Sustainability of multi-floor buildings using renewable non-renewable materials in Lithuania

BENCH VALUE

Bioeconomy and wood construction in Lithuania

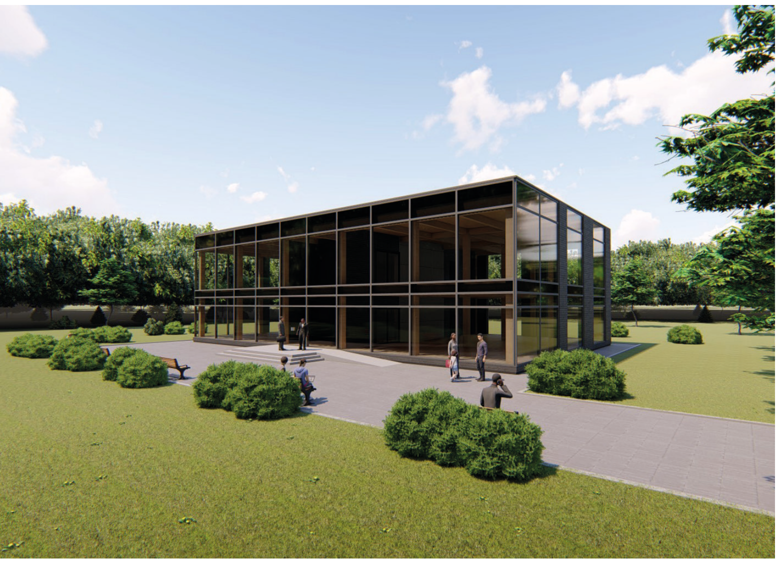
Mitigation of climate change, carbon sequestration and low carbon economy are the corner stones of the European bioeconomy. To support bioeconomy development, Lithuania has sufficient forest resources and a competitive wood industry, however, more than 20% of the annual industrial roundwood harvest is exported. Lithuania exports large quantities of final products that might be used in the construction sector instead of fossil materials. For example, about 80% of glue laminated timber (glulam) for wooden constructions is exported, and only 20% is used in the national construction sector. As a result, Lithuania looses the possibility to develop its low-carbon economy based on high value-added products. So far, in Lithuania there is no political decision to promote the wider use of wood in the construction sector. The public sector as a main client of design and construction services could influence the process, for example, by application of Green Public Procurement criteria, as well as application of Building Sustainability Assessment Schemes or Building Information Modelling (BIM).

The case study

The production of glulam is rapidly growing in Lithuania. The aim of this case study was to quantify and to compare sustainability impacts of national value chains for non-renewable materials (concrete/reinforced concrete (RC)) and renewable materials (glulam) used in the construction sector. The glulam value chain involves forest logging, transport, timber sawing, and glulam production; and the RC value chain involves raw material extraction for cement and concrete, transport, cement production, and RC production.

The glulam value chain is based on the processes of Jures medis, the largest manufacturer of glulam structures in the Baltic states, and sawn timber company Stora Enso Lithuania. In order to compare the sustainability impacts of glulam and RC constructions in practise, material use and construction processes for two-storey (765 m^2) and five-storey (1913 m^2) glulam and RC building frames were modelled.

Selected sustainability indicators. After consultation with stakeholders following economic, social and environmental indicators for this case study were chosen (Table 1).



The projected two-storey (left) and five-storey (right) building designs.

Table 1. Economic, environmental and social indicators selected for the analysis.

Economic indicators	Environmental indicators	Social indicators
Gross value added €/unit	Greenhouse gas emissions, kg CO_2 equivalent/unit	Employment, full time equivalent/unit
Production price, €/unit	Generation of waste, t/unit, calculated as non-hazardous	Occupational accidents, cases/unit
	Water use, m^3/unit, calculated as consumed underground freshwater	Wages and salaries, €/unit
	Energy use for production, MJ/unit	
	Non-renewable raw material used, t/unit	
	Carbon inflow into the pool t of C/unit	

Results

Greenhouse gas emissions of CO_2 equivalent, kg/m². The highest emissions of CO_2 equivalent, kg/m² were estimated when constructing the five-storey RC frame. When constructing glulam constructions emissions were about three times lower compared to RC constructions. The most efficient frame regarding this indicator was the two-storey glulam frame with CO_2 equivalent value of 87.4 kg/m² compared to 208.0 kg/m² for the two-storey RC frame.

Biogenic carbon storage (carbon inflow into the pool) t/m². Only glulam frames have a capacity of biogenic carbon storage in wood 0.0304 t/m². It was estimated that the five-storey glulam frames store 0.0304 tC/m² or 58.2 tC/projected building frame.

Energy use, MJ/m². The most efficient frame regarding this indicator was the two-storey glulam frame with 510 MJ/m². When constructing RC frames, 3 times higher amounts of energy is consumed compared to glulam frames.

Water use (freshwater intake by industry), m³/m². The most efficient frame regarding this indicator was the two-storey glulam frame 0.23 m³/m². When constructing RC frames, four times more water is consumed.

Generation of waste in total, t/m². The most efficient frame regarding this indicator was the two-storey glulam frame. When producing this frame 0.00090 t/m² was generated. When constructing RC frames, three times higher amount of wastes are produced compared to glulam frames.

Non-renewable raw material, t/m². To build the two- or five-storey RC frames much higher amount of non-renewable raw materials is needed than in building glulam frames. The most efficient frame regarding this indicator was the two-storey glulam frame with 0.327 t/m².

Production price, €/m². The most efficient frame regarding this indicator was the five-storey glulam frame 46.93 €/m². Production of one glulam cubic meter used in these frames is twice as expensive as RC frames. Yet, three times less materials are needed for the glulam frames in comparison to the RC frames.

Wages and salaries, €/m². To construct RC two- and five-storey frames, about three times the amount of work is needed compared to glulam frames. The most efficient frame regarding this indicator was the two-storey glulam frame with 6.94 €/m².

Occupational accidents, cases/m². There were no remarkable differences regarding occupational accidents when producing other frames.

Employment, FTE/m². The most efficient frame regarding this indicator was the two-storey glulam frame that required 0.00052 person/m². However, precast reinforced concrete value chain generates more working places.

Gross value added (GVA) (at factor cost), €/m². The data for this indicator was available only for glulam frames. The GVA for the two-storey frame was the highest equalling to 14.5 €/m².

Substitution factors

Dry wood is composed of approximately 50% carbon, furthermore while trees grow, they absorb carbon dioxide emissions and consequently contribute to climate change mitigation. The displacement factor (DF) presented below as tC in wood products shows the amount of GHG emission avoided when wood is chosen instead of other materials. Calculated DF for a two-storey building was 1.82, meaning that for each tC in wood products substituted for other products, there is an average GHG emission reduction of approximately 1.82 tC. For a five-storey building we calculated slightly higher DF – 1.95 (or 1.95 tC per 1tC of wood products).

National level displacement factors were calculated for sawnwood. According to calculations, weighted DF for all presented end products is 0.99, and for construction sector (displacing steel, concrete and masonry) 1.39, meaning that for each tC in wood products substituted in place of non-wood products, there is an average GHG emission reduction of approximately 0.99 and 1.39 tC respectively.

The increase of wood in construction will result in higher demand, and consequently on the reduction of GHG emissions from substitution. Based on this assumption three scenarios were made regarding the increase of Lithuanian annual market share of wood used in structural framing of multi-storey buildings: a) 1%; b) 5%; c) 20%. Substitution impact for those assumptions was calculated. In 2018 multi-storey residential buildings were built on 0.315 million m^2. In order to displace 1% of non-wood material-based building area (3150 m^2) to wood-based building area, annually 3087 m^3 round wood or 1260 m^3 wood products would be needed (0.4 m^3/m^2), with total 1610 tCO^{2}eq substitution value. In order to displace 5% of non-wood material-based building area (15 750 m^2) annually, 15 435 m^3 round wood or 6300 m^3 wood products would be needed, with total of 8050 tCO^{2}eq substitution value. In order to displace 20% of non-wood material-based building area (63 000 m^2), annually 61 740 m^3 round wood or 25200 m^3 wood products would be needed, with total of 32 202 tCO^{2}eq substitution value.

Stakeholder interaction and results of discussions

To clarify the present situation of Lithuanian bioeconomy as well as its future development possibilities, a stakeholder workshop was organized in May 2018. Stakeholders, representing wood industry, reinforced concrete industry, policy makers, science, environment and house construction sector, were invited. In the workshop, to have more straightforward oriented discussions, the Ketso method, based on learning by doing and stimulating the outcomes through the interaction of stakeholders, was used.

Stakeholders highlighted further possibilities for Lithuanian bioeconomy: increased sawmilling and wood gluing industries, cooperation between science and industry, review of wood building regulations, development of new innovative products that can give some impulse for Lithuanian bioeconomy. However, there were some contrary affecting factors that cannot be ignored: bureaucracy and planning at the municipality level, bad cooperation between forestry and wood industry, lack of knowledge between architect groups and strong competitors in non-bioeconomy sector. Stakeholders clarified that policy makers are inclined to get requests from the wood industries how the bioeconomy sector must be shaped. Yet, wood industries are not eager to express their requests but rather wait for the regulations from the politicians. In this way, the status quo situation arises.

According to the stakeholders, the most appropriate measures to promote Lithuanian bioeconomy were the development of bioeconomy strategy for Lithuania, with a clear focus to construction sector that should be based on renewable materials like wood. Also, remarkable measures must be taken to educate society via media channels.

National recommendations

The case study findings suggest the following recommendations:

1. The developed "Benchvalue" method which is used to evaluate renewable and non-renewable material flows, value chains and sustainability indicators, provides scientifically proven results and could be further used for studies to support decision makers.

2. To enable material use comparison at the large scale it is recommend to create a monitoring system and a database on material use in the construction sector. This is especially important due to the emergence of structural materials, used in the construction sector, for example cross laminated timber.

3. The results of the Lithuanian case study highlighted the environmental advantages of wood-based material use in the construction sector. In order to meet the global, European and national goals to reduce CO_2 emissions, it is recommended to promote negative emissions technologies such as carbon storage in wood-based constructions. Additionally, non-compliance rates could be compensated by using additional renewable technologies, for example, heating or/and electricity supply systems.

4. The current legal framework in Lithuania does not provide any incentives to use more environmentally friendly building materials. It is recommended for policy makers to initiate regulations especially for the public sector to promote building materials that has lowest environmental impacts.

5. Education of the public, architects, designers and the construction industry on the environmental benefits of wood products, by highlighting its benefits in terms of climate change mitigation is crucially important and, thus, is highly recommended.

6. Lithuania should develop the national bioeconomy strategy including the construction sector. Construction is one of the most resource and energy intensive sectors in Lithuania. Local renewable resources, for example wood, should be one of the key components in increasing the sustainability of construction sector. Large scale carbon storage in wood-based constructions might significantly reduce net CO_2 emissions.

7. Involvement of stakeholders representing construction sector, forest-based sector and scientists is essential in the preparation of the Lithuanian bioeconomy strategy.

Contributors:
Marius Aleinikovas (firstname.lastname@mi.lt)
Povilas Žemaitis
Edgaras Linkevičius
Gediminas Jasinevičius

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