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EVALUATION OF CARBON FOOTPRINT AND ENVIRONMENTAL IMPACT IN WOOD BASED PRODUCT

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Abstract

The climate change is becoming an increasingly important problem for life. It is now recognized that greenhouse gas emissions caused by humans have a negative impact on the environment. The total greenhouse gas emission caused directly and indirectly by an individual and an organization is generally called a carbon footprint. Determining an organization's carbon footprint is an important step in reducing emissions generated during its activities. Wood-based products have many advantages in terms of environmental impact compared to their alternatives. Documentation of these advantages and detection of environmental impacts will contribute significantly to the competitiveness of wood materials in future building materials. Moreover, thanks to the detection and control of the emission outputs from the production of wood-based products, it will be possible to realize a more environmentally friendly production. In this study, the concept of carbon footprint in wood-based products and their effects on the environment will be emphasized.

Keywords: Carbon footprint, wood based products, greenhouse gas emissions, CO_2

1. Introduction

Climate change is defined as changes in the state or variability of climate over a long period. Today, when it comes to global climate change, it is meant the changes caused by human activities in addition to the natural variability of the climate throughout the long geological history of the earth. The heat energy held in the earth and the atmosphere is dissipated in the earth by the circulation of the atmosphere and the ocean and is released back into the atmosphere as long wave ground radiation. Clouds and greenhouse gases cool some of this. Then it is released back from the atmosphere. In this way, the earth's surface and the lower atmosphere are heated. This process, which allows the earth to warm more than expected and regulates the heat balance, is called the natural greenhouse effect. However, human activities based on fossil fuels after the industrial revolution disrupted this balance (Türkeş, 2008, MGM, 2015).

Humanity leaves its mark on the nature with the activities it performs while continuing its life. The most important activity of humanity, which causes the earth to be negatively affected because of its traces in nature, is fossil fuel consumption. While humanity wants to sustain its life on earth, it ignores the fact that it is a part of that environment, just as it never thinks about the natural environment. For this reason, it is destroying the environment and consuming especially non-renewable resources irresponsibly. Fossil fuels are the leading non-renewable resources. Excess consumption of fossil fuels used in obtaining energy causes global warming. Global warming brings along changes and degradation in the climate (Hua et al., 2011; Üreden and Özden, 2018; Muthu, 2014).

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Human consumption activities create permanent effects on nature. Carbon footprint is also a way of expressing these long lasting effects. Carbon footprint; It can be defined as the sum of carbon gas released into the atmosphere in different processes for each product purchased or each activity performed. In other words, it is the amount of greenhouse gas emissions resulting from the activities of the organization or individuals, measured in unit carbon dioxide such as transportation, heating, electricity consumption, etc.

Some greenhouse gases are occur naturally (biological activities, volcanic activities, forest fires, etc.). As a result of human activities (consumption of fossil fuels, agriculture, etc.), their formation rates and concentrations in the atmosphere increase even more. These types of greenhouse gases; water vapor, carbon dioxide, ozone, methane and nitrous oxides (Houghton at al., 2001, Franchetti and Apul, 2012).

The world population increasing uncontrollably and the growing industrialization activities cause an increase for gas released into the world atmosphere. As a result of statistical data and scientific studies, issues of global warming and climate change occupy an important place in the world agenda and studies on this subject are increasing day by day. With the Kyoto Protocol in 1997, it was aimed to reduce carbon dioxide and gases that cause greenhouse effect (Mgbemene at al., 2016). The greenhouse gases that are formed only because of human activities; such as chloro fluoro carbons (CFCs), hydrochloro fluoro carbons (HCFCs), hydro fluoro carbons (HFCs) and sulfur hexafluoride (SF_6) (Gillenwater at al. 2002).

Carbon footprint is divided into two categories as primary and secondary carbon footprint. The primary carbon footprint refers to carbon dioxide emissions resulting from the acquisition of energy used in housing and transportation. The secondary carbon footprint refers to the emissions caused by each element that comes into our lives throughout the life cycle. It is possible to say that the secondary carbon footprint contains the primary carbon footprint. It is ensured that food or products imported from abroad are transported by air, land, sea and rail until they reach the consumer. Considering that the wastes caused by the spoilage or consumption of these products are taken to the storage and disposal areas, the secondary carbon footprint is very important. A person's secondary carbon footprint is known to equal 54% of the total carbon footprint (IPCC, 2014, Argun at al., 2019).

CO_2 emissions reached a record 35.9 GtCO2 in 2014. These high values have forced governments to implement strategies to reduce CO_2 emissions. The European Union has set a long-term goal to reduce greenhouse gas emissions by 80-95 % by 2050 compared to 1990 levels (Debek, 2016). Emissions from fossil fuel and industry (FF&I) are expected to reach 36.81 billion tonnes of CO_2 ($GtCO_2$) in 2019, according to the latest estimates from the Global Carbon Project (GCP). Overall, human-induced CO_2 emissions, including those from the fossil fuel industry, are expected to increase 1.3 % in 2019. This is due to a 0.29 GtCO2 (5 %) increase in land use emissions, including deforestation. This situation represents the fastest increase value in the last five years. Land use represents only about 14 % of total emissions up to 2019, while contributing more than half of the emissions increase in 2019. The historical annual CO_2 emissions for the first six countries and confederations are given in figure 1 (EDGAR, 2019).

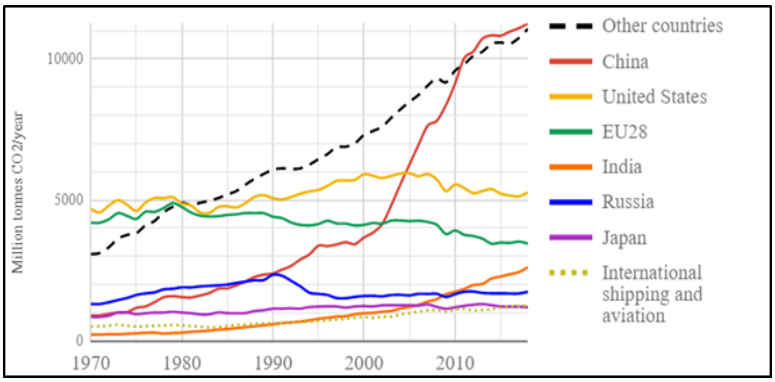

Figure 1: List of countries by carbon dioxide emissions 1970-2018

Due to the increasing emissions of various pollutants, rapidly increasing energy demands and possible global warming, renewable and environmentally friendly building materials are gaining importance. In addition, buildings consume a lot of material and energy during their lifetime and also generate waste. For this reason, the use of bio products (mainly wood) and clean energy as source (such as wind power, solar power) material for construction has become important. Wood and forest-based bio products and their structures in built homes are ideal for storing CO_2 for long periods, decades and even centuries. Also, wood can be reused after its life cycle or eventually used for energy recovery (Kunič, 2007; Košir at al., 2010).

In this study, the effects of wood and wood-based products on carbon dioxide emissions will be examined. In addition, carbon emissions and environmental impacts with equivalent materials used in the building sector will be compared.

In this study, radial stick sawing optimization from logs was aimed. Otherwise quantity and quality (tangential or radial) yield change were evaluated with different sawing pattern.

2. Environmental Effects on Wood Based Products

2.1. CO_2 Emission and Environmental Impacts of Forests

Recently, the role of the forest has been neglected in increasing environmental and health research to counter air pollution and environmental degradation. The conversion of CO_2 in the atmosphere to oxygen through the photosynthesis process helps to reduce the amount of emissions with the planting of new forests (Palmer, 2012). It has been stated that stopping deforestation in the world can reduce 7 billion CO_2 dioxide emissions annually and 42 % of the total emission reduction can be achieved by reforestation of all grazing lands in forest areas. Additionally, forests are carbon sinks, so afforestation and forest restoration (ARR) activities can effectively remove carbon emissions from the atmosphere (Minnemeyer, 2017; Ahmad, 2017).

It has been determined that significant health problems have increased in countries with rapid increase in greenhouse gas emissions (especially CO_2) (Chaabouni, 2016). The impact of air pollution on people also lead to decrease in labor productivity. It has been suggested that health problems can also be minimized if air pollution can be controlled by planting more forests through CO_2 emissions. The CO_2 levels in the atmosphere can be lowered, which can help minimize health problems when afforestation and forest investments are encouraged (Yazdi and Khanalizadeh, 2017).

World forests store enormous amounts of carbon. They only store 283 gigatons (Gt) of carbon in their biomass. In addition, it is estimated that the carbon stored in dried wood, garbage and soil is more than the carbon in the atmosphere (IPCC, 2007). Total annual carbon turnover among global forests ranges from 55 to 85 Gt per year (Zhang, 2009). The amount of atmospheric carbon converted into forest biomass is estimated at 25 to 30 Gt per year (Sabine at al., 2004).

Forests around the world have significant effects on CO_2 levels in the atmosphere. Forest area losses, mostly due to deforestation in tropical regions, cause 0.5 to 2.7 Gt of carbon emissions into the atmosphere each year. The amounts extracted from industrial roundwood are relatively small compared to the amounts of carbon converted into forest biomass annually (Miner, 2009).

Young, vigorous growing trees absorb higher rates of CO_2 than mature trees. Trees grow as defined as the sigmoid curve. While the growth rate is the highest in the early and middle years, it decreases as it matures. This decline ranges from 60 to 150 years old, depending on the species and environmental factors. When a tree is harvested, about half of the carbon remains in the tree. When forest soil degrades during harvest, some carbon is released and carbon releases as the remaining roots, branches and leaves rot. However, once the harvested area is revitalized by planting seedlings, the forest once again begins to absorb and store carbon. Thanks to photosynthesis, trees in the forest hold 0.9 t CO_2 per cubic meter. The total carbon stored in European forests is estimated at to be 9,552 million tons C per year. Managed forests have a higher carbon sequestration effect than forests left in their natural state. Tree planting is the easiest and most effective method to reduce carbon emissions according to these data (SFI, 2003; BSL Council, 2009).

2.2. CO_2 Emissions in Wood Based Products

Forests play an important role in reducing carbon emissions in terms of separating carbon from the atmosphere and storing them in their bodies (Kayo et al., 2015). Harvested forest products have the ability to store carbon emissions in the atmosphere for a certain period. In this way, wood-based materials gain an important environmentally friendly alternative, especially for concrete and steel as building materials, petroleum-derived products and coal fuels. In recent years, the use of wood-based building materials has been encouraged to reduce carbon emissions (Lun et al., 2016). According to "Architecture 2030" established within the scope of combating climate change, buildings are a major problem in terms of carbon emissions. The construction industry consumes almost half of all energy produced in the USA and 75 percent of the electricity produced is used to power buildings. In 2010, the construction industry was responsible for almost half of the USA CO_2 emissions. However, 75% of the buildings are planned to be renewed until 2035 in order to reduce the carbon footprint (Rethink, 2015). On the other hand, some environmental problems caused by harvesting forest resources and carbon emissions may occur due to

material consumption. In this respect, studies focus on the environmental impacts of harvested forest products on energy consumption and carbon emissions (Eshun et al., 2010; Wilson, 2010; Heath et al., 2010). Figure 2 shows a carbon cycle of forest products (Rethink, 2005).

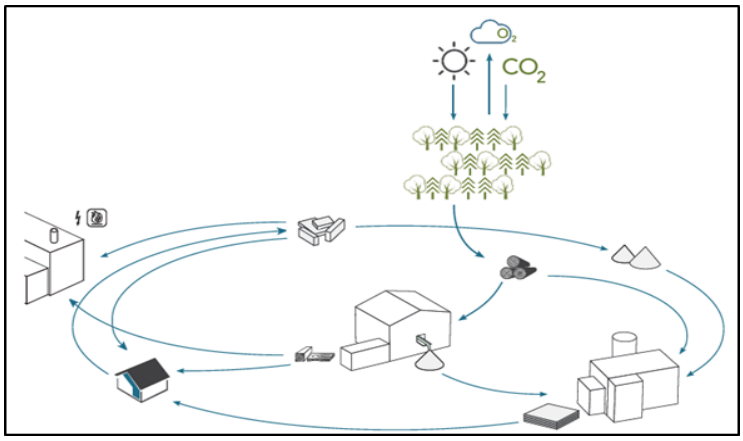

Figure 2: Sustainable forestry carbon cycle

Wood-based products have many features that will give priority to selection when it comes to combating climate change. About 50% of the carbon absorbed by growing trees is stored in products such as timber and furniture. Increased use of wood-based products also causes a decrease in fossil fuel consumption. Wood is a renewable resource produced by natural energy from the sun. Life cycle assessment (LCA) studies show that it requires much less energy to manufacture, transport, build and maintain than materials such as steel and concrete. Wood-based products can be easily applied and reused in buildings and continue to store carbon throughout their lifecycle (BSL Council, 2009).

It is very important to follow the life cycle in the cutting and production of wood-based products. Life cycle assessment determines the environmental impacts of processes, services or products, through production, usage, and disposal. Due to the ever-changing regulations, it has become important to determine in advance, where the material comes from, how it is used or how it is transformed into a product and its environmental impacts (Hauschild, 2018). An example of environmental performance for 1 m^3 of softwood dry timber is given in Table 1 (Puettmann et al., 2013).

Table 1: Environmental performance of 1 m^3 dry softwood lumber

Impact category	**Unit**	**Total**	**Forestry Operations**	**Wood Production**
Global warming potential (GWP)	kg CO2 equiv	92.89	14.52	78.38
Acidification Potential	H+ moles equiv	49.90	11.34	38.56
Eutrophication Potential	kg N equiv	0.0371	0.0120	0.0251
Ozone depletion Potential	kg CFC-11 equiv	0.0000	0.0000	0.0000
Smog Potential	kg O3 equiv	21.66	6.37	15.29
Total Primary Energy Consumption	**Unit**	**Total**	**Forestry Operations**	**Wood Production**
Non-renewable fossil	MJ	1342.09	212.57	1130.54
Non-renewable nuclear	MJ	182.35	2.10	180.25
Renewable (solar, wind, hydroelectric, and geothermal)	MJ	25.31	0.23	25.08
Renewable, biomass	MJ	2586.16	0.00	2586.16
Material resources consumption (Non-fuel resources)	**Unit**	**Total**	**Forestry Operations**	**Wood Production**
Non-renewable materials	kg	0.0853	0.00	0.0853
Renewable materials	kg	403.17	0.00	403.17
Fresh water	L	179.38	0.00	179.38
Waste generated	**Unit**	**Total**	**Forestry Operations**	**Wood Production**
Solid waste	kg	13.22	0.22	13.00

Life cycle information is needed to guide material selection decisions by building designers and earn credit for green certification of buildings under standards such as the Leadership in Energy and Environmental Design (LEED), the National Green Building Standard (NGBS), the International Green Construction Code (IGCC) and Building Standards Code (CalGreen). Wood product manufacturers take care to publish Environmental Product Declarations (EPDs) containing life cycle environmental impact data for their products (Atanda et al., 2019).

The carbon storage effect of wood products plays an important role in reducing greenhouse gases with an estimated European wood product stock of around 60 million tons. Wood products store carbon instead of carbon absorption, as they cannot hold CO_2 in the atmosphere. However, they extend the time that CO_2 held by forests is kept out of the atmosphere. In addition, the recyclability of wood-based products reduces the carbon footprint. According to the latest researches, the usage period of wood-based products varies from 2 months (newspapers) to 75 years (building elements). The longer this period is the more beneficial it is for the environment. The amount of CO_2 stored will increase and energy savings will be achieved with the use of wood-based materials (Beyer at al., 2006).

The cellular structure of wood with many small air pockets increases its thermal efficiency, providing 400 times better thermal insulation than steel and 10 times better than concrete. Steel and concrete structures need more insulation to achieve the same thermal performance as wood materials. In addition, longer-lasting structures are obtained with the use of wood-based materials in buildings. The use of wood as a building material is becoming advantageous because of less energy is required for their changes (Zhen and Zhang, 2018). The possibility of using agricultural wastes and used wood products in reproduction also provides an environmental advantage.

2.3. The Effect of Wood as Building Materials on CO_2 Emission

Energy used in construction, including the manufacture and construction of buildings, is significantly lower for wood-based products and systems than for other building materials (Gustavsson and Sathre, 2011). The wood based composites have a negative effect in terms of CO_2 emission when used in building materials. It seems that wood composites do not emit carbon, but also have carbon storage properties. Figure 3 shows the CO_2 emissions of some wood-based building materials and their comparison with the common construction materials.

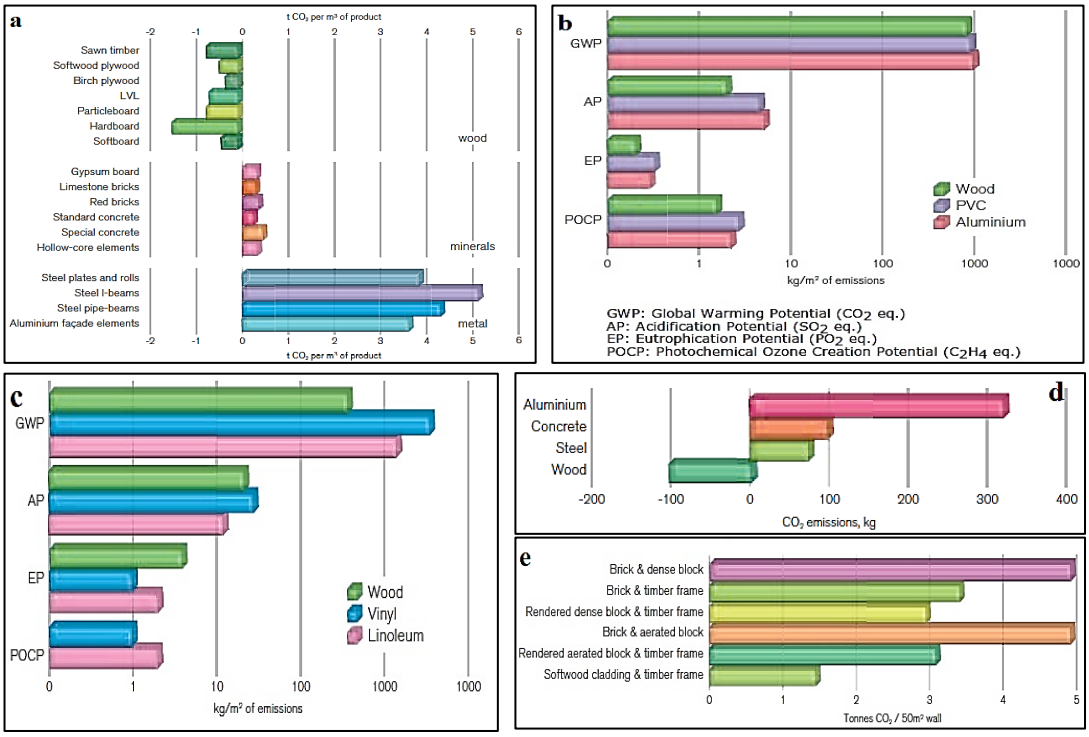

Figure 3: CO_2 emission of building materials (a: building materials, b: window elements, c: flooring materials, d: beams elements, e: wall elements

It is seen in the figures that steel and aluminium materials emit very high CO_2 emissions. When the materials used in window production are examined, it is seen that the use of wood-based materials causes

less carbon emission than PVC and aluminium materials. As flooring material, wood-based materials show low polluting effect compared to vinyl and linoleum materials. When using wood as beams material, it realizes very low carbon emission compared to aluminium materials thanks to its carbon storage feature. In addition, when used with other construction materials as wall material, timber reduces CO_2 emission significantly.

3. Conclusion

Trees capture CO_2 in the atmosphere and store it as carbon. Solid wood and wood-based products used in buildings are also a carbon absorber. The use of wood-based products instead of other construction materials will both reduce the use of high CO_2-containing materials and carbon dioxide emissions thanks to their carbon retention feature. The easiest way to reduce carbon emission from materials is to increase the use of wood materials in buildings. The use of wood in buildings is a very economical method of reducing CO_2 emission. In addition, the use of wood in buildings is a very economical method of reducing CO2 emission in terms of cost. The carbon absorbing effect of forests and carbon sink of wood based product make wood a very advantageous material today where the amount of carbon emission is constantly increasing. Especially, LCA of wood-based composites used in buildings will be important in terms of increasing the use of wood materials.

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