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GREEN ECONOMY AND CONSTRUCTION

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Abstract. A green economy is an economy that aims at reducing environmental risks and resource scarcity, and that aims for sustainable development without degrading the environment. Construction industry is one of the most important branches of the global economy and it is one of the most energy-intensive industrial sectors worldwide. There are many emerging technologies and latest energy-efficient building materials that can reduce its environmental burden. Sustainably-sourced wood products help reduce the impacts of climate change.

Key words: green economy, construction, eco-risks, wood structures, sustainable development, environment, skyscrapers.

Introductions. *A green economy* is an economy that aims at reducing environmental risks and resource scarcity, and that aims for sustainable development without degrading the environment. It's an economy that is low-carbon, resource efficient and socially inclusive.

Green economics is defined as any theory of economics by which an economy is considered to be component of the ecosystem in which it resides. The environmental sector has the dual benefit of mitigating environmental challenges as well as helping economic growth. At the same time, such a model of economy reduces eco-risks – the growth of water scarcity, the effects of climate change.

The economy includes many branches. Construction industry is one of the most important branches of the global economy. The buildings sector – a huge engine of

the global economy – employs as much as 12 % of the workforce in many countries. However, at the same time, the construction industry is one of the most energy-intensive industrial sectors worldwide.

Construction represent 6 % of final energy demand globally and almost 11 % of global energy- and process-related emissions [1]. In addition, the manufacture of steel, concrete and brick accounts for about 16 % of global fossil-fuel consumption – and up to 30 % when transport and assembly of the materials is considered [2].

Materials and methods. There are many emerging technologies and latest energy-efficient building materials that can improve all steps of the construction process and reduce its environmental burden.

Results and discussion. Despite centuries of technological advances and the invention of many synthetic materials, wood is still a popular choice for building projects. Importantly for construction, wood have unique technological properties. Each wooden detail is a unique piece of nature, showing its individual beauty. Wood is good for our health. Research is showing that incorporating wood and natural materials into our buildings – sometimes called biophilic design – can reduce stress and contribute to good mental health [3].

With its distinct properties, wood's versatility is vast. The new possibilities in timber architecture are capturing the imaginations of today's design and construction professionals. Excellent technological characteristics of wood made it possible to start using it even for the construction of skyscrapers in Europe, America, Japan.

Durable and strong, wood is a resilient material that can provide decades, even centuries, of service. Today's modern timber buildings are built to perform in the event of fire, strong winds and the wear and tear of time. From light-frame and mass timber to new hybrid designs, wood construction is meeting and exceeding rigorous performance standards. Wood structures can withstand earthquakes. In the aftermath of an unfortunate disaster, wood is a versatile and resilient building material well-suited to repairing and rebuilding structures. Wood has a lower thermal conductivity compared to concrete, steel-frame, and masonry construction and is well-suited to energy-efficient design. Wood offers distinctive value from its aesthetic warmth and

health benefits to its versatility and smaller carbon footprint when compared with steel and concrete [3].

Mjøstårnet (Mjösa Tower) is the world's tallest wooden building. It opened in March 2019 in Brumunddal, Norway. The tower provides homes, five office stories, a four-story hotel with 72 rooms and a public viewing terrace on both the 18th and 19th floor. The building is a modern mixed-use tower, with facilities that the residents, locals and visitors can exploit. It is an 18-floor building. The ground floor is public, with lobby, reception and restaurant. The new building is complemented by a public swimming pool with two 25 meters length pools in the low-rise building adjacent to the tower. *Mjøstårnet* stretches up to 85,4 metres in height [4].

The Mjösa Tower symbolizes environmental trends in construction, and it is proof that tall buildings can be built using local resources, local suppliers and sustainable wood products. All key structural components of *Mjøstårnet* are composed of engineered timber, utilizing glue-laminated timber for beams and columns and cross-laminated timber for the core walls containing the building's elevator and stairway shafts. The tower is made from about 3 500 m^3 of timber or about 14 000 threes [5].

The glue-laminated columns were fabricated with pre-drilled holes and assembled onsite into vertical trusses of up to five floors in height, providing stability to horizontal and vertical forces. Floor slabs for levels 11 and below are also crafted from timber beams, topped with laminated veneer lumber and a thin 50-millimeter layer of concrete for acoustical and vibrational performance, while levels 12 and above have floor slabs fully composed of concrete to increase weight and achieve the desired dynamic behavior in periods of strong winds [6].

Mjøstårnet has been awarded a 2021 Aw. of Excellence Winner by *Council on Tall Buildings & Urb. Habitat*. The award is given for the structural engineering.

HoHo (Holz-Hochhäuser) Wien is a modern wooden tower located in the Austrian capital. With a height of 84 meters and a total of 24 above-ground floors, the building is the highest timber high-rise in the EU and the second tallest wooden high-rise building in the world after *Mjøstårnet*. The HoHo Wien accommodates a host of

different uses, from hotel, restaurant, fitness/beauty/wellness facilities to offices and conference rooms as well as 24 apartments [7]. It opened in 2019.

The “simple” structural system consists of four pre-fabricated, serial constructive elements (studs, joists, ceiling and facade elements). Its special feature is the drastically lowered usage of steel fasteners and a high degree of prefabrication, made possible by employment of newly developed timber-concrete junctions. The walls and beams are 100 % made of Austrian spruce wood. The ceiling is realized as a timber concrete composite ceiling. From the third floor up, the building features fiber cement boards completely made of natural resources for its curtain wall façade [7]. The wooden supports, in turn, form a common mounting element with the prefabricated outer wall modules made of solid wood, as well as the isolated exterior paneling in “earthy tones”.

The tower shows the advantages of the wood hybrid system over pure timber construction. Reinforcing concrete cores support vertical circulation and supply. The timber construction is docked on to provide the volumes for actual building use. The combination of conceptual ideas makes sustainability possible: wood is easy on the environment. Direct advantages of *HoHo Wien* [8; 9]: • hybrid construction allows the use of flexible walls in all building parts (economy), no rigid walls are necessary; • wood is visible part inside (atmosphere), no cover required for fire protection reasons; • a high degree of prefabrication saves time on the construction site; • timber from Austria’s sustainably managed forests.

The new *Brock Commons* student residence at the University of British Columbia in Vancouver – currently one of the tallest mass timber building in the world, which opened in July 2017. The building stands 53 meters tall [10].

The term “mass timber” or “mass wood” covers an array of approaches, usually referring to a structural system combining engineered wood columns and floor slabs [11]. *Tallwood House* presenting a pragmatic argument for how mass wood can be used for all types of buildings, from the audacious to the everyday.

Brock Commons consists of a 17-storey mass timber hybrid superstructure atop a one-storey concrete podium with two full-height concrete cores that house

elevators, stairs and service conduits. The roof is made of prefabricated sections of steel beams and metal decking [12].

Seventeen storeys of *Brock Commons* are built with a hybrid structure that includes prefabricated glulam columns and CLT floor slabs. The structure was erected at a rate of two floors per week. A CLT floor slab is lowered into place and fastened to the glulam columns; the hybrid structure is primarily wood but also includes a concrete ground floor and core; even though mass timber has inherent fire resistance, the glulam and CLT were encapsulated with drywall to facilitate approvals, and a concrete floor topping was added for acoustic protection [11].

Tallwood House is home to students who enjoy its central location, spectacular views and unique building features [13]. It accommodates 404 upper-year and graduate students in a total of 305 units (272 studios and 33 four-bedroom quads) [11]. Social and study spaces are located on the ground floor for student residents and commuter students, as well as a lounge on the 18th floor where the mass timber structure is left exposed [12].

The innovative mass timber-hybrid structural system developed for *Brock Commons Tallwood House* is economically viable, repeatable and adaptable to other building types and uses.

Today, wooden high-rises are designed and built in many countries around the world. The most ambitious project is the *W350*.

Japanese timber company *Sumitomo Forestry* has plans for the world's tallest wooden building in Tokyo, a 350-metre skyscraper. Named *W350*, the ambitious tower will be almost four times higher than the world’s current tallest timber building – the 18-storey *Mjøstårnet*.

Sumitomo Forestry is proposing the 70-storey hybrid timber skyscraper to mark the company's 350th anniversary in 2041 (hence the tower’s name and symbolic height). The 350-metre tower designed by Sumitomo’s *Tsukuba Research Laboratory* in collaboration with practice *Nikken Sekkei*, will also Japan’s tallest building [14].

Timber is expected to make up 90 % of the hybrid structure, while the steel component will be reduced to only 10 % of the material used. Infact, will be install a

tubular steel frame for controlling vibrations. The facade of the *W350* will feature balconies all around it. Each floor will have the view on all four sides of the building and will be enriched with plants that will filter the sunlight. It is thanks to the balconies that the greenery can grow and cover the whole building, transforming itself into a vertical forest in the true meaning of the phrase. Inside the structure of the skyscraper will be a hybrid between wood and steel and will have to take into account the anti-seismic parameters imposed on Japanese construction for earthquakes.

Japan launched a law in 2010 that requires construction companies to use organic material for public buildings over three stories high. The aim of the *W350 Project* is to create environmentally-friendly and timber-utilizing cities that become forests through increased use of wooden architecture for high-rise buildings. This concept plan has been prepared primarily at *Tsukuba Research Institute, Sumitomo Forestry's research and development facility*. The institute is expanding possibilities for wooden buildings as a roadmap for future technology such as the development of building methods, environmentally-friendly technologies, and trees that become resources and building materials [14].

The wooden skyscraper *W350*, in addition to the height, will also record a record for costs: 600 billion yen (about *€* 4,5 billion) is the figure expected, twice as much as a building of equal size built with techniques and traditional materials (cement, steel and glass) [15]. However, the company is working to reduce these costs by developing new technology.

Construction companies hope that technological advances in timber construction and further research will help lower costs. The construction cost of *Brock Commons Tallwood House* was $2 476 per square meter. According to *Metras* [13], in 2017 the construction cost for a comparable scale of building with a concrete structure would be $2 260-2 315 per square meter.

This is well in alignment with current market costs for this building type. *Metras* attributes the additional cost relative to concrete construction to the "innovation premium", and believes it would now be possible to build a similar tall wood building for less than *Brock Commons*, given the knowledge that has been

gleaned from this project [13].

The negative impacts of climate change are a threat to the world's forests, oceans, waterways and vital ecosystems. Closely related to climate change is the earth's carbon cycle. The carbon cycle refers to the continuous transfer of carbon from land and water to the atmosphere and living things. Forests are a vital part of this carbon cycle, both storing and releasing it in a dynamic process of growth, decay and renewal [16].

The design concept of Mjøstårnet was inspired by the Paris Agreement to combat climate change and began as an idea to reduce carbon dioxide emissions while sustainably sourcing construction materials locally [6].

Sustainably-sourced wood products help reduce the impacts of climate change. Their carbon-locking capability makes them an eco-friendlier choice when compared with non-renewable materials with high emissions such as steel or concrete. It is one of the few structural building materials we can grow using the sun while absorbing harmful carbon dioxide emissions from our atmosphere.

Cement, on the other hand, is the source of about eight percent of the world's CO_2 emissions. Constructing more and taller structures with wood, and reducing our use of high-emission materials, such as steel and concrete, is a practical way to reduce the embodied carbon of our buildings [16].

According to a 2013 article in the *Journal of Sustainable Forestry*, substituting wood for current construction materials could save 14 to 31 percent of global carbon dioxide emissions and 12 to 19 % of global fossil fuel consumption by using 34 to 100 percent of the world's sustainable wood growth [17].

The city, which creates about 600 000 square meters of new buildings each year, has the opportunity to store the equivalent of 30 000-200 000 tons of CO_2 emissions per year if all new buildings were made of wood. In addition, an abundance of concrete has worsened urban flooding, and made cities hotter, environmentalists say. In contrast, wood requires fewer fossil fuels to transport and assemble, and also effectively stores large amounts of carbon – trapped as the trees grew – for years, helping curb emissions [2].

The estimated avoided and sequestered greenhouse gases from the wood used in the building of *Brock Commons Tallwood House* is equivalent to removing 511 cars off the road for a year [12]. The total carbon dioxide equivalent avoided by using wood products over other materials in the building is more than 2 432 metric tons: the building stores 1 753 metric tons of carbon dioxide and avoids production of 679 metric tons of greenhouse gas emissions [10].

In Austria 30 million cubic meters of wood grow every year, of which 26 million cubic meters are used. The remaining 4 million cubic meters remain in the forest and steadily increase the wood supply. This means that 1 m^3 of wood grows again every second. The entire *HoHo Vienna* grew back in our local forests in just one hour and 17 minutes. The timber construction saves around 2 800 tons of CO_2 equivalents compared to a reinforced concrete construction. This corresponds to approx. 20 million car kilometers or 1 300 years of daily 40 kilometer car journeys [18]. Construction method saves some 300 000 megawatt hours of primary energy. This is approximately the amount of energy needed to heat a tenement with 32 apartments over a period of 1 100 years [9].

According to the preliminary estimates, the construction of the *W350* will take 185 000 cubic meters of wood [15]. Each cubic meter of timber used in construction stores a carbon equivalent of over 900 kilograms of CO_2 emissions [17]. So the fabric of the *W350* tower will store over 166 500 tons of carbon dioxide. This is a huge amount of CO_2.

Modern high-rise buildings in Ukraine are built with reinforced concrete frameworks and brick walls. But Ukrainian architects are designing futuristic wooden skyscrapers.

Guess Line Architects, an innovative architectural bureau in Lviv, recently won the prestigious international competition *eVolo Skyscraper Competition*, an annual architectural contest to design futuristic skyscrapers. *The Guess Line* team designed a living skyscraper for New York entirely built from a pre-programmed tree. The building will function in the middle of a grey megalopolis and solve a number of important environmental and urban issues [19].

A skyscraper tree is a separate living organism with its own root system, irrigation, care mechanisms, and features of development focused on its adaptation to use in architecture. It is a group of unique fast-growing and tall hardwood deciduous trees, which are planted in groups in specially prepared soil and in the process of their growth, form a unique architectural volume.

The plant absorbs water and nutrients. At the same time, the growth of the trunk circumference will gradually increase the strength of the wood structure and improve its self-supporting properties. During development, the branches of nearby trees will be grafted at different levels and form a network structure – a kind of conjugation that will strengthen the structure and continue its growth.

The branches of hybrid *trees of the future* will form the structure of a living skyscraper, form even, separate biomorphic structures, and feed on soil, water, and sun resources, forming an ecosystem that is essential for large agglomerations. As it grows, a living skyscraper can connect with nearby buildings and form green overhanging communications over a block. The functional purpose of skyscrapers can vary depending on the need [19].

Conclusions. A green economy is low-carbon, resource efficient and socially inclusive. Construction industry is one of the most important branches and it is one of the most energy-intensive industrial sectors. There are many emerging technologies and latest energy-efficient building materials that can improve all steps of the construction process and reduce its environmental burden. Wood building materials have many environmental advantages. The manufacture of wood products requires less fuel than alternative building materials such as concrete, metals, or bricks.

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