Primary energy implications for low-energy buildings with different frame construction systems under varying climate scenarios

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Introduction

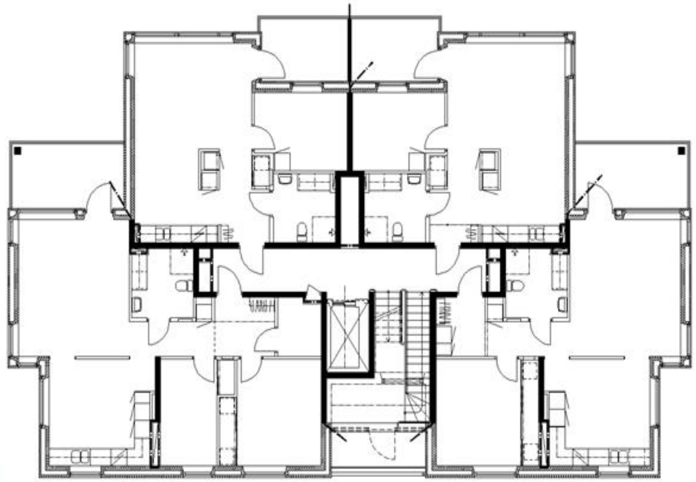
- About 72% of the total primary energy use in the EU came from fossil fuels in 2016
- The residential and service sectors accounted for around 39% of the total final energy use in 2016
- Average EU outdoor temperature increased by 1.3 ° C from 2002–2011 compared to 1850-1899
- Projections for Sweden show average temperature rise of 2-6 ° C by 2100 relative to 1961-1990

Aim

To analyse the life cycle primary energy implications of different frame construction systems under various climate scenarios

Studied building

(a)



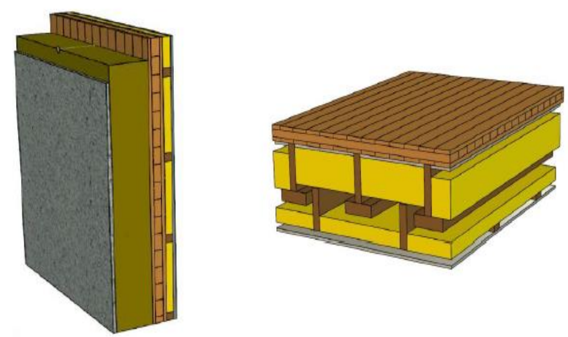
(b)

- Built in 2014 in Växjö
- Concrete frame
- 6 storeys
- 24 apartments
- 1686 m^2 living area
- Redesigned to a low energy building

The analysis is based on building alternatives with concrete-frame, modular timber-frame or cross laminated timber-frame

Prefabricated concrete frame

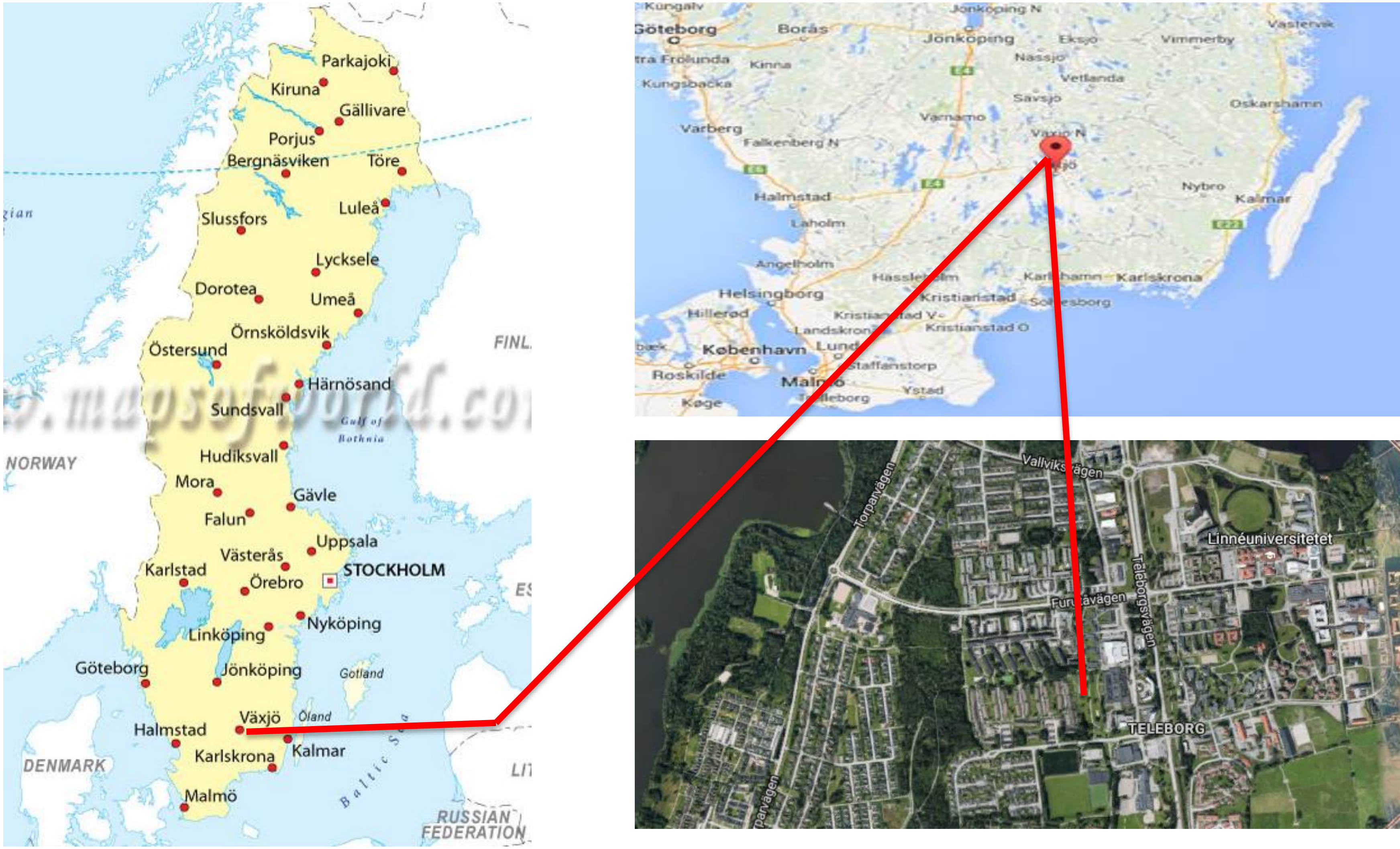
Modular timber-frame



Cross laminated timber-frame

The building alternatives are designed to have the same housing service

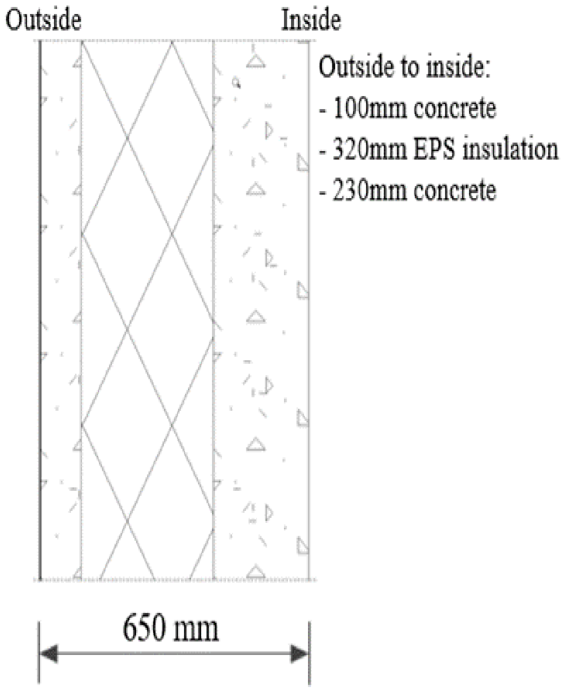
Studied building location



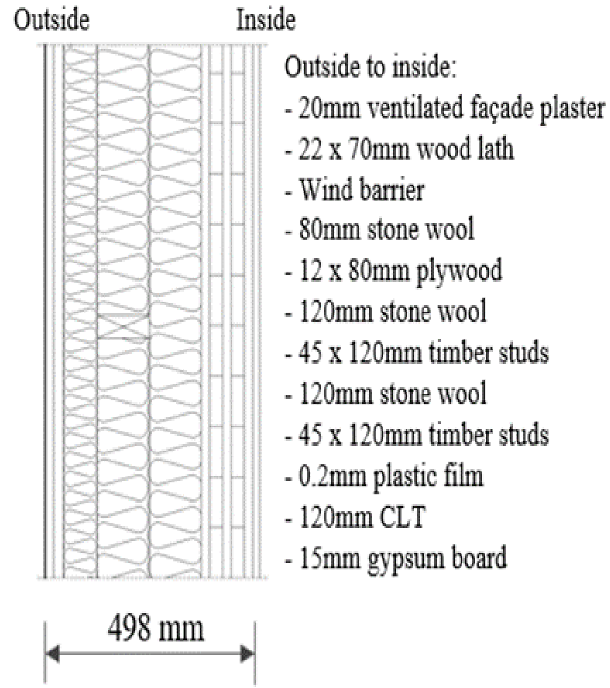
Energy performance of building alternatives

Description	U-value (W/m^2K)					Air-leakage at 50 Pa ($l/s\ m^2$)	Mechanical ventilation
	Ground floor	External walls	Windows	Doors	Roof		
Low energy building	0.11	0.108	0.80	0.80	0.05	0.30	Balanced with (76%) heat recovery

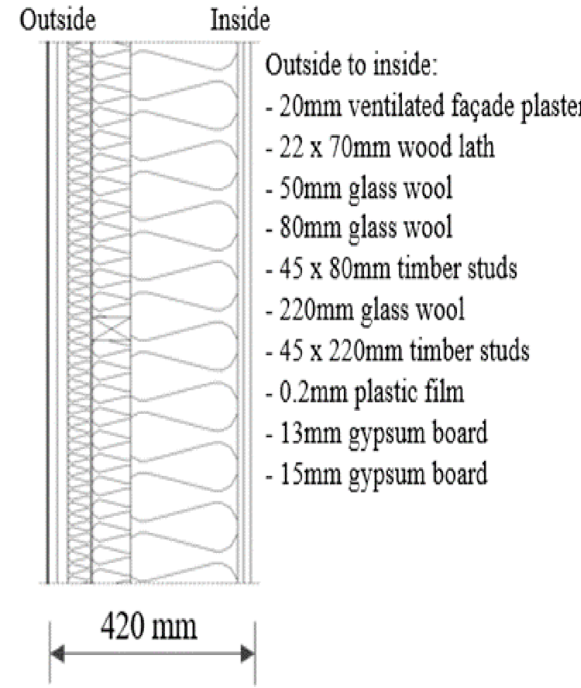
External wall details for the different frame construction systems



Prefabricated concrete frame



Cross laminated timber frame (CLT)



Prefabricated modular timber frame (Modular)

Assumptions

- We consider total material mass inputs for the buildings including losses during production and construction
- The production primary energy analysis covers the complete materials and energy chains, including material losses, conversion and fuel cycle losses
- Steel is assumed to be produced from 50% ore and 50% scrap steel
- Biomass residues from forestry, wood processing, construction and end-of-life of building systems are shown
- Building service life is 80 years

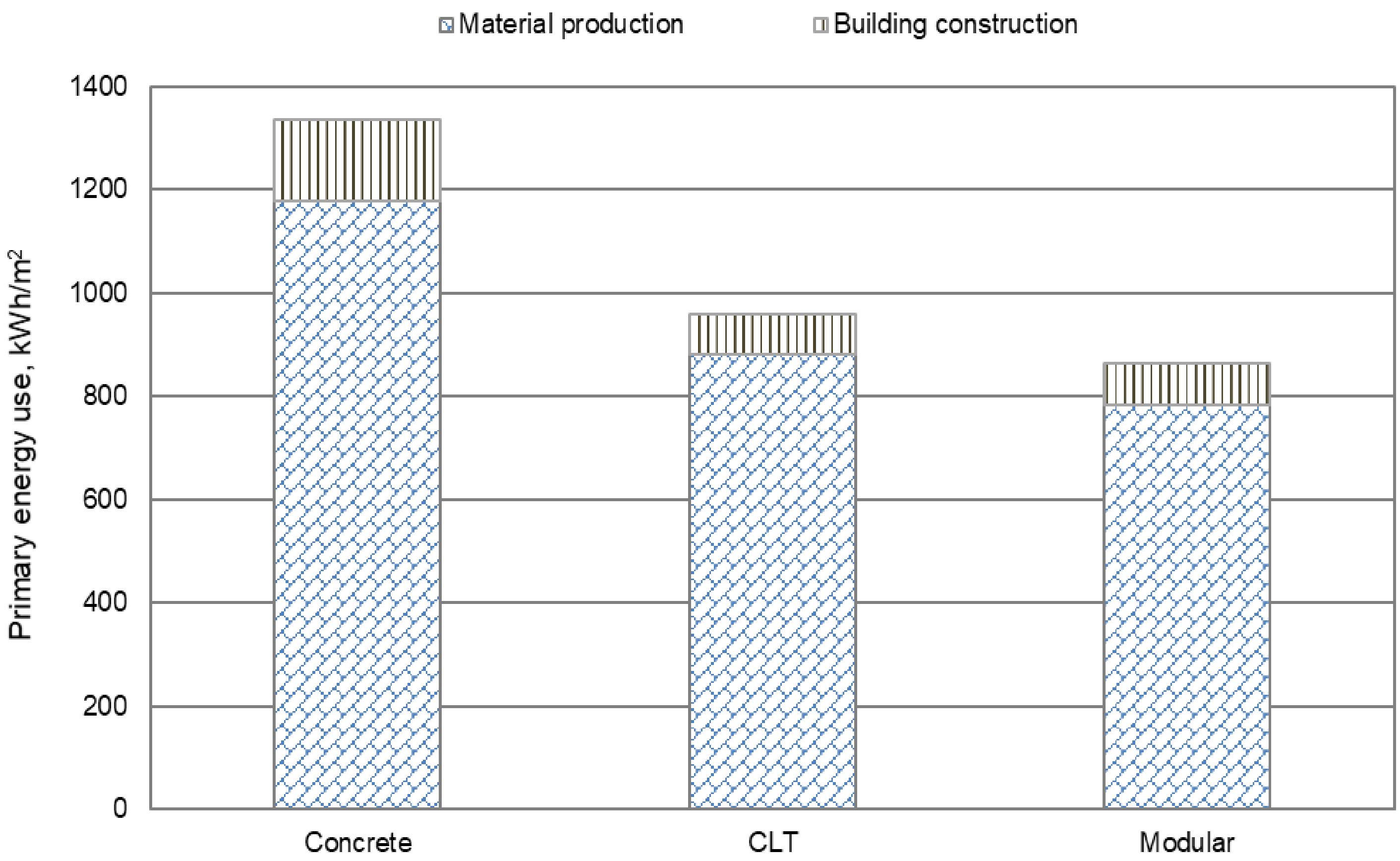
Assumptions

- The future climates are for the period 2090-2099 and based on the representative concentration pathway (RCP) scenarios from the IPCC
- The annual operation energy demand, including space heating and cooling, tap water heating, as well as electricity for ventilation, household and facility electricity were modelled with VIP-Energy, version 4.1.0
- VIP-Energy is a validated energy simulation software with dynamic hour-by-hour and multi-zone whole-building calculation features

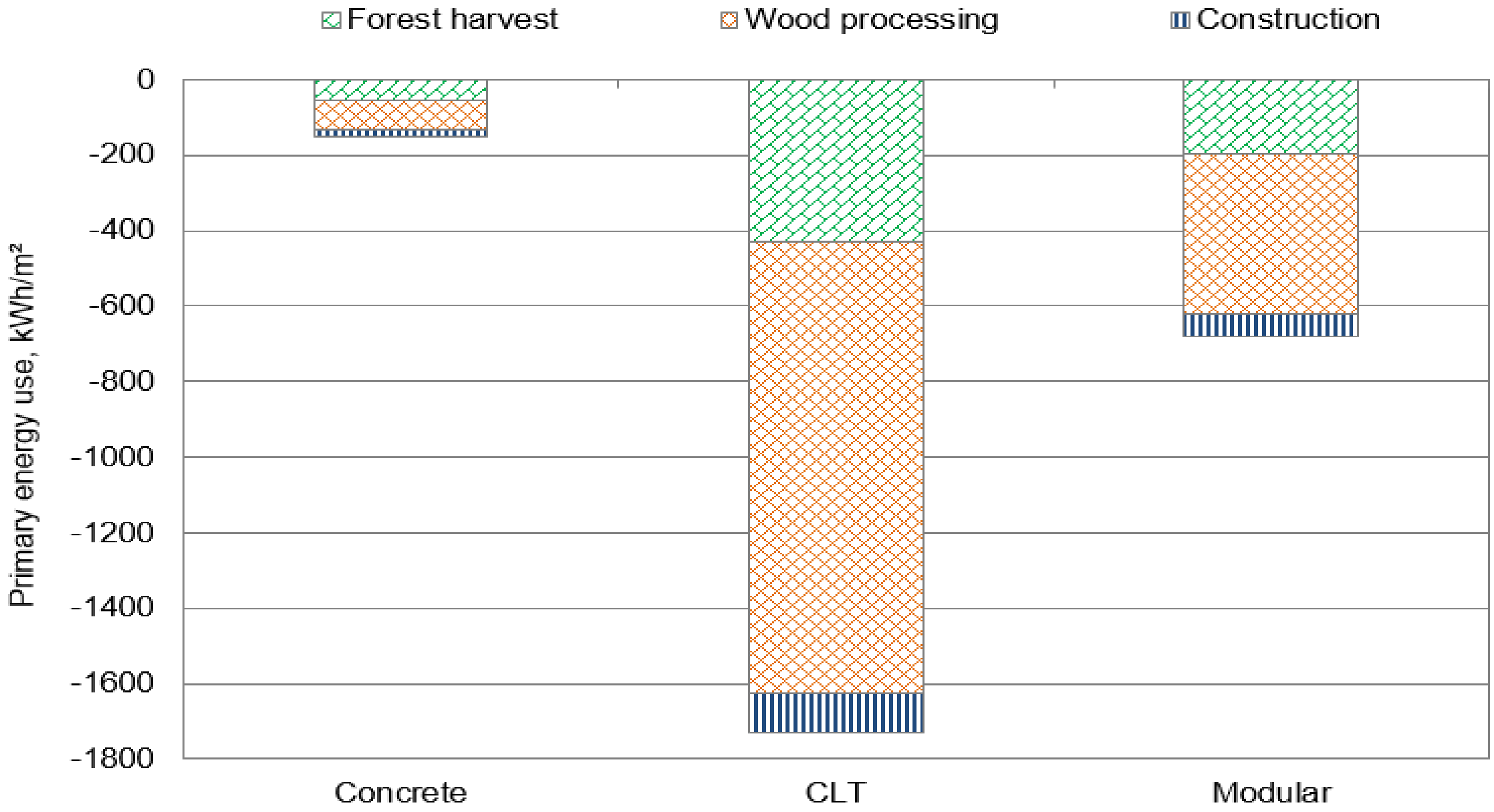
Mass (tonnes) of major materials in the analysed building alternatives

Materials	Concrete	CLT	Modular
Concrete	2870	229	229
Steel	95.2	12.6	14.2
Lumber	50.9	127	154
Particleboard	20.8	0.0	22.8
Plywood	3.0	20.9	29.0
CLT	0.0	176	0.0
Glue-laminated wood	0.0	40.3	7.8
Stone wool insulation	11.1	26.8	5.9
Glass wool insulation	0.0	0.0	19.3
EPS insulation	13.6	1.8	1.8
Plasterboard	22.6	110	116

Primary energy use for material production and building construction

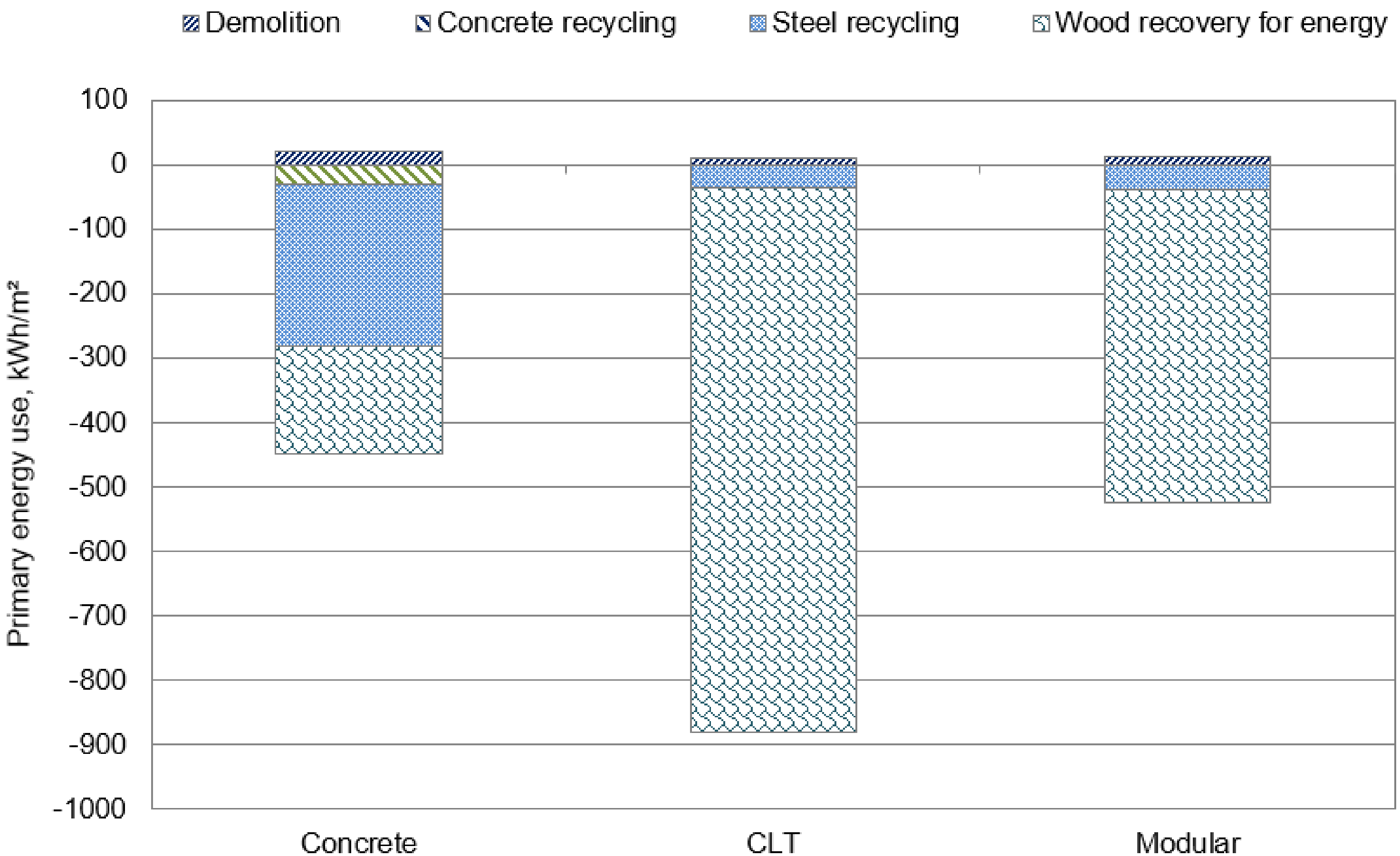


Potential available biomass residues* from material production and building construction



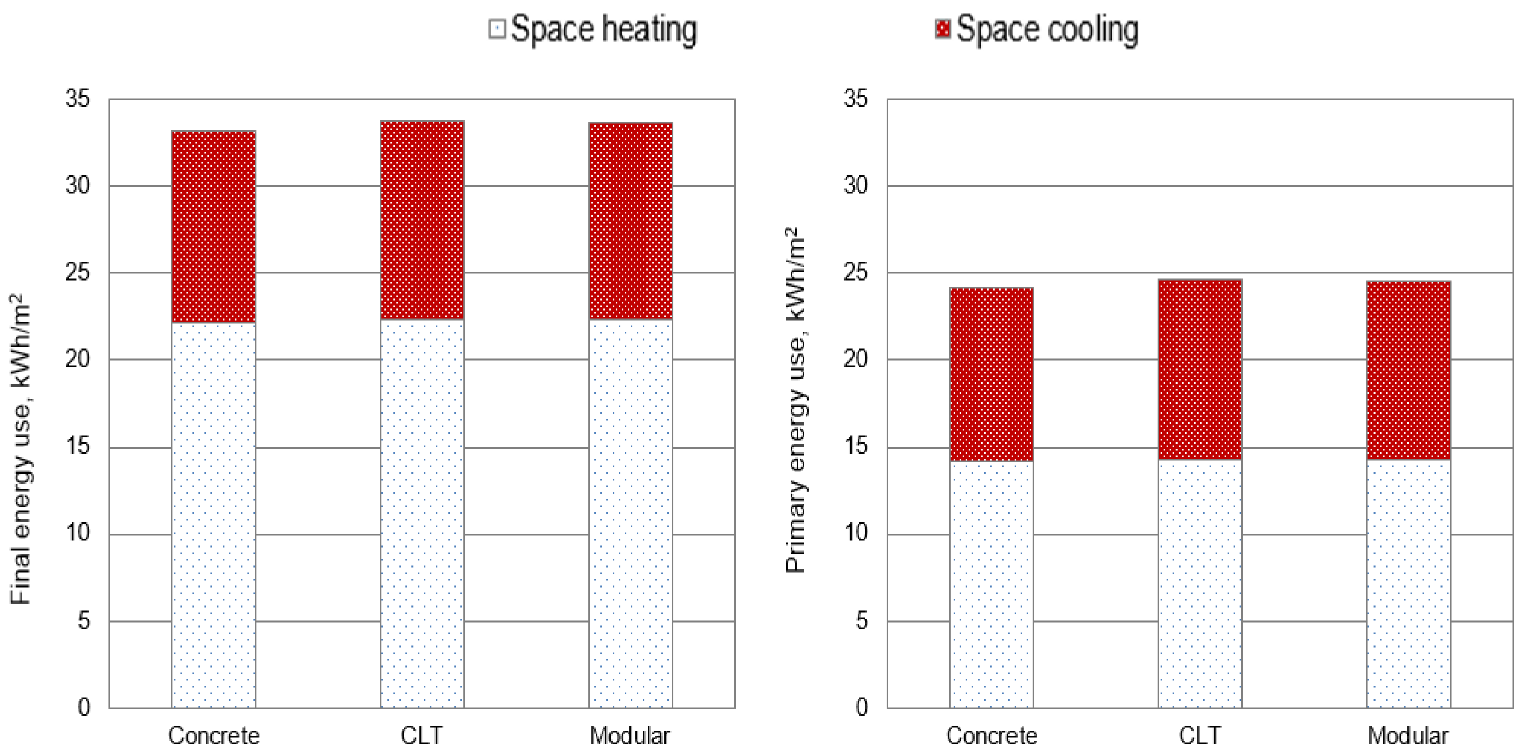
* Energy content based on lower heating value.
Forest harvest residues include branches and tops.
Negative numbers show primary energy benefits.

End of life primary energy balance, kWh/m²



Negative numbers show primary energy benefits.

Annual energy demand, kWh/m² for space heating and cooling under the reference climate of Växjö 2013

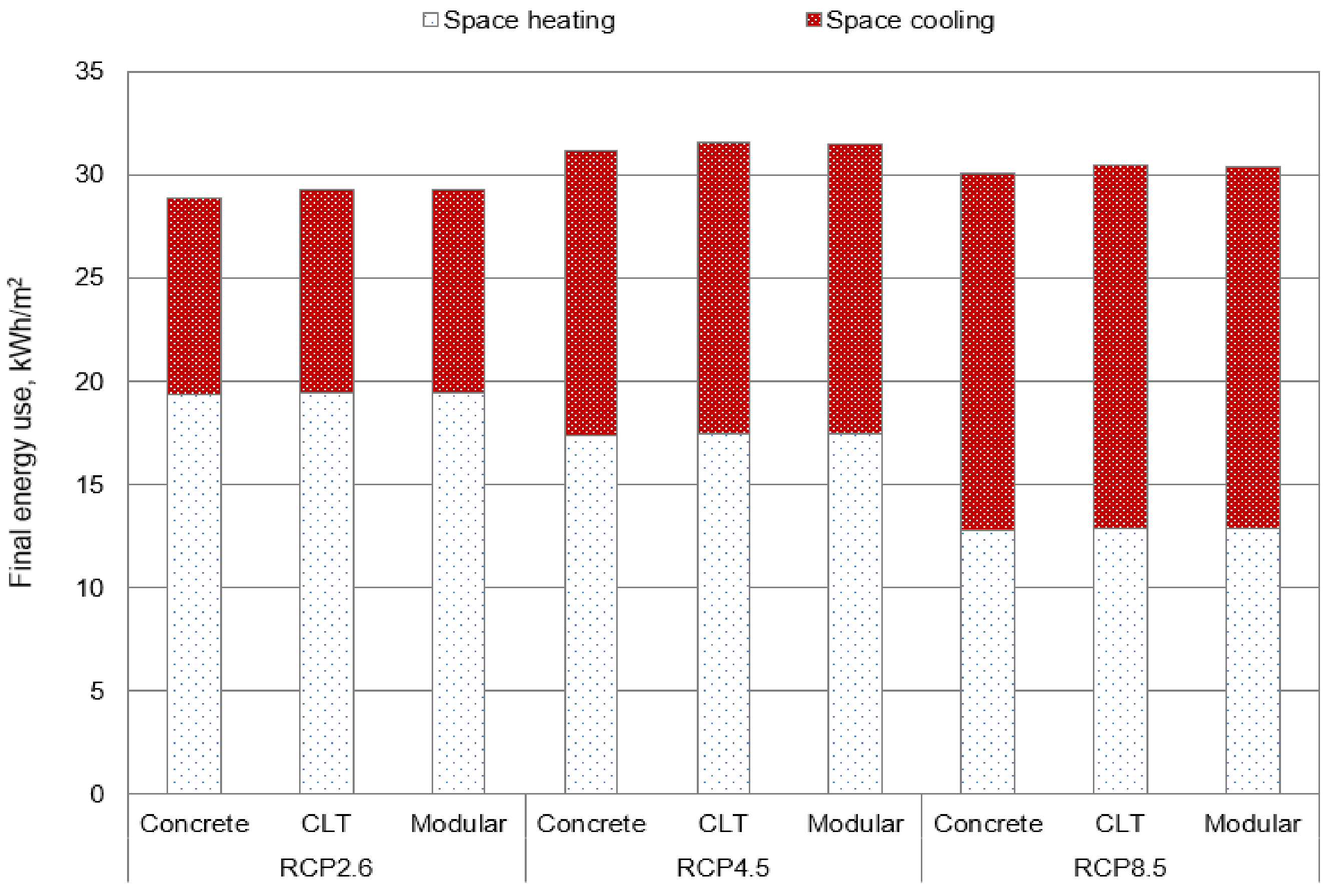


Final energy | Primary energy

The concrete frame system gives slightly lower space heating and cooling demand than the CLT and modular alternatives due to thermal mass.

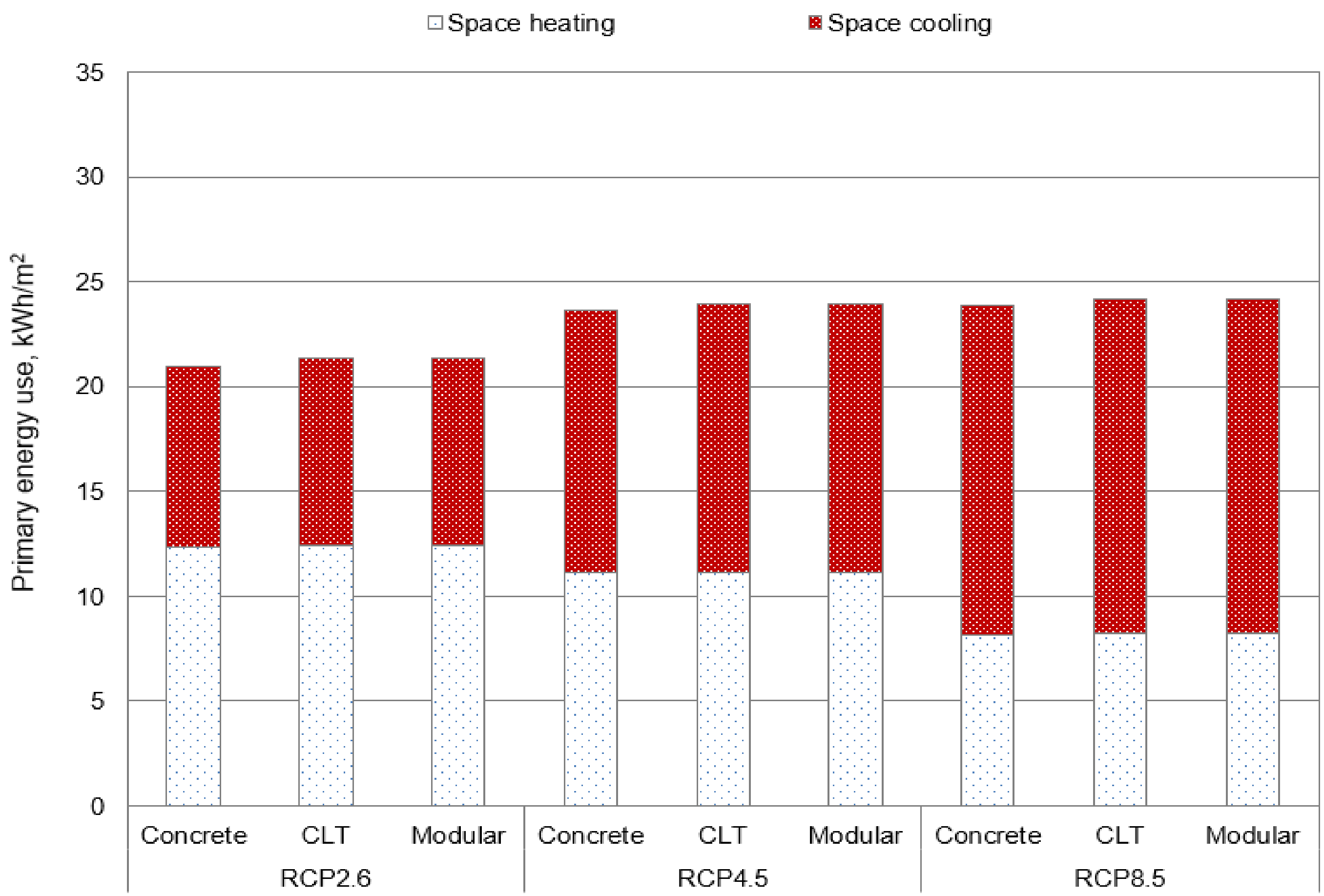
Space heating is based on combined heat and power (68%) and boiler units using biomass. Space cooling is based on electricity from stand-alone plants with biomass steam turbine technology. COP of 3 is assumed for room air conditioners.

Annual final energy demand, kWh/m² for space heating and cooling under the future climate scenarios



The concrete frame system gives slightly lower space heating and cooling demand than the CLT and modular alternatives due to thermal mass

Annual primary energy use, kWh/m² for space heating and cooling under the future climate scenarios



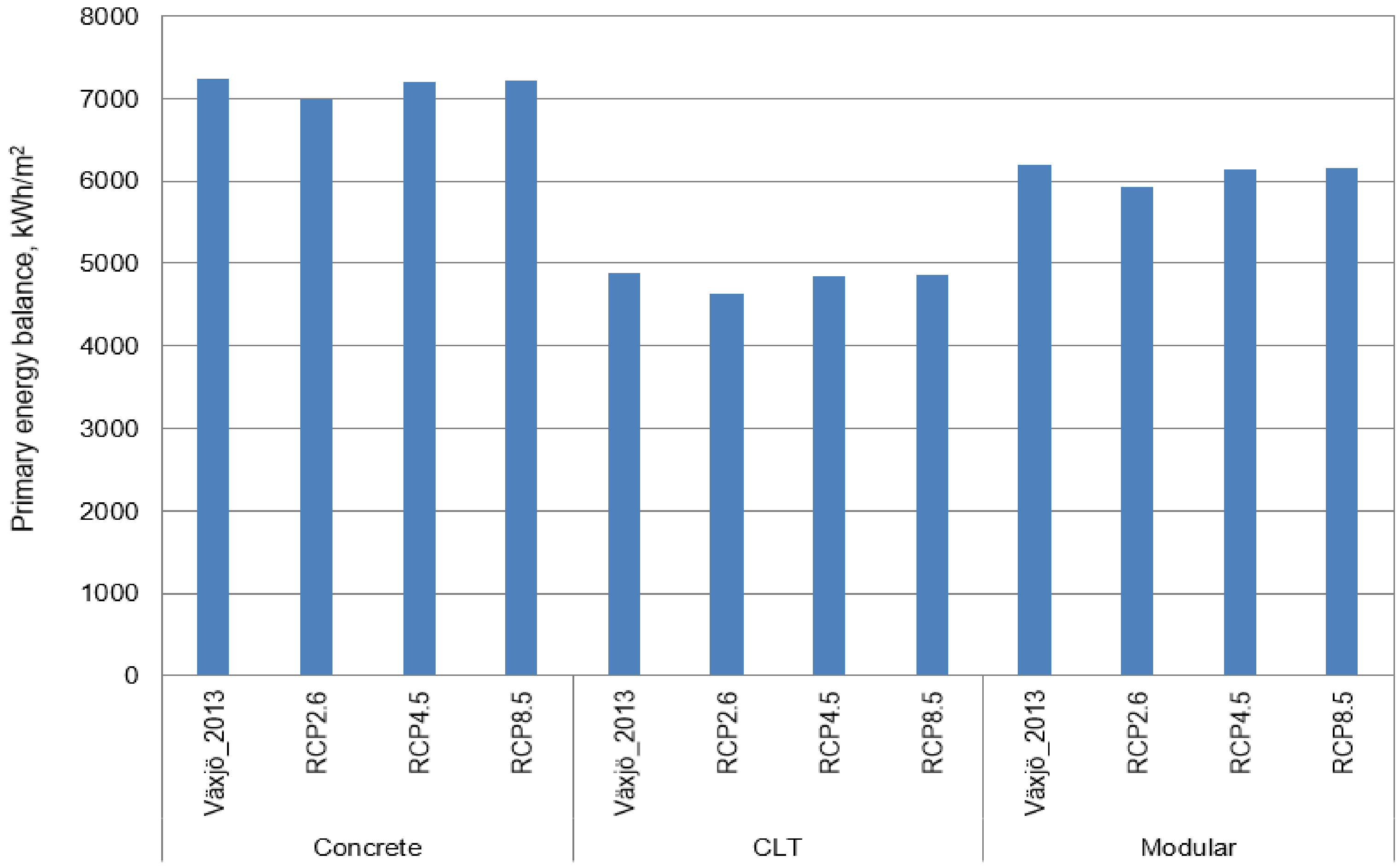
Space heating is based on combined heat and power (68%) and boiler units using biomass. Space cooling is based on electricity from stand-alone plants with biomass steam turbine technology. COP of 3 is assumed for room air conditioners.

Life cycle primary energy balance, kWh/m^2 under the reference climate of Växjö 2013

Operation primary energy use includes space and tap water heating, and electricity for space cooling and ventilation.

Negative numbers show primary energy benefits.

Variations in life cycle primary energy balance, kWh/m² under different climate scenarios



Conclusions

- The CLT and modular timber building systems give lower production primary energy use than the concrete alternative

- The primary energy use for material production and construction of the building systems constitutes 14 - 20% of the total primary energy use for material production, construction, space heating and cooling, ventilation and demolition

- The CLT and modular buildings give significant residues from forest harvest, wood processing and construction activities

- The space heating demand decreases and the cooling demand increases under the considered climate scenarios

Conclusions

- The space heating and cooling demands for the concrete building are slightly lower than that of the CLT and modular building systems due to thermal mass

- End-of-life primary energy benefits from demolished wood-based materials are higher than that of recovered concrete and steel

- The CLT building system results in the lowest life cycle primary energy balance, followed by the modular and then the concrete alternative

Thank you