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SUSTAINABLE INFRASTRUCTURE: BUILDINGS AND ENERGY – MODULAR
CONSTRUCTION

CENG 404: Sustainable Cities
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Abstract

Sustainability is becoming more and more relevant, especially in policy making, as our society struggles to combat the effects of global climate change. At a city level, sustainability is key in the construction and operation of all infrastructure, such as transportation, buildings, water resources, etc. Exemplified in their Delta Works Program, the Dutch, with a mindset centered upon solidarity and flexibility, have invested heavily into the environmental, societal, and economical aspects of sustainability, and strive to be at the forefront of sustainable innovations and adaptations. Regarding the area of action of buildings and energy, the Netherlands ambitiously enacted policy which mandates that, as of January 1, 2021, all new construction must be nearly energy-neutral buildings. One particular sustainable strategy the Dutch are utilizing to meet these requirements, which Spokane is poised to potentially adapt, is the implementation of modular construction.

Introduction: Overview of Sustainable Cities

A sustainable city is one which has thoughtfully organized infrastructure, strives to utilize renewable energies, and is actively adapting to anticipate and address future issues. Sustainable cities focus not only on the environment, but also take into account economic and social considerations. This is key, as sustainability is dependent upon all three of these pillars.

In *Sustainability: An Environmental Science Perspective*, John C. Ayers talks about the importance of balancing the three pillars and what each pillar entails. Environmentally sustainable cities can accommodate a variety of modes of transportation such as walking, biking, and public transit. These modes of transportation have low environmental impacts and reduce the carbon emissions that would be coming from cars. Some of the ways cities promote these modes of transportation are by having a system of designated walking and bike paths, implementing public transportation systems that are affordable and reliable, and charging personal motor vehicles a fee to access certain areas of the city to discourage people from driving. Socially sustainable cities are ones which promote interactions and the building of relationships between individuals and foster a sense of solidarity. An economically sustainable city maintains “a steady-state economy that equitably provides the resources required for all citizens to enjoy healthy, productive lives” (Ayers, 2017). These communities have a relatively stable population and can maintain a store of goods and services which exceeds the demand. A sustainable city which combines the environmental, social, and economical components can be denoted by minimizing their environmental impact and maintaining a high human development index¹ (Ayers, 2017).

Sustainability at the city level (as opposed to state and national level) is important as sustainability starts with everyday citizens who largely live in cities. Bottom-up policies afford citizens much more control, say, or leverage on policies, and are also often easier to implement as they are on a smaller scale.

¹ Human development index: A measure of human well-being developed by the United Nations Development Program which considers progress made in education, life expectancy, and standard of living based upon gross domestic product (Ayers, 2017).

Civil engineers play a pivotal role in promoting a more environmentally, socially, and economically sustainable city. In a broad sense, civil engineers are responsible for the design and construction of a city's infrastructure. This includes but is not limited to the design of transportation systems, sewage systems, water distribution networks, and buildings. It is the engineer's responsibility to keep sustainability at the forefront of their minds in their designs, ensuring that they consider the social, economic, and environmental aspects of their projects. Economically, they must ensure that their designs spur economic growth, are relatively affordable, and able to last for as long as possible. Socially, the infrastructure systems should encourage interactions between individuals, promote solidarity, and further the well-being of citizens. This could be seen in the design of transportation networks as engineers should consider providing pedestrians and cyclists with protected and/or separate paths for safety, or the implementation of parks, trees, and water features to increase citizen's connection with nature. Environmentally, engineers must actively pursue energy efficient solutions. This includes the use of sustainable building materials (such as cross-laminated timber² (CLT)), construction methods (such as modular construction), and design features (such as rain catchment systems, solar panel optimization, green roofs, and passive heating systems³). Additionally, the design of transportation systems should prioritize public transportation which can lessen the use of personal vehicles and reduce greenhouse gas emissions. It is extremely difficult if not impossible for cities to be sustainable without sustainably designed infrastructure.

The remainder of this report addresses (1) the relevance of the buildings and energy area of action as it pertains to sustainability, and (2) the potential benefits of integrating the sustainable strategy of modular construction to support sustainability. Spokane can learn a thing or two from the Dutch who have done an exceptional job at adopting a mindset which has allowed them to remain at the forefront of sustainable innovations.

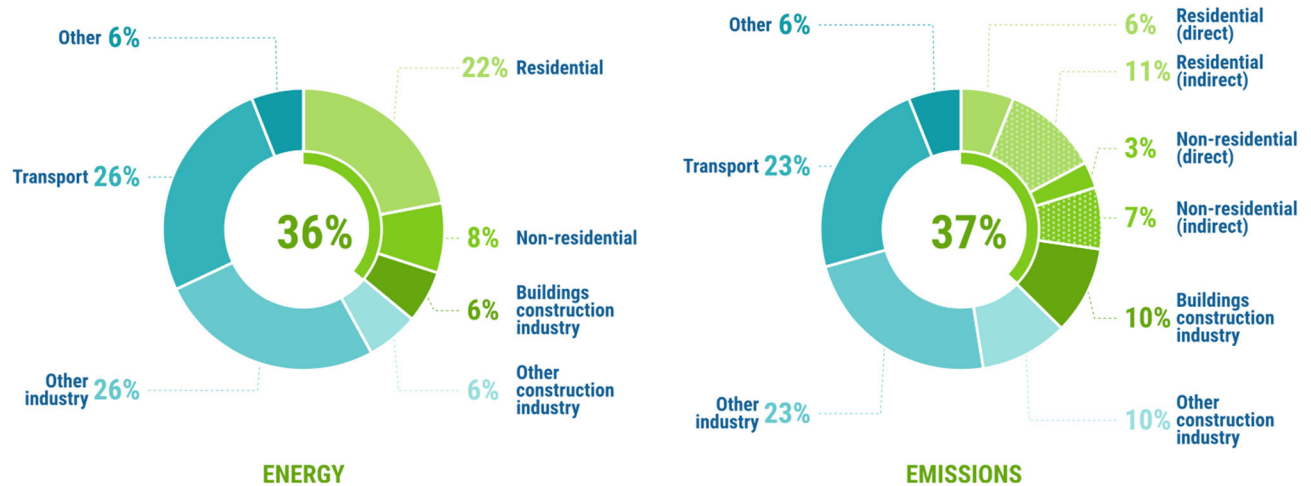
² Cross-laminated timber: A prefabricated building system that consists of panels of manufactured wood which are comprised of orthogonally stacked layers of wood that are glued together.

³ Passive heating system: Optimization of windows, insulation, heat flow, and other design elements to maximize the use of the energy from the sun in the heating of a building.

Area of Action: Buildings and Energy

The City of Spokane notes in their Sustainability Action Plan (SAP) that their approach for sustainability planning is one that “Balances the need to reduce greenhouse gas emissions with our commitment to create good jobs, a healthy environment and an equitable community” (Spokane Sustainability Action Committee, 2021). This wholistic approach is reflected in the objectives of each ‘area of action’ outlined in the SAP. For buildings and energy, the City of Spokane’s main objectives are to reduce greenhouse gas (GHG) emissions, improve air and water quality, and provide energy savings to businesses owners (Spokane Sustainability Action Committee, 2021). Discussed in more detail below, buildings and energy are areas that have significant impact on sustainability as they account for a significant amount of energy usage and carbon dioxide (CO₂) related emissions.

In a sustainable city, the design and construction of buildings play a pivotal role in promoting economic prosperity, protecting the natural environment, and ensuring the health and well-being of the public. Well-designed buildings grounded in sustainability minimize their carbon emission impact in both the construction and operation phases, are available and affordable for all individuals who need them, complement the surrounding natural environment, and address the needs of the community. The United Nation’s (UN) 2021 Global Status Report denotes that the construction and use of buildings accounts for 36% of the world’s energy consumption and 37% of the world’s CO₂ related emissions. This full breakdown can be seen in Figure 1 below



Note: "Buildings construction industry" is the portion (estimated) of overall industry devoted to manufacturing building construction materials such as steel, cement and glass. Indirect emissions are emissions from power generation for electricity and commercial heat.
Source: IEA 2021a. All rights reserved. Adapted from "Tracking Clean Energy Progress"

Figure 1. Buildings and constructions share of global final energy-related CO₂ emissions, 2020. (Source: UN, 2021)

As seen in Figure 1, for the CO₂ related emissions only 18% of the 37% is related to the operation of buildings while 19% is related to the construction of buildings and other structures. This portion that comes from the construction of buildings is due to the construction method and the materials used. Spokane's SAP has multiple strategies that is directed towards mitigating the operational emissions by making sure "new structures [are] as efficient as possible" and by "upgrading existing buildings for high efficiency." These efforts are in part to meet the Washington Clean Buildings Act Energy Use Intensity targets. It should be noted that these targets mainly focus on the operation of buildings and do not account for the construction of buildings.

As is the case with most countries around the world, the Netherlands and the United States are attempting to reduce, and eventually eliminate, their dependency on fossil fuels. Spokane's SAP outlines that Spokane will contribute to this effort by promoting the "Local production and sourcing or renewable energy." The Dutch have already begun to implement some of the strategies that Spokane hopes to implement such as utilizing energy at wastewater treatment

plants, incentivizing the implementation of solar panels, and optimizing the efficiency of buildings.

The Dutch standards on energy efficiency on buildings entails that “For all new construction, both residential and non-residential, applications for the environmental permit must meet the requirements for nearly energy-neutral buildings (NZEB) from 1 January 2021” (NEA, 2021). NZEB is defined by a maximum amount of energy required in kilowatt hour (kWh) per square meter, a maximum fossil energy consumption in kWh per square meter, and a minimum amount of generated renewable energy in relation to the total amount of energy used (NEA, 2022). Due to their dependency on natural gas, the Netherlands were forced to go to such measures as supplies of natural gas become less reliable and more difficult to obtain. Additionally, the Netherlands was also looking at ways to renovate older existing structures to make them more efficient. The Dutch have been carefully considering their methods of construction and the use of more sustainable materials. They have adopted modular construction which uses prefabricated materials and components which can be reused as one method that will address the standards on energy efficiency. This method of construction is one which is a very viable option for the City of Spokane to consider integrating into their sustainable strategies.

Sustainable Strategy: Modular Construction

Modular construction is a potential sustainable strategy the City of Spokane could adopt and promote to meet their SAP goals. Modular construction is a building technique that incorporates components that are built in ideal conditions off site, transported to the site, and assembled on site with traditional building methods. Modularity speeds up construction as work is less impacted by weather and it allows construction to occur in a non-linear fashion as components and systems can be built off site while landscaping, foundation work, and other work occurs on site (Kawecki, 2010). This improves livability and well-being around construction as it reduces the construction time on site and expedites completion of the building, making them available for use sooner. Environmentally, modular construction optimizes the usage of materials and minimizes construction waste, allows for the usage of sustainable materials, and promotes the deconstruction and reuse of materials (Subramanya et al., 2020). Although it is important to be wary that the cost involved with the logistics of modular construction can add up quickly without adequate planning, the increased speed of construction cuts back on labor costs (Subramanya et al., 2020). Adoption of modular construction in Spokane may meet more opposition from the public since prior to the last decade there has been little variation in building methods. The recent Catalyst Spokane project provides a good example of the possibilities that modular construction and sustainable design offer to the city of Spokane in meeting their sustainability goals.

The Catalyst Spokane building is a project which utilized the benefits of modular construction while maximizing resources local to Spokane. If modular construction is to be more widely adopted in Spokane, the ideal modular building system to implement is CLT. Spokane's proximity to the lumber industry provides an opportunity for a localized supply chain, which can stimulate the local economy while also reducing emissions from the transportation of materials (Hairstans et al., 2018). CLT panels have seen unrivaled growth in the mass timber market as the structural characteristics of the panels allow them to be utilized in more applications (Hairstans et al., 2018). Since timber is capable of sequestering carbon, the use of CLT would assist the City of Spokane in meeting the goals laid out in the SAP by the Spokane Sustainability Action Committee.

In adopting CLT as a modular building strategy, the City of Spokane should be cognizant of the potential benefits and potential challenges. As growth continues in the Spokane area, modular construction using CLT would allow a streamlined building process for new, relatively affordable housing. This localized supply chain would also minimize some of the logistic costs which can hamper modular construction projects. As mentioned above, the use of timber from the surrounding lumber industry could allow for savings during the transportation of material. It should be noted that in order to maximize the carbon sequestering benefits timber used in the CLT must be sourced from a sustainably managed forest (Hammond et al. 2020). Unlike the Netherlands, the United States, including Spokane, can be a bit skeptical of change which may cause some difficulties in adopting modularity in the construction industry and in the eye of the public. One key misconception is the belief that the reduced work on site reduces the overall number of available jobs. In reality, the jobs which no longer take place on site simply occur at the fabrication facilities off site.

Conclusion and Recommendations

A city's transition to becoming more sustainable begins with engineers who are responsible for designing infrastructure with a wholistic mindset, taking the social, economic, and environmental aspects of their project into account. Buildings and energy is a specific area of action that has significant potential to help the City of Spokane become more sustainable by increasing the efficiency of the construction and operations of buildings. It is recommended that the City of Spokane consider integrating and incentivizing the use of modular construction systems, namely CLT, into new projects in order to achieve the goals outline in the SAP.

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