site visits and interviews were performed in the Southeast United states as well as in England, Spain, Italy, Austria, the Czech Republic, Germany and France from May 7th to July 18th, 2012. The projects were studied based on the carbon output of the building. Two projects that were studied were examples of a strategy used to achieve zero carbon rather that utilizing the more traditional measures of obtaining a zero carbon building. Some of the interviews were done in person while others were done through email or over the phone. The interviews from European professionals were conducted with Josef Gartner GmBH in Germany; Willmott Dixon Group in England; Ramboll UK in England; and Schmidt, Hammer, Lassen Architects in Denmark. The United States interviews were conducted with two individuals from Skanska US and one individual from Balfour Beatty Construction. Questions for each interview were tailored depending on the interviewee’s expertise, location and relative knowledge of zero carbon practices. The interviews were conducted in order to determine the individual and the company’s perspective on zero carbon buildings, to understand the government’s stance on carbon reduction, what guidelines are in place regarding zero carbon buildings, and to learn about the future of zero carbon buildings in these respective countries.

Several projects were studied which provided much of the technical information. They included Tate Modern in London, England; Amazon Court in Prague, Czech Republic; Grondalavej in Aarhus, Denmark; The Smith House in Urbana, Illinois; the Aldo Leopold Legacy Center in Baraboo, Wisconsin; the Cliff House in San Francisco, California; Carbon-free Chicago House in Chicago, Illinois; and the National Renewable Energy Laboratory in Golden, Colorado. Each project revealed different and sometimes unique methods being used, adding to the analysis of different zero carbon approaches that are currently being used in the construction industry. These projects were chosen because of the significant carbon reduction that took place on each project.

Implementation strategies

This section describes some of the techniques used and some unorthodox methods taken to achieve a zero carbon project. The first, most commonly used and required strategy implemented for a zero carbon project is obtaining renewable, or carbon free energy for the project. Renewable energy relates to naturally available sources that are constantly being replenished and are capable of being harnessed for human benefit (Watts, 2012). Many people are aware of a few types of renewable energy such as utilizing the wind with wind turbines, capturing the sun’s energy by using PV panel arrays, or the ancient art of using moving water for energy through the use of hydroelectric power. Some methods that are not as commonly understood will be discussed in this section. The first type of renewable energy that will be discussed is a renewable energy source known as geothermal energy and it is relatively new to the construction industry. Geothermal energy is energy harnessed through the capture of heat, either in steam form or hot water form, from beneath the earth’s surface. This type of energy is harnessed by digging deep wells and using pumps to bring the steam or hot water to the surface and using it to heat or cool a building. Geothermal energy can also be used to provide electricity for a building. Geothermal heat is found mainly at plate boundaries so it all depends on the location of the site as to whether or not this form of renewable energy is available. The United States is the largest producer and user of geothermal energy in the world. This is because the US has the technology, and geothermal energy is located mainly along the ring of fire, which is the area surrounding the Pacific Ocean. All of the United States’ geothermal power plants are located in the Western part of the country (EIA Geothermal, 2012). An innovative design that has not been used in the United States, but a few times in Europe is a building technology called energy piles. Skanska Construction Co. has copyright shares on this technology and they built the first building using energy piles in downtown London, United Kingdom. Skanska came to the conclusion that, if you are going to dig a deep hole for foundation piles, why not go ahead and make that foundation pile be a geothermal energy system as well. That is how the energy pile was conceived and it is a relatively simple approach. The engineer accounts for the extra depth needed to reach geothermal level and adjusts pile depth accordingly. Pipes are laid out through the pile and the hot water or steam is pumped up through them just like any other geothermal system (Dannenbring, 2012).

Another type of renewable energy, one of the oldest forms of renewable energy, since fire was first discovered, is called biomass energy. Biomass energy is created using the waste from plants and animals. When burned, the chemical energy in biomass is released as heat, which can then be used to produce steam for making electricity or provide heat to buildings. What makes biomass so resourceful is the fact that it can be converted not only to heat energy but it can be converted to other useful forms such as methane gas, ethanol, and biodiesel. Methane gas is a main ingredient in natural gas; ethanol and biodiesel are used in transportation fuel. Only about 4% of energy used in 2011 was derived using biomass (EIA Biomass, 2012). Biomass is a very resourceful type of renewable energy; biomass would diminish landfills and eliminate unwanted waste. A common misconception brought about when discussing biomass is that when biomass is burned, it creates carbon emissions. This is true, but the carbon dioxide captured during its own growth balances out the carbon emitted during its use, therefore it is still classified as renewable. The only time that biomass would not be environmentally beneficial would be if forests were cleared to grow biomass, which is why most biomass companies try and use previously cleared land such as under-utilized farm land (NREL, 2012). Renewable energy is essential for a zero carbon building; deciding which type(s) of renewable energy to use is crucial to the success of the project's carbon neutrality.

Two approaches that will be discussed are strategies used to achieve a zero carbon project while the building is in fact, still creating carbon emissions. The first, which is used mainly in Europe, is called allowable solutions. The theory of allowable solutions suggests that, if you get your building as carbon efficient as possible, and then through your renewable energy source, provide renewable energy for another development, then your building is seen as zero carbon for the carbon you saved the other development. Per the example given by Mr. Donn, a developer is building a school and surrounding buildings and the project is as carbon efficient as it is going to get and it still is producing carbon. Say the school has a large PV panel array on the roof and produces enough energy for the school and then some. If the school provides solar power for surrounding buildings or even a nearby neighborhood, then the carbon created by the school is then offset by this dispersion of renewable energy. So by making the entire area lower carbon as a whole, the school has achieved a zero carbon effect. As Mr. Donn said, "This is a complicated approach and still has some kinks, mainly with dishonest developers, to work out before it is perfect but it is still a widely used zero carbon technique within the United Kingdom." As seen in Figure 1 below, allowable solutions offer the opportunity to achieve a zero carbon building, where the project could not otherwise reach carbon neutrality.

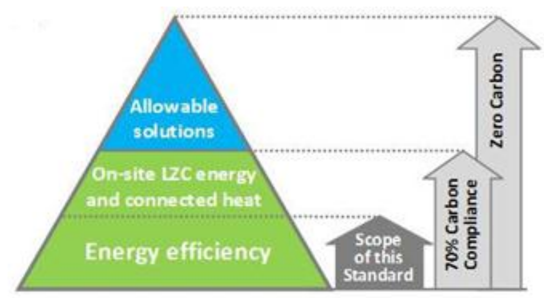

Figure 1: Theory of Allowable Solutions (Modelling Tech Demo 007 zcal Allowable Solutions.pdf, 2012)

The second strategy, which is used mainly in the United States, is called carbon offsetting. Carbon offsetting can be done in two ways. The first way is becoming less and less prevalent in the construction industry just because of the lack of honesty on the part of the company providing the offsets and the lack of control on the part of the developer. This first method is done by paying a company, hopefully one that is reputable, a varying amount of money to replenish a site. For example, a developer can purchase a plot of land in the Brazilian jungle to save it from deforestation, thereby offsetting the carbon created on his/her project. The problem with this way of offsetting is the fact that companies that are being paid by these developers may or may not sell the same plot of land to multiple developers, so the fact is that even though they are paying, they are not truly offsetting the carbon they are creating. So it is a lose-lose situation, the developer is creating carbon that has not been offset (and paying for it) and the land that was paid for is not being protected. Another method of offsetting a projects' carbon, which is more controllable, is done within the United States or through a method where a developer can actually see what has been paid for. Through this method, a developer will pay a company that will invest money into a renewable power company or invest the money into re-growing deforested lands or marine life. A good example of where this is used is the Cliff House in San Francisco, California. The Cliff House is a zero carbon project, but not by design. The Cliff House became zero carbon through a company called Planktos. Planktos takes Cliff House's money and invests it in re-growing forests and regenerating plankton populations all around the world, both of which produce carbon, in turn offsetting the carbon dioxide emissions created on the project site. These two strategies may seem unorthodox but they both are a great way for a previously built building, or one that simply could not achieve zero carbon status, to become zero carbon while regenerating what has already been destroyed.

There is a scheme within the European Union called the Carbon Trading Scheme that is very similar in nature to offsetting in the United States, just on a much larger scale. By paying money to the EU, companies can offset their carbon created on-site. The money is then put into developing and researching renewable energy sources. There is another method that is used sparsely throughout the United States. After researching and interviewing multiple professionals, only one instance was discussed. While interviewing Ms. Mary Bartoe with Skanska US, she indulged me with project details where the building actually provided power to the local grid. This sounds like the allowable solutions approach in Europe but the building was not providing power to other buildings. This building in the Washington DC area has an enormous PV panel array onsite that provides ample energy needed for operation during daylight hours. However, the building still needs power at night so the building is connected to the city grid. The building produces so much renewable energy during the day, and puts it back into the grid, that the non-renewable energy it uses during night time hours is offset by the energy produced earlier that day.

Conclusions

The methods described to achieve a zero carbon project have been used throughout Europe and the United States. Both countries have particular technologies they have focused on and perfected. The main difference, other than a few building technologies, is the strategic methods that are used in each country. In Europe they utilize the system of allowable solutions and carbon trading and in the United States they use carbon offsetting and, in some places, a tactical strategy of providing power back to the grid.

Throughout the research gathering stage of this project, there was one recurring fact that kept arising in both the United States and in Europe, and that was the fact that not one person/company/organization could provide any one answer as to what implementation strategies are best used to achieve a zero carbon project. Almost every single interviewee stated that there is just no set standard or definitive guideline on how to achieve a carbon neutral project. Also, it was stated in the professional interviews that achieving a zero carbon project all depends on the location and type of the project. For instance, one of the most innovative strategies discovered was the use of Skanska's energy piles, however geothermal energy is not available everywhere on the planet so it is all site dependent. Since there is no definite strategy to achieving a zero carbon project, the following list will show all of the methods that were discovered during the extent of this research. The methods include:

- Must have an onsite source of renewable energy such as: geothermal, biomass, hydroelectric, wind, or solar. Not all of these are required, but a combination of two or more of these sources is not an uncommon practice.
- The orientation of the building can have a crucial impact on the building's ability to achieve maximum natural daylight and ventilation.
- By providing shading and glazing on the windows the building will be able to alter the amount of sunlight let into the building.
- Using recycled materials when possible is a good way to reduce the buildings' carbon footprint.
- By having an ultra-tight building envelope, the building requires less insulation and less power is required to heat and cool the building.
- By utilizing natural ventilation when possible, a building can have zero energy required for ventilation. Natural air can be captured and treated within the building and then dispersed safely and with no operating cost.
- By utilizing natural rainwater, there is no need to purchase water. The rainwater can be treated and used for washing, flushing toilets, and site irrigation.
- By recycling the building after its useful life, it is insured that there will not be any carbon emissions created by the buildings' waste.
- By increasing the thermal insulation of the building the energy needed to heat and cool the building may be reduced significantly.

All of these methods, when combined with some or all of the others can lead to a zero carbon building. However, it still may not be enough. This is where applying allowable solutions and offsetting will come into play. By utilizing some or all of the above mentioned and either allowable solutions in the UK or carbon offsetting in the United States, a building is able to achieve a truly carbon neutral status.

There is a significant amount of research that remains to be done. This paper focuses on the strategies that are currently being utilized in the construction industry. Additional study of this topic could investigate the governmental regulations and restrictions regarding zero carbon buildings. This information would explain the difficulty that the construction industry is facing while trying to achieve a zero carbon emissions built environment. Another example of further research is in the technology, planning, and logistics that are involved in a zero carbon project.

Construction practices are a major cause of climate change and environmental chaos in todays' society, this is a proven fact. At one point in time a LEED Certified building was the best thing that ever happened for the construction industry. Today society calls for better. This is where zero carbon buildings have originated from and construction professionals are working to achieve the demands that are necessary to sustain the worlds' environment. If construction practices continue the way they are, there will be a catastrophic destruction of the environment and ultimately the world's economy. To fix this, carbon reductions in buildings are becoming the future of construction practices. While the research compiled here is noteworthy, zero carbon buildings are a new age goal and there is an abundance of research still left to do. Zero carbon buildings are a possibility, it is up to construction professionals to make them a reality. "Development which has no regard for whom or what it harms is not development. It is the opposite of progress…" George Monbiot (2012).

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