Effects of Energy and Carbon Taxes on Building Material Competitiveness

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This presentation is based on

Gustavsson, L., Pingoud, K. and Sathre, R. 2006. Carbon dioxide balance of wood substitution: comparing concrete- and wood-framed buildings. *Mitigation and Adaptation Strategies for Global Change,* 11(3): 667-691.

Gustavsson, L. and Sathre, R. 2006. Variability in energy and carbon dioxide balances of wood and concrete building materials. *Building and Environment*, 41(7): 940-951.

Sathre, R. and Gustavsson, L. 2007. Effects of energy and carbon taxes on building material competitiveness. *Energy and Buildings*, 39(4): 488-494.

Sathre, R. and Gustavsson, L. 2007. Using wood products to mitigate climate change: external costs and structural change. *3rd International Green Energy Conference*. 18-20 June, Västerås, Sweden.

Background

Previous research has shown that:

- Wood-framed building construction uses less primary energy and emits less CO_2 compared to reinforced-concrete construction
- Using wood as a construction material is a cost-effective and biomass-efficient way to reduce carbon emission

This suggests that effective economic policy instruments for reducing carbon emission should favour wood construction

Aim

In this study we model the effects of energy and carbon taxes on construction costs, focussing on two factors:

(1) the cost of emissions from fossil fuels and cement reactions in the manufacture of the materials

(2) the cost of using wood byproducts to replace coal

Case study: Wälludden building

- Växjo, Sweden
- 1190 usable m^2
- 4 stories, 16 apartments
- Built with wooden frame
- Compared to a hypothetical, equivalent building with concrete frame

Energy and carbon balance calculations include:

- Primary energy use for production of building materials
- The carbon cycle of wood products
- Using biomass residues to substitution fossil fuels
- CO_2 balance of cement process reactions

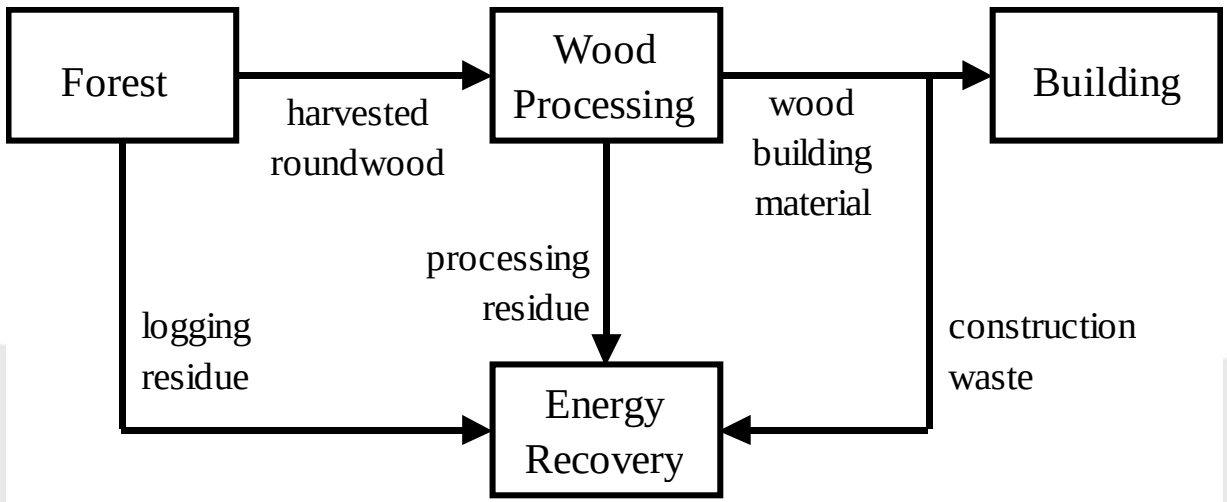
Fossil reference system

- The fossil fuel cycle includes the complete energy chain, including fuel extraction, transportation, conversion and distribution

- Assumed fossil fuel cycle emissions (g C/MJ):
  - Natural gas: 18
  - Oil: 22
  - Coal: 30

Biofuel recovery and use

- Sources of biofuel:
  - Branches and foliage 70%
  - Bark, Construction site waste, Sawmill residue (net) 100%
- Biofuels at appropriate moisture content and heat value
- Fossil energy (diesel) for biofuel recovery included
- Appropriate conversion efficiencies when biomass substitutes fossil fuels



Energy and carbon taxation scenarios

- **Base prices for fuels and electricity with zero taxes**
- **Swedish taxation rate on industrial energy use**
  (carbon tax of 77 €/tC on end-use fossil fuels; energy taxes on diesel fuel; low energy tax on electricity use)
- **Swedish taxation rate on residential energy use**
  (carbon tax of 367 €/tC on end-use fossil fuels, the same energy tax on diesel fuel as in the industrial tax scenario, and a higher energy tax on electricity use than the industrial rate)

Energy and carbon taxation scenarios

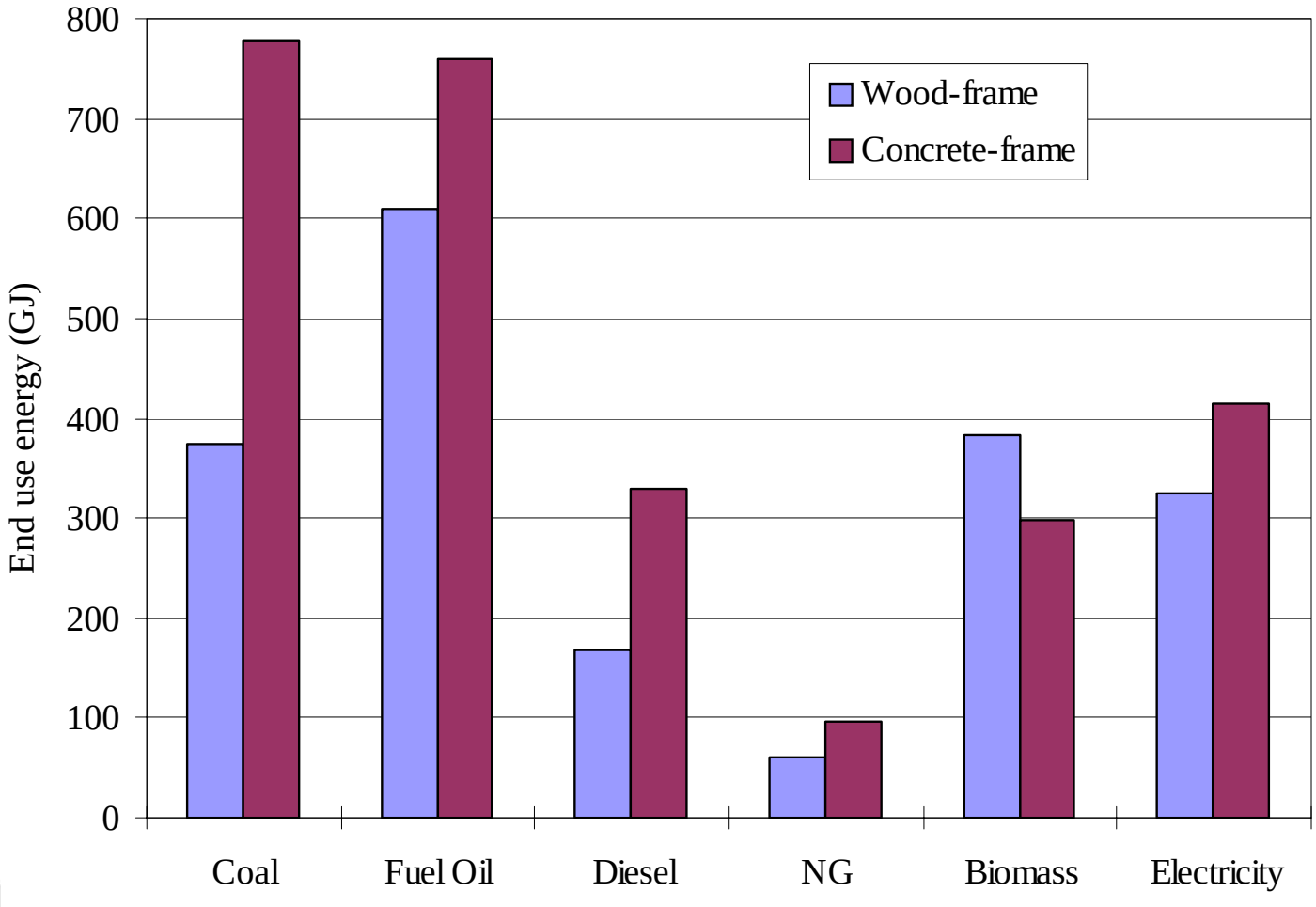
- **Low uniform carbon tax**
  (carbon tax of 77 €/tC on all carbon emissions)
- **High uniform carbon tax**
  (carbon tax of 367 €/tC on all carbon emissions)
- **Social Cost of Carbon if atmospheric CO_2 is stabilised at 550 ppm**
  (uniform carbon tax of 92 €/tC on all fossil and cement process emissions, based on *Stern Report* estimate)
- **Social Cost of Carbon if "Business as Usual" continues**
  (uniform carbon tax of 260 €/tC on all fossil and cement process emissions, based on *Stern Report* estimate)

Assumed energy prices and taxes

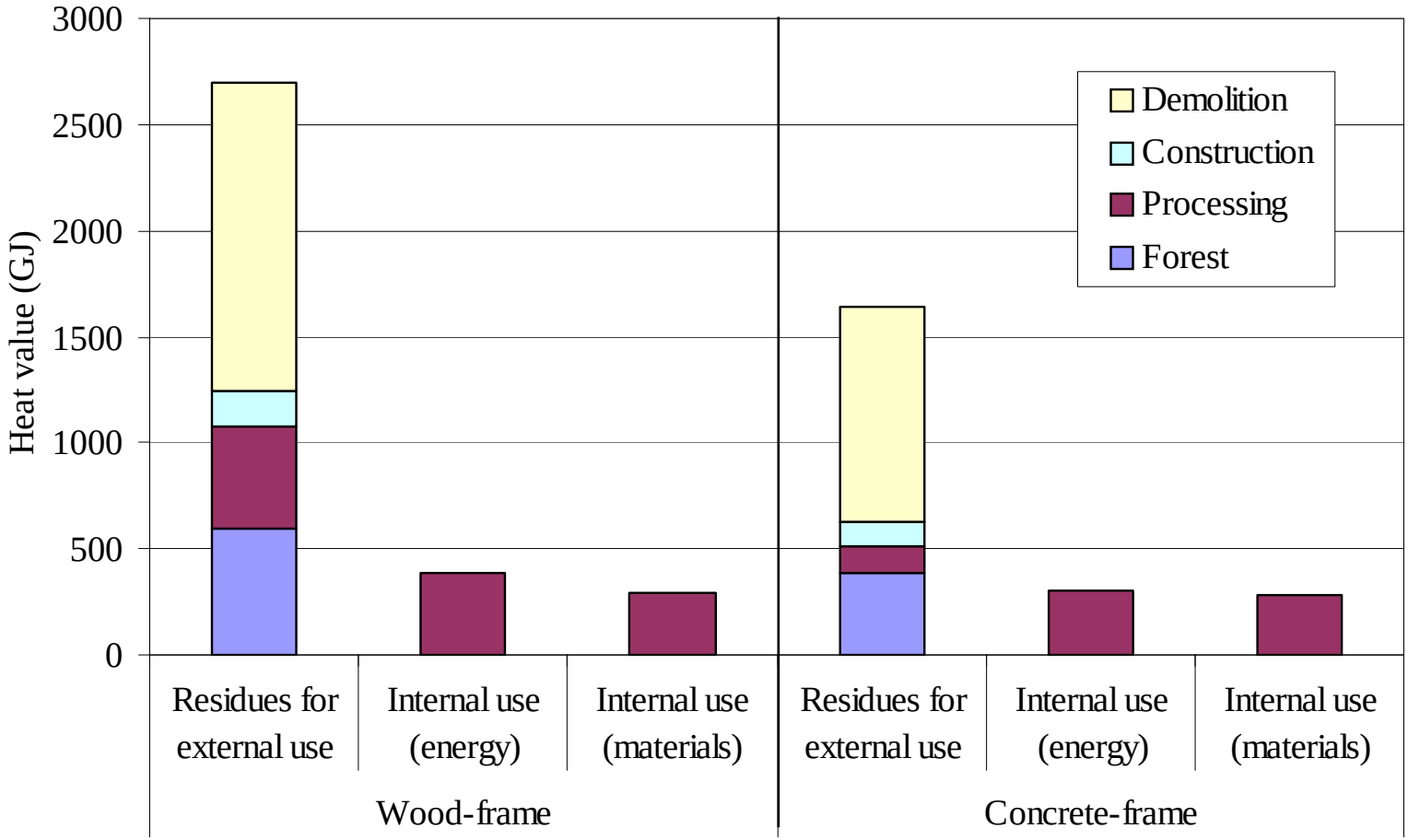
($€_{2005}$ / GJ)

	Coal	Fuel Oil	Diesel	NG	Bio-forest	Bio-processing	Bio-construction	Electricity
Zero tax rate	2.08	7.16	14.37	7.01	3.59	3.54	2.31	10.45
Industrial tax rate	4.00	8.73	25.27	8.25	4.14	3.65	2.42	10.60
Residential tax rate	12.46	16.75	25.27	13.66	4.14	3.65	2.42	18.33
Uniform carbon tax (low)	4.33	8.76	16.04	8.20	3.68	3.56	2.32	16.06
Uniform carbon tax (high)	12.77	14.77	22.33	12.71	3.99	3.62	2.39	37.17
Stern (550 ppm)	4.76	9.06	16.36	8.43	3.69	3.56	2.33	17.13
Stern (BAU)	9.66	12.55	20.01	11.05	3.87	3.60	2.36	29.38

End-use energy for material production



Recovery and use of biomass residues



(use of demolition residues is **not** considered in the tax scenarios)

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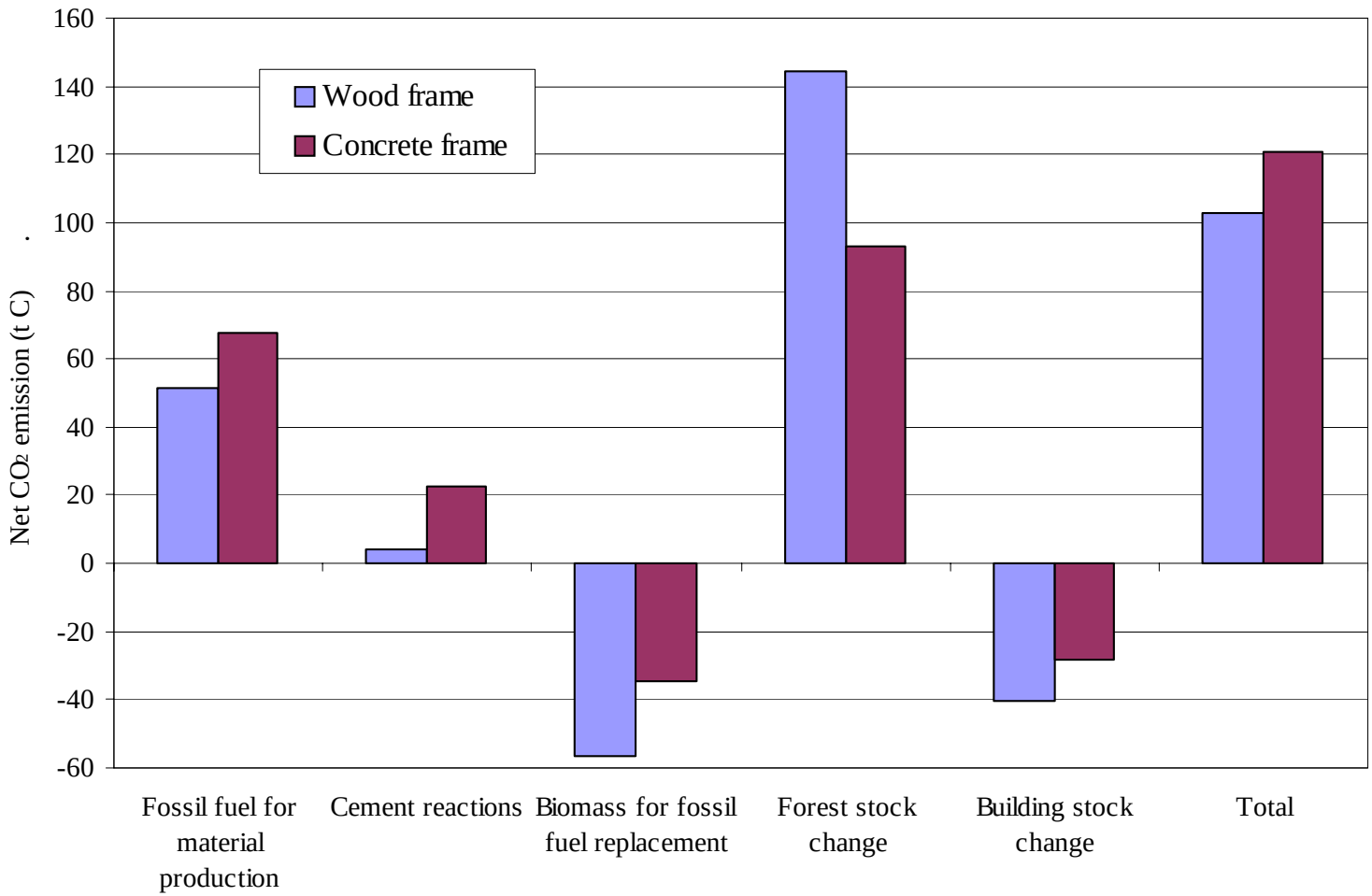
Net carbon emission at year of construction



(reference fossil fuel is **coal**)

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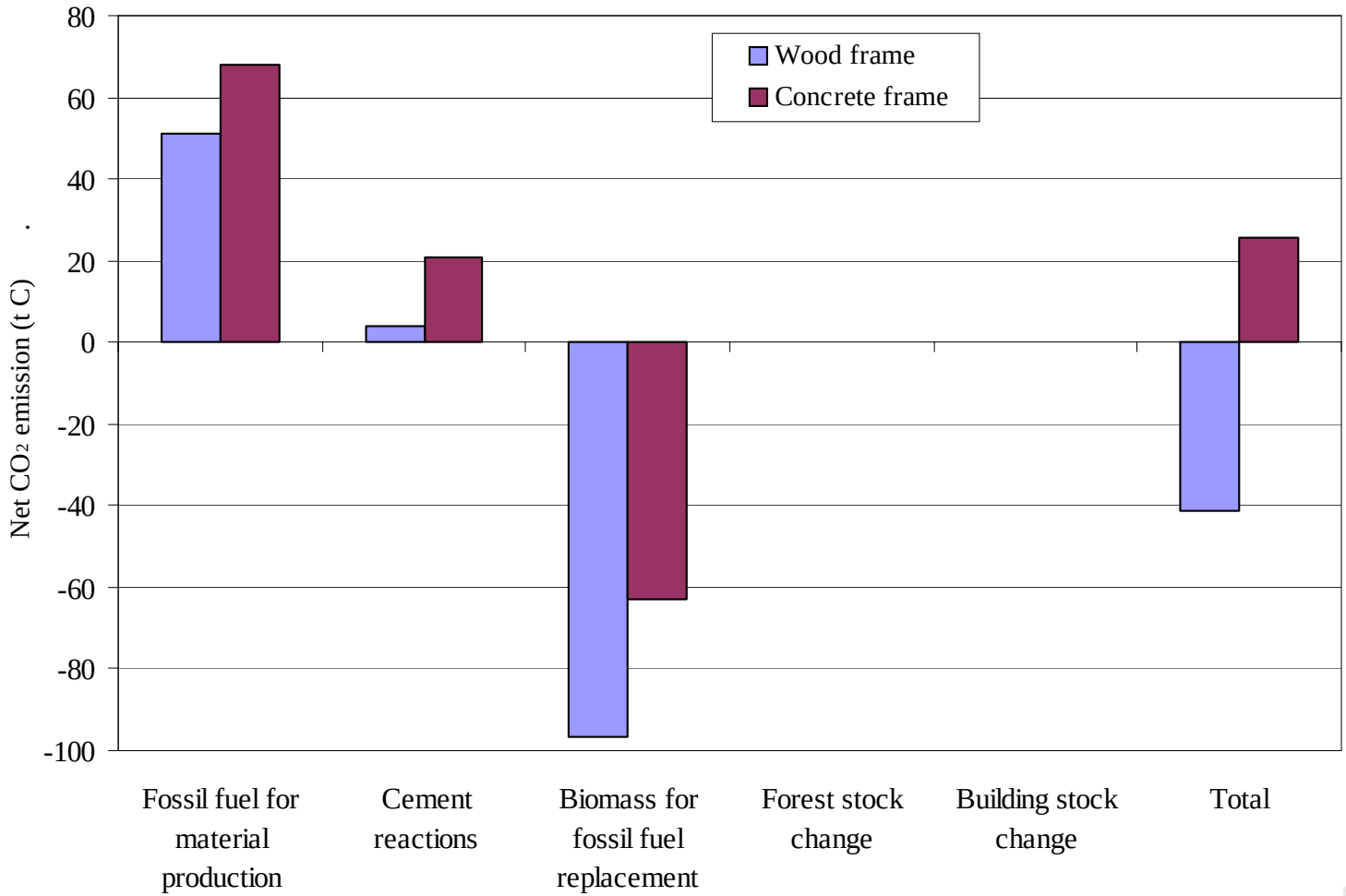
Net carbon emission over building lifecycle



(reference fossil fuel is **coal**)

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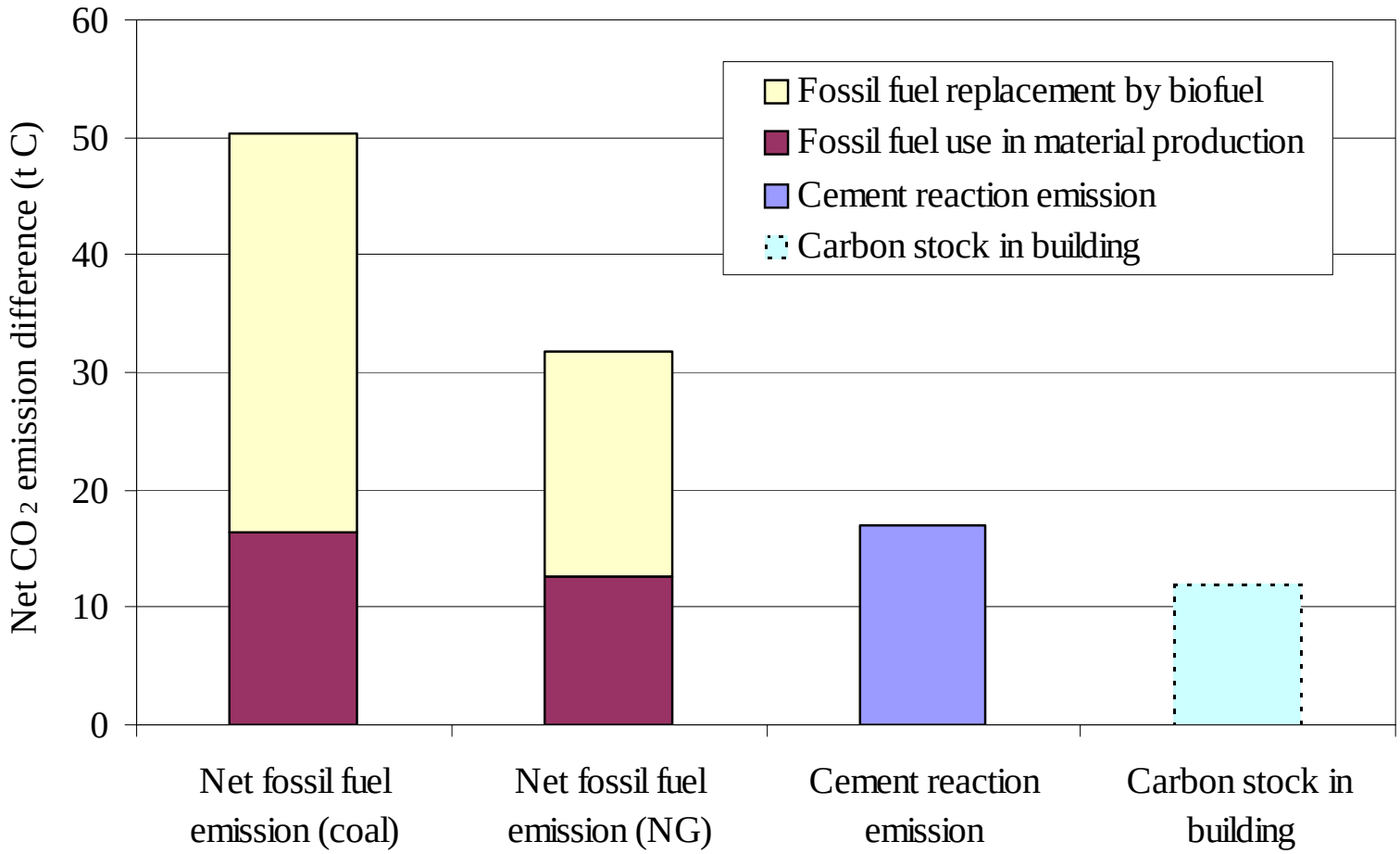
Emission difference between concrete- and wood-frame buildings



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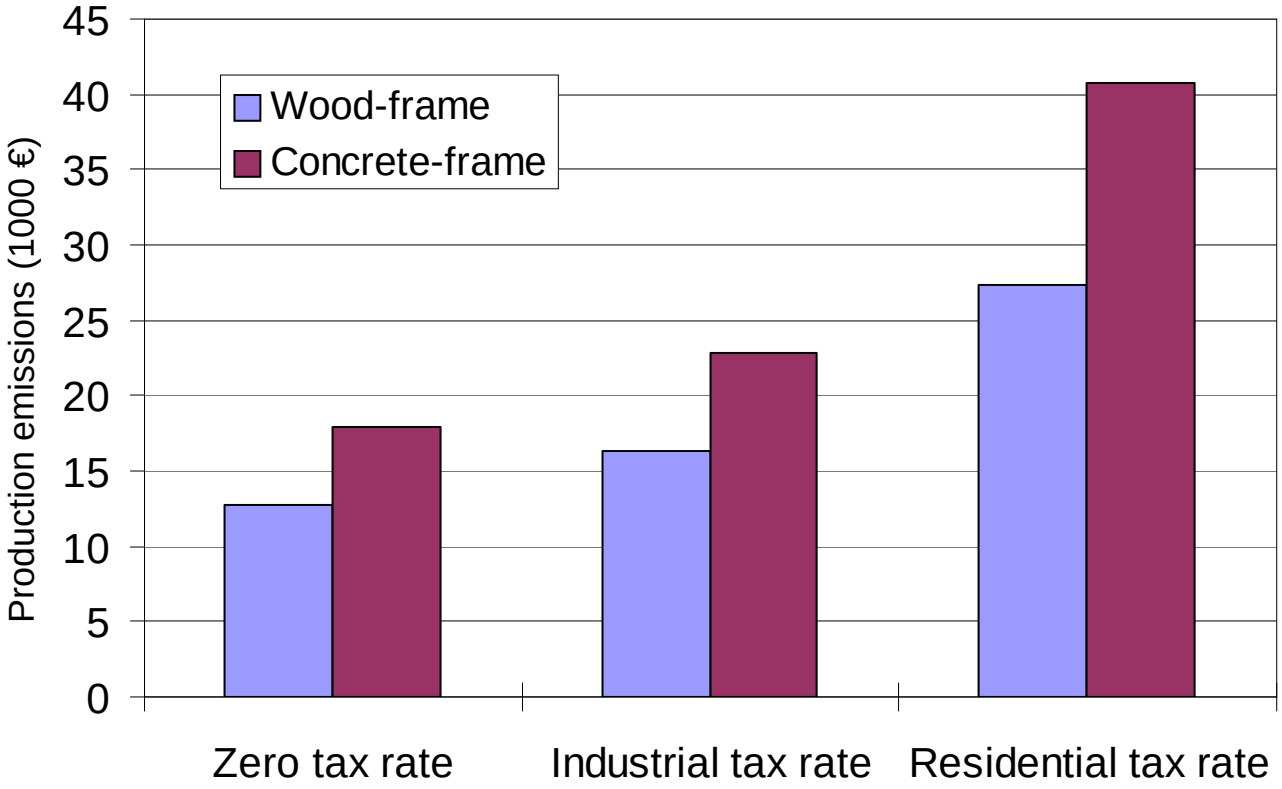
Cost of energy and carbon emissions from material production



Building cost ($€_{2005}$)

Wood frame:	**1,283,000**
Concrete frame:	**1,338,000**

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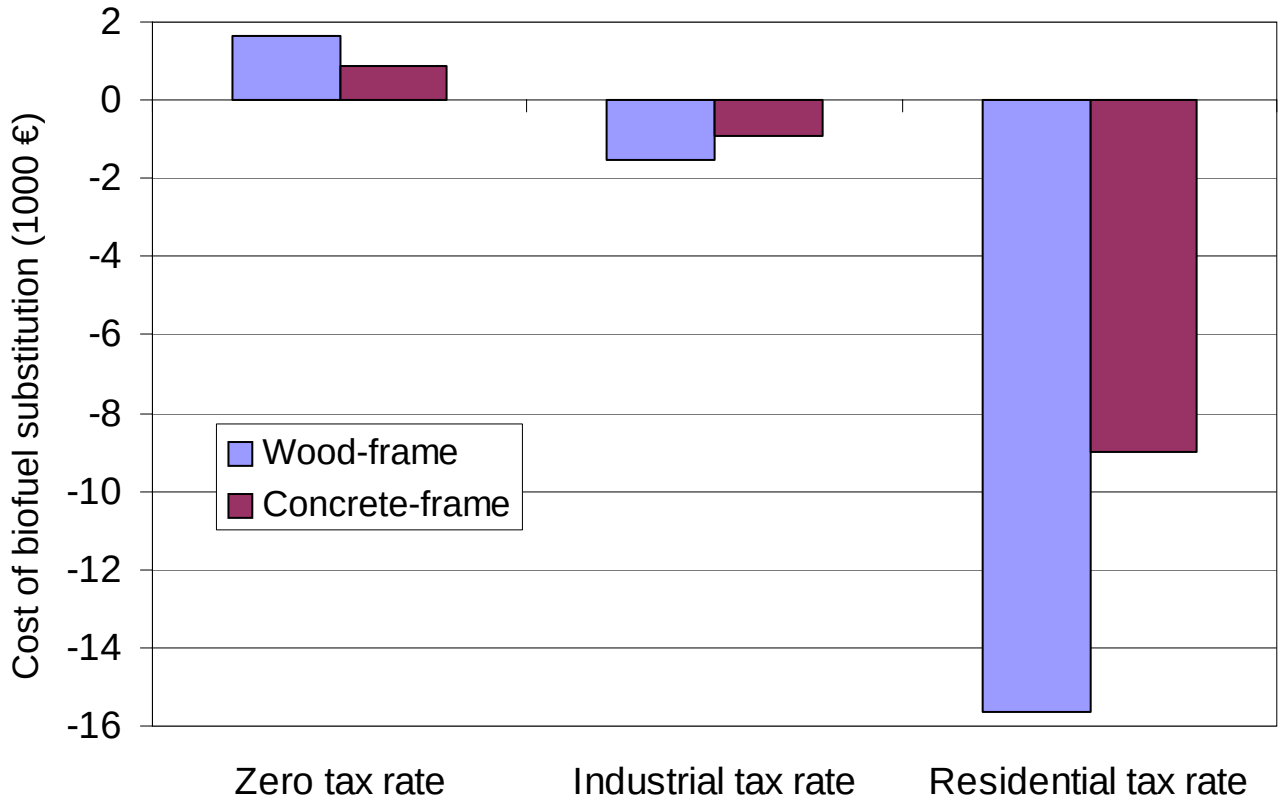
Cost of biofuel substitution
(cost difference between avoided coal and recovered biofuels)



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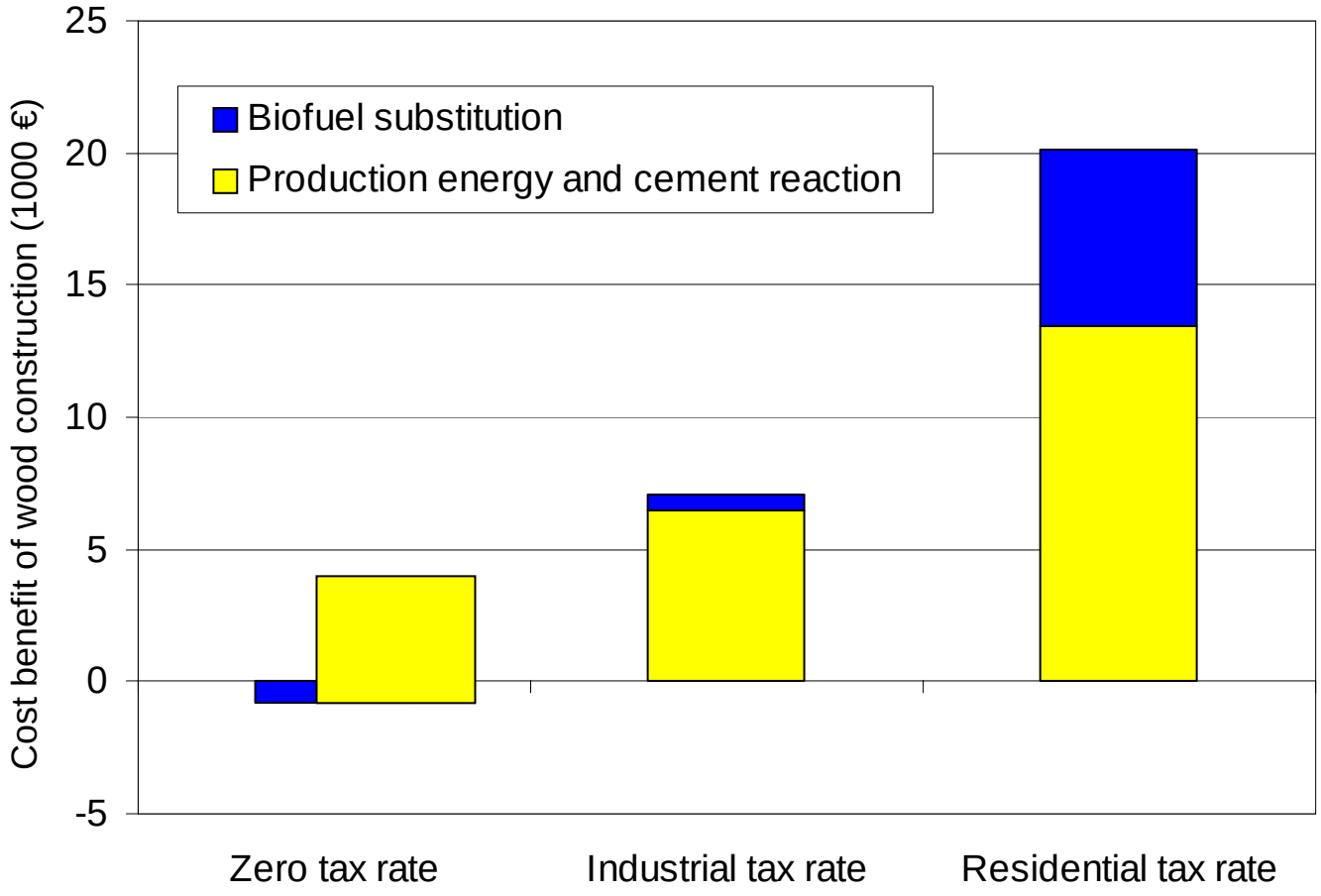
Energy and carbon emission cost difference between concrete- and wood-frame buildings



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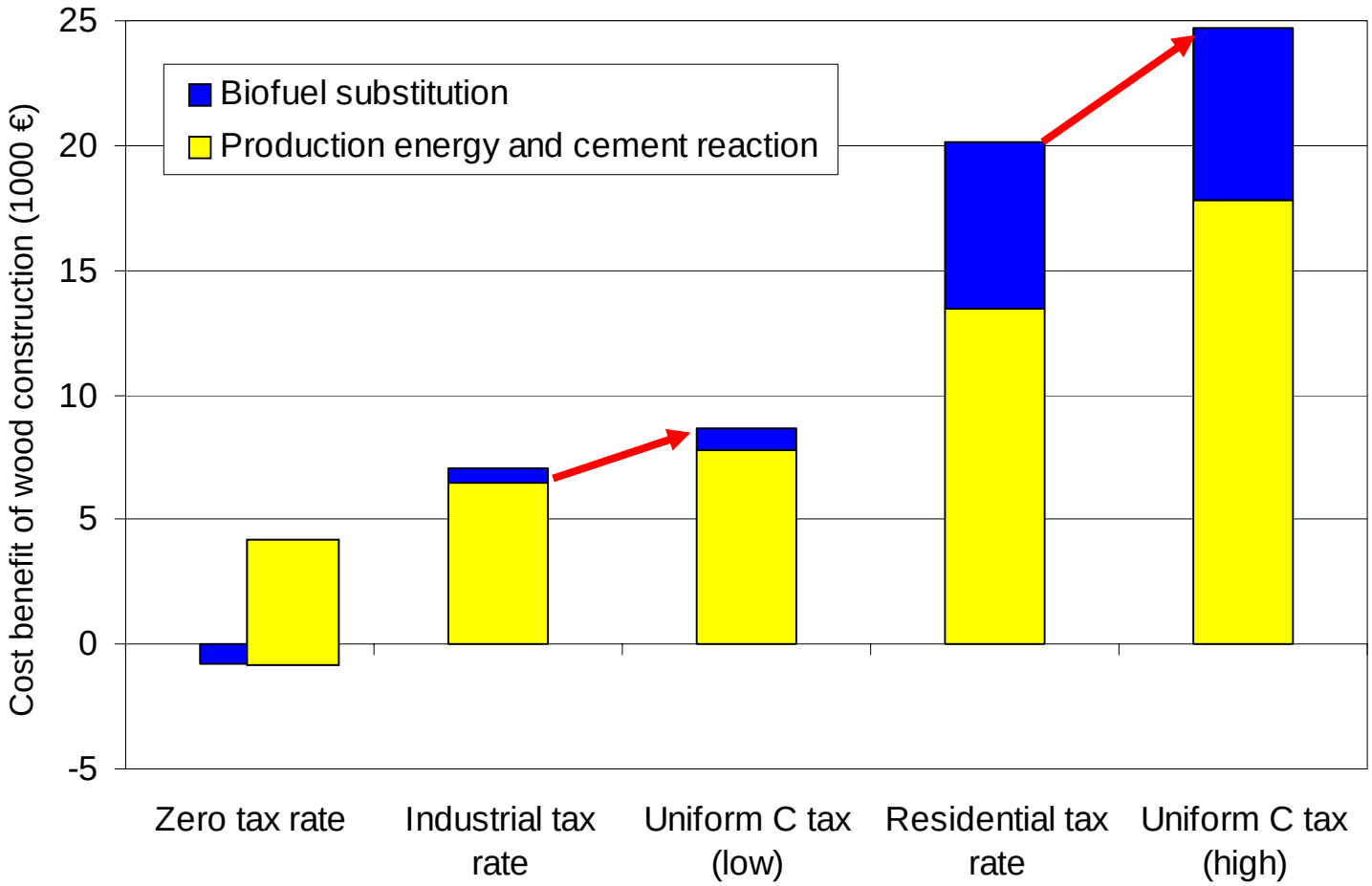
Cost benefit (energy and carbon) of wood construction considering a uniform carbon tax



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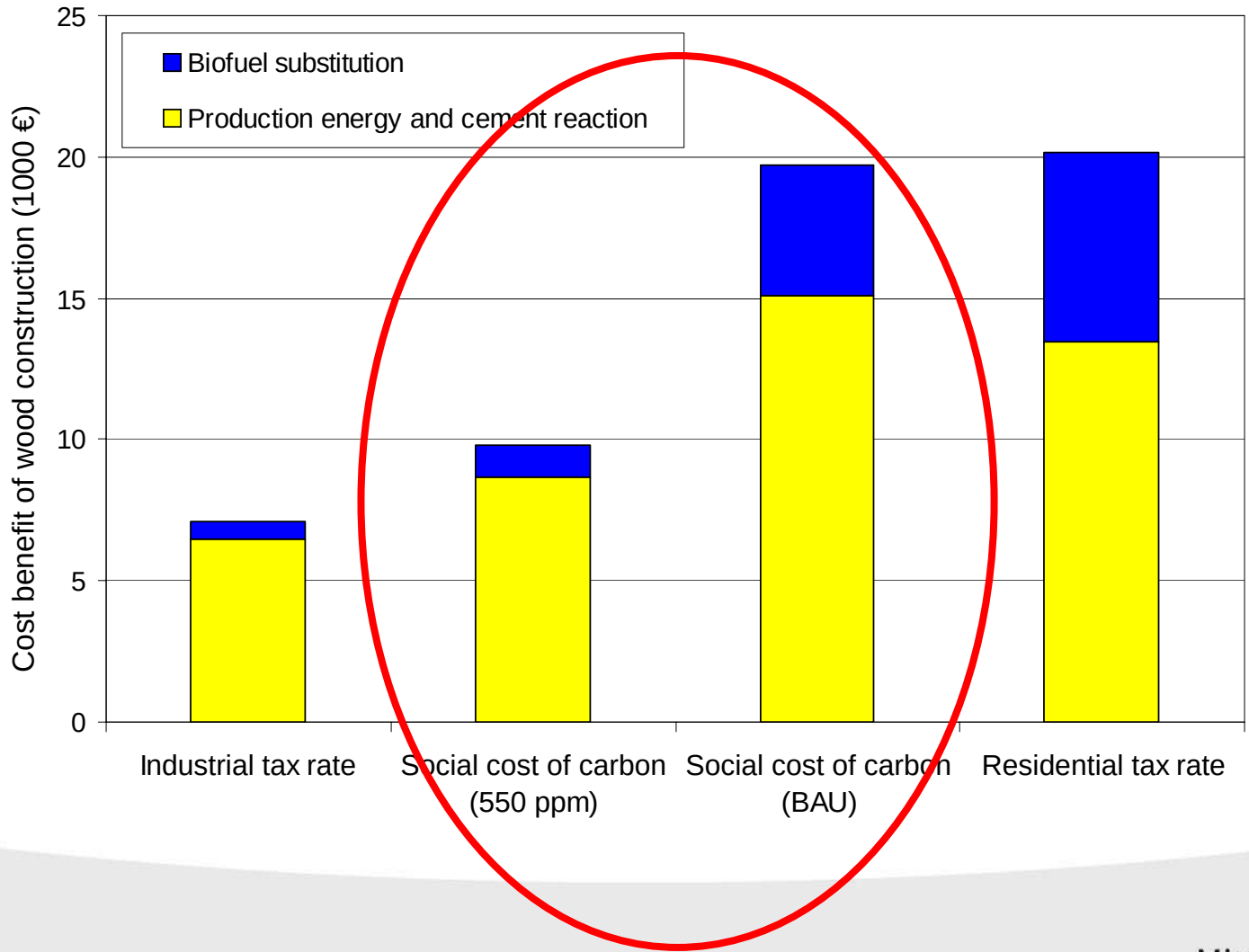
Cost benefit (energy and carbon) of wood construction considering social cost of carbon



Reference: Stern, N. et al., 2006, *Stern Review on the Economics of Climate Change*

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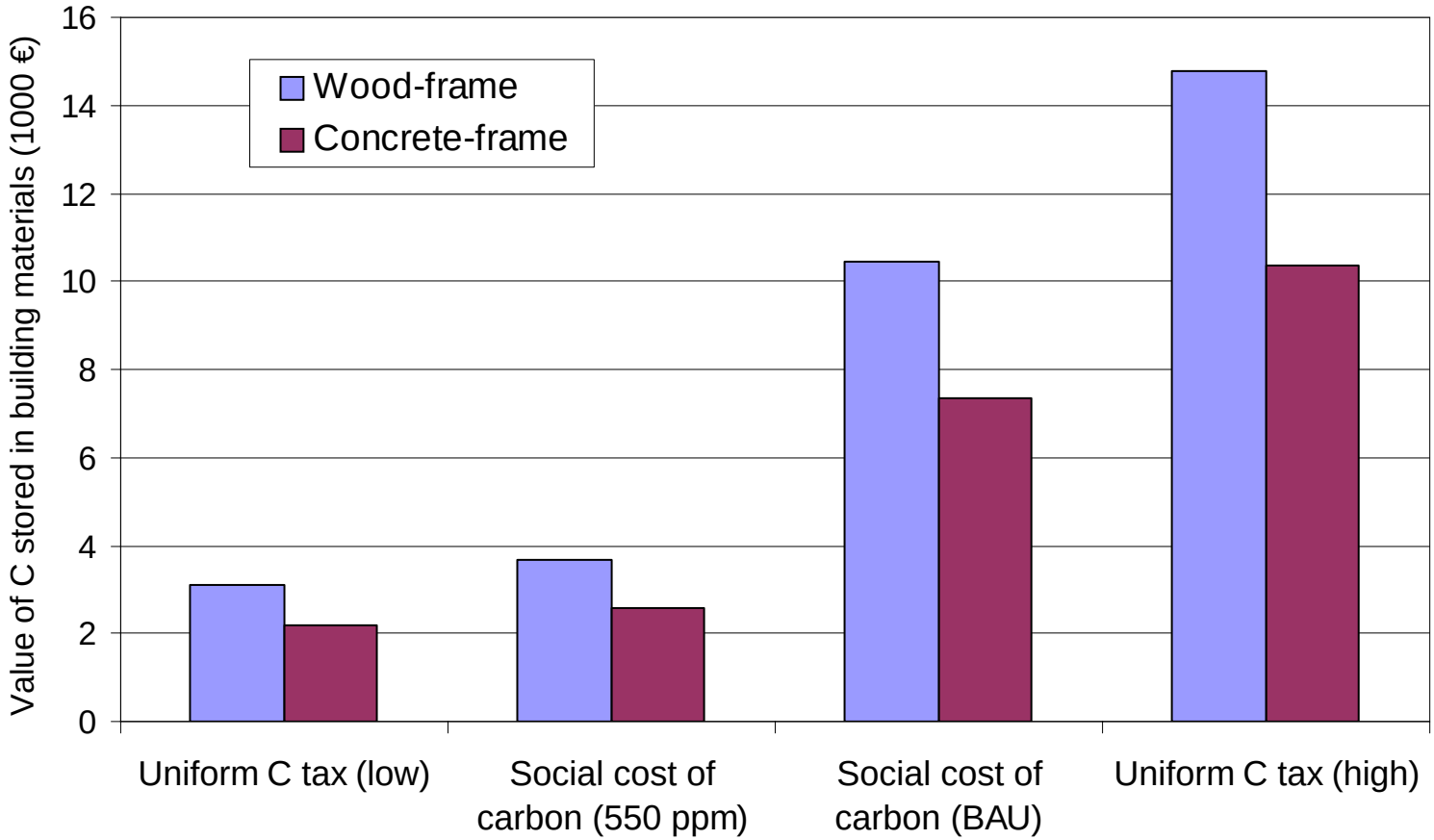
Value of C stored in wood building material



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Uncertainties

- Amount of each building material used varies with architectural and engineering design of building
- Primary energy used for the production of building materials varies with time, place, and technology
- Uncertainty analysis shows that wood building materials have lower energy and CO_2 balances than concrete materials over a wide range of parameter variations
- *Absolute* effect of energy/carbon taxes is somewhat uncertain, while *relative* effect is quite robust

Conclusions

- Taxes on fossil energy use and carbon emission give cost benefits to wood-frame construction relative to reinforced-concrete construction
- The greatest wood benefit comes from lower energy use and emissions during material manufacture
- Carbon tax changes the substitution value of biomass residues from negative to positive. Biofuel substitution benefits increase at higher tax rates
- The value of carbon storage in building materials is less significant and temporally
- Material costs will vary in *absolute* terms, but the *relative* effect of energy and carbon taxes remains valid

Thank you