HOW TO MITIGATE THE CONSTRUCTION INDUSTRY'S EFFECTS ON CLIMATE CHANGE

Architectural Research - EG

BME, Faculty of Architecture, Department of Building Energetics and Services

Course Director: Csaba Szikra

Student: Oliver-Oskar Bruun Christiansen, FRJ3HG

Indhold

Abstract

This paper researches ways on which the construction industry will handle and mitigate the climate crisis. A look into the current problems and an overview of possible solutions is drawn in the introduction section. First a section about material usage expands on the idea of embodied carbon, and how wood might be the returning material in the building industry. Second a look into the future of energy design, provides an overview on the different solutions which may help future buildings to become carbon neutral as well as adapting to the future of energy productions.
Third a quick overview on the grave scenario of building materials, explains why recycling is a necessity when it comes to the future of buildings.
Lastly the paper is summed up by a conclusion, and an overall view of the possible realization of a climate friendly construction industry.

1 Introduction:

The world is currently facing the biggest environmental challenge we have ever seen. For the last 150 years, humans have changed the natural balance of the earth by living beyond our means. Burning of fossil fuels, over breeding of methane- producing livestock, and demolition of forests, are just some of the bigger reasons for this on-going climate change.
When it comes to general CO2 emission it is easy to solely put the blame on the burning of fossil fuels. However, if we look towards the building and construction industry, we will find that it has a very big share in these environmental issues. It is about time that this industry looks at its own environmentally harmful actions. According to the U.S Energy Information Administration, the building sector was responsible for 44 percent of the overall CO2 emission in 2010 in the U.S, mainly through greenfield development and cement production. This number is way higher than the transport sector which contributed to 34 percent or the industrial operations 21 percent.[1]
According to the non-profit organization Architecture 2030, which was established to put focus on the climate change crisis, an estimated area around 3.5 times the entire currently build environment in the U.S, will be redesigned and rebuilt over the next 20 years, which will be the perfect opportunity for the building sector to shift from its traditional approach and drastically reduce its CO2 footprint.
There are plenty of ways for the building sector to reduce their climate footprint etc. choosing more sustainable materials, making better energy focused designs, using waste and recycled materials, extending the life of buildings, or increase the use of prefabricated elements and offsite manufacturing, just to mention a few.
As the building industry implements more energy-efficient buildings it should also start concerning about how to power these buildings from renewable energy sources. In a production case the priority should be to implement renewable on-site power from perhaps solar, geothermal, or wind energy, and if this is not possible, the production should obtain its energy from other certified and renewable sources.
Optimizing the general energy consumption on a building construction from cradle to grave is one thing, another and just as important factor is the overall carbon footprint. The building sector is already focusing on reducing operational carbon emission, but not as much focus has been put on the so-called embodied carbon, which is a term for the overall carbon footprint of a material released through the supply chain generally measured form factory to building site.[2]

[1] **https://constructionexec.com/article/how-to-mitigate-the-construction-industrys-effects-on-climate-change**

[2] http://www.circularecology.com/embodied-carbon.html

2 Material

2.1 Current Production

As mentioned, embodied carbon is one of the biggest climate threats to the building sector. A major step towards lowering the amount of embodied carbon in a production, is changing the materials used. Most of the currently common building materials, concrete and steel, contains high amounts of embodied carbon. Concrete especially has a very high footprint because it contains cement. The cement production is very complicated and contains a lot of environmentally impactful steps, from getting the materials at a quarry, to breaking it down and melting it at extremely high heats, as well as to transport it from factory to site, all steps that consume a lot of energy and release high amounts of CO2 which is seen on *figure 1*.[3]

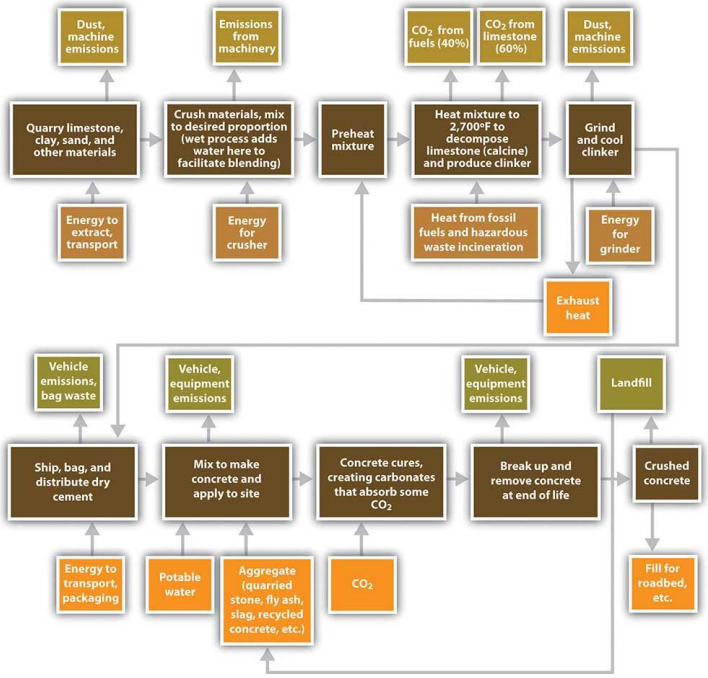

Figure 1 – The footprint of concrete production

The production of concrete is currently the third highest producer of man-made CO2 after transport and energy generation, and approximately 5% of the worlds total CO2 emission is caused by the cement production, with its footprint of 780 kg of CO2 per ton of cement produced. Looking at these numbers, it is clear, that to work towards a better footprint in the building industry, an alternative to these impactful materials must be found.
Or maybe reinvented, cause it just so happens, that we here on planet earth have a very good substitute for concrete and steel, the natural product wood.

[3] http://www.greenspec.co.uk/building-design/environmental-impacts-of-concrete/

2.2 Wood constructions

The use of wood in the building industry is not a new idea, but using it in a way bigger scale, as the it requires today, is. Using wood instead of more conventional materials, comes with several environmental advantages. Wood has the unique property of capturing and storing approximately 1 ton of CO2 per m3 from the atmosphere, throughout its entire lifecycle.
Figure 2 shows how trees throughout their whole lifecycle will store carbon, and how fabricated timber elements can be recycled or used for bioenergy.
Wood based materials can be used in almost all parts of a conventional building and is therefore a great help for architects and engineers to reach ambitious CO2 reduction goals.

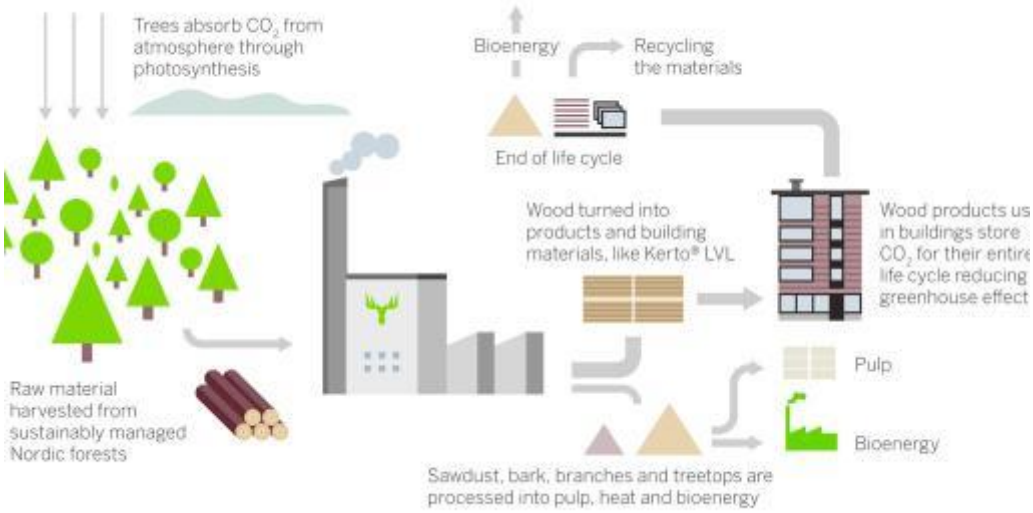

Figure 2 – Lifecycle of wood

Matti Kuittinen a researcher and architect from Aalto University, Finland, did a study on passive houses, making two identical houses, one with an exterior made of wood and wood-fiber insulation and another with an aircrete outer and EPS insulation. The study showed how both options had equivalently good results in their level of energy efficiency, however the wooden structure caused 40% less CO2 emission, and the amount of atmospheric carbon stored was almost 4 times bigger than for the concrete construction.[4]
The biggest challenge in modern wooden constructions is achieving the same enormous scale which the building industry requires today. Urbanization, huge growth, and growing density of people means that the cities of today have an increasingly high expectation of architects, engineers, and constructors to come up with bigger, cheaper, quicker, and more efficient constructions.

[4] https://www.multivu.com/players/uk/8043651-wood-construction-climate-carbon-storage/

2.3 Bigger scale

The best way to utilize space in a big city is by building higher. With tall skyscrapers you can supply housing for more people on a smaller ground area, and thereby utilize the space of dense cities. The first named skyscraper was the Home Insurance Building in Chicago It consisted of an interior structural steel and metal frame, which also included reinforced concrete, and stood 42 meters tall. Today this feat is not in anyway impressive, with structures like the 828 meters tall Burj Khalifa in Dubai. But looking at currently build wooden constructions, it is close to what humans have achieved today.

The tallest wooden construction today, is known as the Brock Commons and is in Vancouver. Brocks was completed in 2017 and is a student residence building at the University of British Columbia. The building is 53 meters tall, so actually 11 meters taller than the Human Insurance Building, and houses 404 students. The building has everything a regular steel/concrete building would have, even though it is mainly constructed using timber, only exception being the two concrete utility shafts inside the building. Brocks was built in only 70 days, because of the efficient use of prefabricated components, which is significantly shorter than the time it would have taken to build a concrete construction of the same size. On top of the impressive speed this timber structure was built in, it also had many economically advantages as well as of course environmental.[5]

Generally speaking a timber construction like Brocks is a great example on why timber constructions will play a huge role in the future of architecture and building construction, but when comparing the size of Brocks to for example 432 Park Avenue, which is currently the tallest residential building in the world, it seems like we still have a long way to go, until timber constructions can fully replace concrete. This seemed to be the case at least until February 2018, when the Tokyo-based architectural firm Nikken Sikkei revealed their plans for their W350 Project. The W350 Project is a 350 meters tall wooden skyscraper positioned in the central part of Tokyo. The project is estimated to be finished in 2041, and will thereby not only be the tallest wooden construction by far, but actually also the tallest building in whole of Japan.

Figure 3 - W350 Project

It is still unknown exactly what kind of wood the construction will consist of, but a form of cross laminated timber would be expected, hence it is the currently strongest technique for wood-based construction elements. The construction material is expected to consist of 90% wood and would have a volume of approximately 0.2 million cubic meters, which would therefore be storing 200.000 tons of CO2 from the atmosphere.[6]

[5] https://www.archdaily.com/879625/inside-vancouvers-brock-commons-the-worlds-tallest-timber-structured-building

[6] https://www.dailymail.co.uk/sciencetech/article-5395371/Worlds-tallest-WOODEN-skyscraper-set-Tokyo-2041.html

3 Energy

3.1 Energy use

Adapting building materials towards lower embodied carbon is a great of tackling the initial steps of an environmentally friendly building industry, but to realize the goal of a totally carbon neutral industry, changes towards the buildings energy usage, must be made as well.
The whole process of a typical residential building, involves a lot of energy heavy steps, from the production of materials, to the construction of the building itself. Then comes the overall service use through maybe 100 years, where the building needs energy for electricity, heating, water, repairs, etc. Finally, the building will eventually have to be torn down, hopefully recycling most of the materials, but still this process will require a lot of energy.

3.2 Architecture 2030

The initiative Architecture 2030 is a non-profit organization working on rapidly transforming the global building sector from one of the biggest contributors of greenhouse gasses to a part of the solution to the climate change. Their primary objectives are to reduce the energy consumption and greenhouse gas emissions of the built environment, as well as developing sustainable, resilient, equitable and carbon-neutral buildings.
In the U.S currently 80% of the top 10 and 65% of the top 20 architectural, engineering and planning firms has adopted the 2030 Challenge, which is one of the action plans developed by Architecture 2030. The 2030 Challenge is a challenge to achieve a carbon neutral building industry in 2030 by following some guidelines and requirements for newly established constructions and renovation of existing buildings. [7]
All new buildings, developments and renovations must be designed to meet a fossil fuel, GHG-emission, and energy consumption performance which is at least 70% lower than the current average we have today, and an equivalent amount of the existing building must be renovated to meet the same 70% lower standard as well. Following these targets should result in a progress towards total carbon neutrality in 2030.

To Achieve these lower numbers on the footprint production firms and architects can use the 2030 Palette. The Palette consist of guidelines divided into categories, ranging from regions, cities, districts, sites, and buildings. It can assist architects and engineers on how to design for example coastal settlements, parks, street networks, elevated structures, or simply building facades in general, just to mention a few.[8] Taking for example the category sustainable sites, the Pallet gives guidelines, considerations, tools and references for ways to develop a sustainable site.[9]

[7] https://www.archdaily.com/869056/7-ways-architects-can-work-toward-carbon-neutral-buildings-by-2030
[8] http://2030palette.org/palette/
[9] http://2030palette.org/sustainable-sites/

3.3 The Passive House Standard

One of the most important goals in creating energy-efficient buildings is to accurately predict in the early design stages, how the building will perform when occupied, so to not only focus on the production, but the ongoing energy use for regular operation.
Architect Nabi Tahan, AIA says that there are three main ways of making a building energy efficient by using less energy, generating more energy from renewable sources, or a combination of both, which would be the best option. Generating more renewable energy is not a solution for the building industry itself, but more a general solution for the whole worlds sustainability, making the building use less energy is on the other hand a factor only the architects, engineers and constructors can solve. Most current buildings waste a lot of energy for either heating or cooling, because the buildings are not airtight or not isolated well enough.
The European-developed standard of Passive Houses has gained worldwide popularity when designing energy efficient and net-zero energy houses. The standard has very high demands to the energy use, assemble and airtightness of a building, and gained popularity because it has proven to accurately predict the energy use of a building during its design phase, by analyzing all aspects of a structure from weather, solar orientation, and insulation systems, to thermal bridges, heating, cooling, and lighting and appliances. [10]

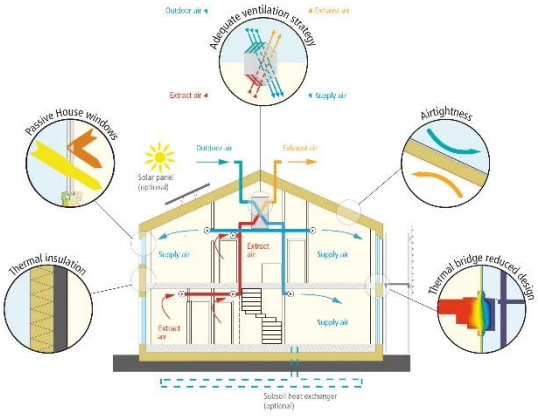

Figure 4 - Passive House

[10] https://www.constructionspecifier.com/energy-efficiency-and-building-with-wood/

3.4 EnergyLab Nordhavn

EnergyLab Nordhavn is a large integrated research and demonstration project, which is contributing to transform the energy system and to efficiently integrate renewable energy. Nordhavn is one of the currently largest developments in Europe. The old harbor area of Copenhagen, Denmark used to house old ware houses, industrial plants and construction facilities, but is currently overgoing a huge transformation into a new residential area of Copenhagen.
By renovating old silos and warehouses, as well as building new and modern residential areas, Nordhavns' goal is to become a new and attractive society of its own. During a period of 50 years it will house 40.000 new residents and 40.000 new jobs. The project is supporting the Copenhagen plan on becoming the first CO2 neutral capital in the world.
The EnergyLab was established in 2015 with a 19 mio. Euro budget from the Danish Energy Technology Development and Demonstration Programme.[11]
The project focuses on a new futuristic energy system that will integrate multiple energy infrastructures involving electricity, thermal, and transportation, as well as providing an intelligent control of both systems and components, which will provide an efficient utilization of renewable energy. [12]
Copenhagen is one of the leading capitals when it comes to supplying sustainable energy from especially wind, and currently around 60% of the energy is sustainable, and this number is steadily growing. This means that using electricity has a sustainable advantaged in Copenhagen, and The EnergyLab is utilizing this. In the Nordhavn area different solutions to store electricity is being experimented with, one of them is the heat storage facility. Here water is heated in a large tank, when there is a surplus of electricity in the grid, which will happen at certain times because the production of electricity can vary a lot. Another storage system uses the same methods, but on a smaller scale as electric radiators in buildings. The radiators can store excess electricity during strong winds or during the nights when the electricity use is low, and then use the stored energy for heating. The last storage solution is a big battery cell in the car parks. These car parks will have intelligent charging stations for electric vehicles, which is currently seeing a huge uprising in the modern society. The charging will be intelligently managed and will interact with the whole energy network in Nordhavn. During periods with a high electricity demand, for example in the evening when people cook dinner, the vehicles wont charge, but will then start charging again, when the electricity demands falls again during night. The vehicles when connected to the energy network, will also work as a battery on its own, so if there is a lack of electricity in the network, the vehicles can supply it with power from their batteries, with blockages so the vehicles always will have power for use when needed.[13]

[11] http://energylabnordhavn.weebly.com/about.html
[12] http://energylabnordhavn.weebly.com/uploads/3/9/5/5/39555879/energylab-brochure_web_10082015.pdf
[13] http://nordhavn.uptime.dk/

4 Recycling

4.1 Fossil materials

Changing materials, lowering energy use, minimizing GHG emissions, and being carbon neutral, is the initial actions to take towards securing the building sector from disrupting the climate, but to finalize the climate crisis, and working towards a sustainable future, it is also necessary to begin recycling.
In 2018 the Earths Overshoot Day fell on August 1st, meaning that by that time this year, we had already spent the resources the earth can renew in a year.[14] Many of these resources are not associated with the building industry, but most of them are. There is currently a growing problem with lack of sand, as well as with the mining industry which is used to gain access to making steel and concrete is threatened by the lessening of resources on earth.
Most commonly used building materials can be recycled. Concrete, metals, glass, bricks, and plastics can all be produced reusing some form of pre-used and recycled material. Adding recycled material to the production of new material, can dramatically lower the energy requirement and the emission of the process. So not only is recycling a necessity for keeping up with building more because of the growth in our population, but it is also a great way of reducing the economical cost and the environmental footprint of non-sustainable materials.

Another trend when it comes to recycling building materials, is the using of the materials provided at a construction site. Every time a new building is constructed, it will be placed at a spot containing something else. It can be an older building which is torn down or a forest with a lot of trees. Also experimenting with other normally wasted materials from different industries, like old plastic jugs, aluminum cans, rubber tires, hay or seaweed, have gained popularity during the climate debate.[15]

[14] https://www.overshootday.org/
[15] https://www.archdaily.com/155549/recyclingbuilding-materials

5 Conclusion

The climate is we know it is changing, and we are first now starting to realize that.
Climate is currently one of the biggest political topics all around the world, because it is a treat against our planet and thereby the human race itself. Climate change involves many difference topics ranging from emission of greenhouse gasses, to lack of materials, and it is therefor a concern to all industries.
The building sector is currently one of the most harmful industries for the climate, but it is about to change. Many big cities are making thorough plans on how to become carbon neutral in the near future, and these plans all involve the building industry.
Use of wood as a building material is gaining more and more popularity because of its unique quality of storing CO2. The development of timber constructions is rapidly growing, and many big architectural firms have already made plans for huge scale projects, which will only become more popular in the future. The term of embodied carbon is the new big focus point, and a building material like concrete is one of the biggest sinners.
Also on the aspect of energy consumption is growing a lot, and many organizations works towards making the building industry CO2 neutral, by focusing on conservation and use of energy in buildings. The project Architecture 2030 is one of the biggest initiatives when it comes to environmental development in the industry.
In the capital of Denmark, Copenhagen, they have invested a lot of money into developing the EnergyLab Nordhavn. The lab is testing new and modern energy solutions, which rely on a future where we have sustainable electrical resources. They work on utilizing intelligent electrical grids, which joins up all energy using factor in a development area, and makes them interact with each other, to always use the energy efficiently.
Generally there are a lot of ways for the construction industry to mitigate its effects on climate change, and by investing time and money into these initiatives, it will be possible to reduce the negative effects, or maybe even improving them through carbon storage and recycling.

References:

Earth Overshoot Day (2018)
https://www.overshootday.org/

Ted Talk by Paul Gilding (2012)
https://www.ted.com/talks/paul_gilding_the_earth_is_full

EnergyLab Nyhavn (2015)
http://energylabnordhavn.weebly.com/
http://energylabnordhavn.weebly.com/uploads/3/9/5/5/39555879/energylab-brochure_web_10082015.pdf
http://nordhavn.uptime.dk/

Construction Executive, by Brent Trenga (2018)
https://constructionexec.com/article/how-to-mitigate-the-construction-industrys-effects-on-climate-change

Architecture 2030 (2018)
https://architecture2030.org/about/

Circular Ecology (2018)
http://www.circularecology.com/embodied-carbon.html/

Construction Specifier, by Nabih Tahan (2014
https://www.constructionspecifier.com/energy-efficiency-and-building-with-wood/

Daily Mail (2018)
https://www.dailymail.co.uk/sciencetech/article-5395371/Worlds-tallest-WOODEN-skyscraper-set-Tokyo-2041.html/

Ach Daily (2017)
https://www.archdaily.com/879625/inside-vancouvers-brock-commons-the-worlds-tallest-timber-structured-building/

Metsä Wood (2017)
https://www.multivu.com/players/uk/8043651-wood-construction-climate-carbon-storage/

Green Spec (2018)
http://www.greenspec.co.uk/building-design/environmental-impacts-of-concrete/

Arch Daily (2011)
https://www.archdaily.com/155549/recyclingbuilding-materials/