EMBODIED ENERGY IN BUILDING MATERIALS

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In 2013, a mining company called Gogebic Taconite set its sights on the beautiful Penokee hills of northern Wisconsin. They proposed a four and a half mile long strip mine (which would eventually be expanded to twenty-two miles long) stretching across thirty-five acres of privately owned and managed forest land. The material mined from this project would be taconite, an ore that contains magnetite that is generally about 20-30% iron, typically of a low grade. To remove this iron from the ground, the mining company must remove forests, which are a natural carbon sink, and the top layer of earth, which, if aggregated, would be around 500 feet high and one and a half mile long (Iron Mining, 2015). This doesn't even begin to cover the tailings left behind by the mining process. Using a computer aided design program called Solidworks, an estimate was done stating that tailings created over thirty five years of operation would be enough to cover the entire country (over 3,750 acres of land) with forty seven feet of tailings. For scale, an acre is just slightly smaller than a football field. The processes of land clearing, excavating, and mining are very fuel intensive, releasing tons of carbon dioxide into the atmosphere. In addition, a study by Bjornerud, Knudsen, and Trotter from Lawrence University shows that in the first thirty-five years of operation alone, two and a half billion pounds of sulfur would be released, which would combine with air and water to create acid rain. Finally, the runoff from this mine would leach heavy metals including arsenic, copper, mercury and zinc, and would also release phosphorus (a major wetlands pollutant) into the watershed (2012). These pollutants are poised to affect the headwaters of both the Tyler Forks and Bad River (which both empty into Lake Superior), in addition to over fifty miles of streams and rivers. The mine will also have a detrimental effect on the traditional wild rice fields of the Ojibwe and Chippewa Native American tribes, and the Penokee Aquifer, which provides clean drinking water to many residents (Iron Mining, 2015). The raw iron from this mine will eventually go on to be refined, and much of it will be combined with carbon to create steel which will be used for building materials around the world. Steel is a strong alloy (mix of metals) that provides many structural benefits. However, the side effects of its production must be considered as well.

Problem

With outcomes as severe and widespread as these emanating from just a single iron mine, scientists have a difficult time accurately measuring the impact that removing resources has on our environment. This problem translates to the building materials that are created out of these resources, and the contractors, builders, and designers who work with them.

While energy efficiency in buildings has been a focus in recent years, the creation of the construction materials themselves is often overlooked. One attempt at quantifying what goes into building materials is the study of embodied energy, which measures the amount of energy that goes into creating building materials such as steel, concrete, and wood. In the construction industry, there is a gap in defining the term embodied energy when it comes to building materials. This is due to the fact that current interpretations of embodied energy are unclear, and varies greatly regarding what is included in the embodied energy calculations (Dixit, Fernandez-Solis, Lavy & Culp, 2010, p. 1238). According to Dixit et al. (2010) embodied energy in the process of building material production includes: the energy used in harvesting the raw materials, such as mining and manufacturing, the transportation to on-site delivery, construction and assembly on-site, renovation, and final demolition (p. 1238). Embodied energy is also defined by Cabeza et al. (2013), who state that the embodied energies of the materials depend on the manufacturing process, availability of the raw materials close by, efficiency of production, and the amount used in the construction (p. 538). From these two similar definitions, a parallel is drawn defining embodied energy as the amount of energy used from harvesting raw materials and the manufacturing process, while taking into account the energy used in the total transportation and installation of the building materials. Since there is not a clear consensus between many definitions to account for the demolition and disposal of a material, it is not included in our definition.

In today's world, many believe the biggest global threat is climate change. In order to reduce climate change, society as a whole needs to start taking specific preventative measures. In the construction industry, a lot of energy is consumed. This causes environmental pollution and emissions of greenhouse gases that greatly contribute to climate change (Dixit et al., 2010). One large contributor to this problem is the lack of consideration of embodied energy in the construction industry. Construction accounts for approximately 24% of the global raw material removed from Earth (Bribián, Capilla & Usón, 2011, para. 1). As of now, Dixit et al. (2010) have calculated that "the building material (production) industry is responsible for 20 percent of the world's fuel consumption" (p. 1240). With such an immense use of energy, the construction industry needs to address this embodied energy issue, which will lessen their energy usage and prevent the emission of large amounts of the greenhouse gases that directly contribute to climate change.

Often times, it is not up to the architect or contractor to decide which materials to use when designing and constructing a home. The owner, or largest shareholder in the construction of the building, has the final say in what materials will be used and where. There is little financial incentive for builders to use the most environmentally friendly materials, and owners often see little to no reason to choose the material with the smallest impact on our planet. The smartest choice for most owners and builders is usually the cheapest option, and unfortunately, that is not always the best for the environment. Energy efficient materials, and those with lower embodied energy, may have a higher initial cost of installation (Balogh, 2015). With greater financial incentive to use materials with less embodied energy, perhaps architects, builders, and owners alike will be more keen on the choices they make during construction.

Thesis

By implementing incentives and stricter building codes, architects, contractors, and owners should use timber over steel and concrete in residential construction in order to slow climate change and lessen the environmental impact of building materials.

Sub-claims

A material with a lower embodied energy uses less energy during its life cycle. This results in less resources consumed to extract raw material, produce specific parts, transport the product, etc… directly leading to less environmental impact. Consuming energy results in the production of greenhouse gas emissions. Excess amounts of greenhouse gases lead to global warming and damage the environment, therefore embodied energy can be considered a measure of the overall environmental impact of building materials (Embodied Energy, 2014, para. 1). Consequently, a material that possesses lower embodied energy will reduce carbon emissions produced and will limit the impact on the environment.

In residential housing, timber framed houses possess lower embodied energy than steel framed houses. The manufacturing of a building material is included in the embodied energy. Figure 1. shows that it takes 24 times less energy to produce one ton of wood than it does steel, making the manufacturing process for wood the most energy efficient compared to any other building material (Wood: Sustainable Building Solutions, 2012, p. 5).

The environmental benefits of using wood over steel in houses are displayed in a case study performed by CORRIM, which is the Consortium for Research on Renewable Industrial Materials. In the study they compare hypothetically built houses, one that is steel framed and one that is wood framed in the cold climate of Minneapolis. They compare these houses by the life-cycle energy requirements and greenhouse gas emissions from the two homes, that have similar heating and cooling requirements, but are constructed from different materials (Upton, Miner, Spinney & Heath, 2008, p. 8). Their conclusions found that timber built houses "required about 15-16% less total energy for non-heating/cooling purposes (compared to steel built houses)" (Upton et al. 2008, p. 8). If a wood base house is using less energy for heating and cooling purposes then it is reducing its environmental impact. The results also found the greenhouse gas benefits of replacing non-wood materials with wood building materials are greater (Upton et al., 2008, p. 8). This is because the "net GHG emissions associated with wood-based houses were 20-50% lower than (comparable steel based systems)" (Upton et al., 2008, p. 8). The wood based house emits less net greenhouse gases due to the low amount of GHG's produced while manufacturing wood compared to the large amount produced when steel in made, this would help limit the environmental impacts by using wood over steel.

Although less environmentally taxing than steel, concrete still possesses a higher embodied energy than timber (Upton et al., 2008, p. 8). Concrete uses limestone, the most abundant mineral on earth (Cabeza et al., 2013, p. 538). This shorter transportation process helps reduce CO2 emissions of the material, lowering the embodied energy. Authors Upton, Miner, Spinney, and Heath. (2008) compared structures of a concrete and a timber wall home, and concluded concrete wall houses have roughly 15% greater energy demands than a wood framed house (p.8). Another reason that concrete has a higher embodied energy is the fact that it deteriorates over time, which results in more energy and resources used to restore the concrete structure. Wood buildings also require significantly less energy to process timber than concrete, which directly results in lower carbon emissions than concrete buildings (Cabeza et al., 2013, p. 539). Environmentally speaking, wood is clearly the best choice for the construction of residential buildings.

The building material with the least impact on the environment is wood. One clear reason timber is better than steel and concrete is because wood is easier to extract and manufacture than the other two materials. Wood is plentiful and all around us, and unlike steel, mining and extracting the materials from underground is not required. Timber is also relatively easy to process and form into sizes and shapes that are widely used across the construction industry. This results in less energy focused into making custom pieces of wood (Timber Frame Homes are Energy Efficient Homes, 2012, para 1). Wood is also a reusable material, thus increasing the duration of the life of the material. Pieces can be reused on other project sites and excess framing can be utilized in other parts of the home. Timber frame construction also encourages the use of local resources, and the closer the extraction point to the project site, the less carbon emissions and embodied energy the material will possess (Timber Frame Homes are Energy Efficient Homes, 2012, para 2). Wood frame homes also allow for more insulation to be placed between the vertical members, allowing for more retention of heat in the winter and helping to regulate cooling in the summer(Timber Frame Homes are Energy Efficient Homes, 2012, para 3). With better insulated homes, homeowners will see their energy bills and usage decrease, resulting in less energy being used during the occupancy phase of the home. Lastly, wood acts as a carbon sink. A carbon sink is a reservoir that captures and stores a carbon compound for an indefinite period. Cabeza et al. (2013) states that timber products actually have a negative carbon coefficient. This means that timber products store more carbon over their lifetime than is released, which cannot be said for concrete or steel.

Proposal

One solution to decrease the amount of embodied energy in building materials would be to explore new ways to get contractors, owners, and architects to use timber over steel and concrete. By offering financial incentives such as tax breaks with the use of timber instead of steel and concrete there would be a greater chance of contractors and owners wanting to use timber in residential construction. To understand how this would work, a parallel must be drawn between our proposal and a similar situation. Tax incentive (IRC section 45L[a]) is a new energy efficient home tax credit that is a source of potential benefits for affordable housing developers, investors and owners (Boureois, Breaus, Chiasson & Mauldin, 2010). Energy efficiency improvements that encompass the building envelope of the property can qualify for certain tax credits on a case-by-case basis. Improvements such as upgrades to insulation or roofing materials qualify you for a credit that is worth up to 30% of the price of the materials that meet the qualification criteria during that current tax year (Boureois et al, 2010). Similarly, if we apply this concept to favor the use of timber framing in the residential housing market it could be very efficient in reducing the overall embodied energy found in the building materials that are being used. To prove how this concept really works we can look at an experience in Oregon and the total financial benefits owners have received. Since 2001 Oregon developers of buildings certified LEED Silver or better have saved nearly $5 million and in 2006 the state received 29 applications totaling $13.7 million in eligible costs (Roberts. 2007). By being able to point out how tax incentives will offset the cost of building at energy higher standards Oregon successfully increased the amount of energy efficient buildings and reduced the city's impact on the environment.

Implementing stricter building codes may be more costly for the market, but would certainly play a role in reducing the impacts of embodied energy found in materials such as steel and concrete. For example, on January 1, 2011 the city of Los Angeles, California put into effect a set of mandatory Green Building code standards for new construction, alterations, and additions to residential and commercial structures (Kim, Green & Kim, 2014).This has resulted in increase of energy savings and has reduce the impact the city of Los Angeles has on the environment (Kim, Green & Kim, 2014). By comparing two buildings, one that meets the green building code standard and one that did not meet the code, Jin-Lee Kim and Martin Greene concluded that the return on investment for more efficient systems could be very significant for owners(Kim et al., 2014). Implementing stricter building codes could help lower embodied energy in our building materials.

Resistant Audience

One may pose that implementing stricter building codes and regulations into residential construction would raise the cost of the construction processes affecting the housing market. Although this may be true temporarily, the return on investment outweighs the initial costs of investing in building with timber framing systems. Contractors need to educate and ensure owners that their investment will be worthwhile. The fact that these materials may be more expensive often drives away potential buyers. Under our plan, subsidies would offset costs and create incentives for those who choose to build with timber. Stricter building codes would also help to level the playing field by making sure that contractors are only able to choose between building materials with low embodied energy. For example, Tax incentive section 1331, the Commercial Building Tax Deduction, claims that owners may claim a tax deduction related to the design and installation of energy efficient systems. “Building owners can claim a tax deduction of up to $1.80 per square foot of building area for the installation of systems that reduce the total energy and power costs by 50 percent or more when compared with a reference building” (State and local, 2008, p.7). Drawing information from the previous example we see how the strategies used behind a similar tax incentive process benefits owners financially to a significant degree. Given this information and considering people’s general desire for money in the market, we can conclude that tax incentives would increase the use of wood in construction processes.

Conclusion

The environmental impact of using energy intensive building materials is too large not to consider the embodied energy when constructing new buildings. Our proposal of increasing timber usage relative to concrete and steel using stricter building codes and financial incentives would help reduce embodied energy. This would in turn benefit the environment and the contractors and builders who use these materials.

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