Substitution effects of wood-based construction materials

Harvested wood products in the context of climate change policies
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Professor Leif Gustavsson

Department of Engineering and Sustainable Development
Mid Sweden University

Östersund, Sweden

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Outline

- Net CO_2 emission effects on wood-based construction
- Uncertainties
- Integrated analysis of forest production, soil carbon and wood substitution
- How could wood substitution be expanded

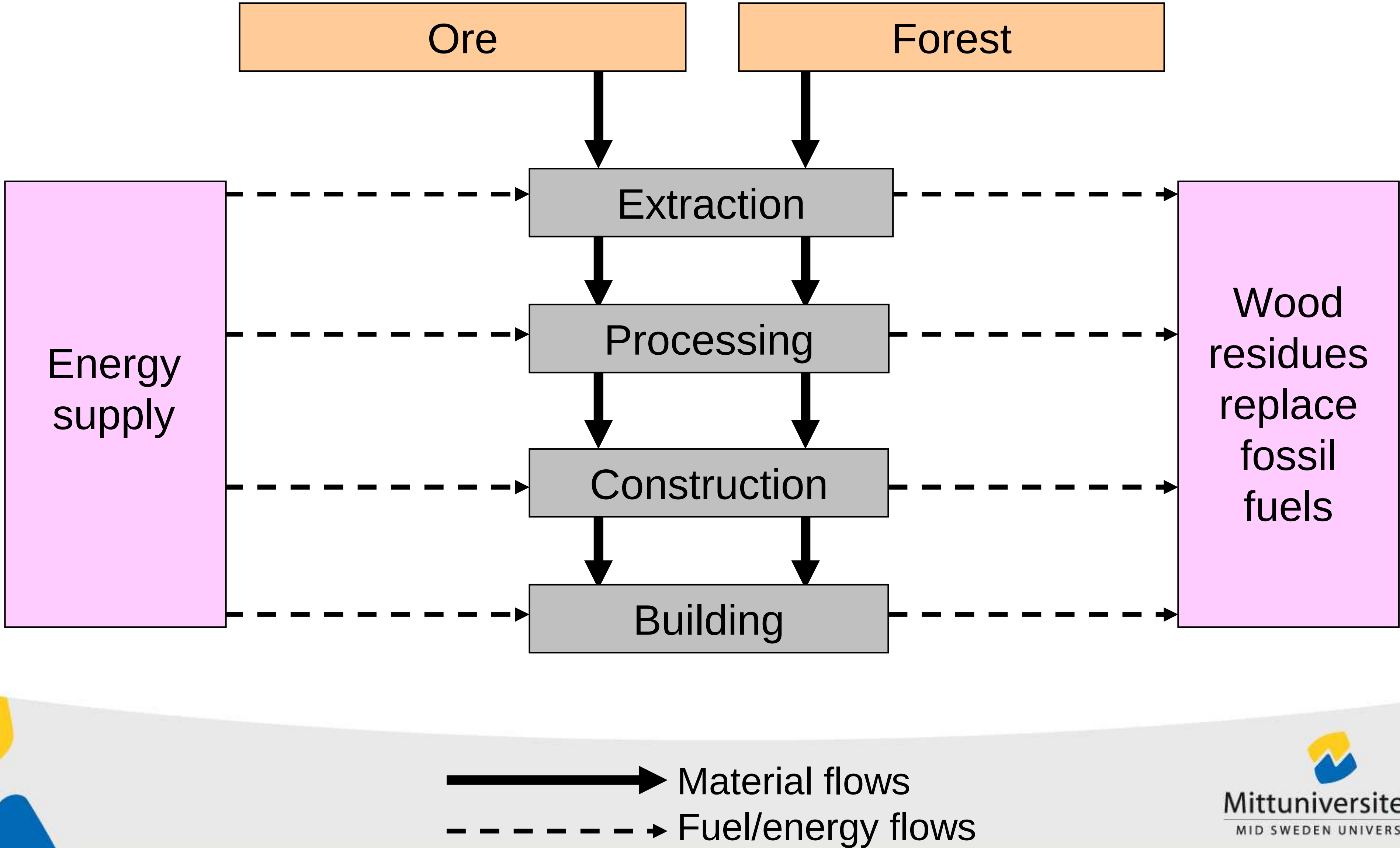
Greenhouse gas balances in building construction - a complex issue to analyse

- Few estimates based on few buildings
- The reference could be difficult to choose and define
- Primary energy use for the production of building materials varies
- Forest practices and wood product industries vary
- Energy supply systems vary

CO_2 balance of building production

- Fossil CO_2 emission from primary energy use for production and distribution of building materials and for assembly and demolition of buildings
- Substitution of fossil fuels with biomass by-products from forestry, wood processing, and demolition
- CO_2 balance of cement reactions (calcination and carbonation)
- Carbon storage in wood products

Building production material and energy flows – From natural resources to a building



A case study approach - Wälludden building

Case-study building: Wood frame

Built in Växjo, Sweden
Construction cost ≈ 1,221,000 $€_{2004}$

Reference building: Reinforced-concrete frame

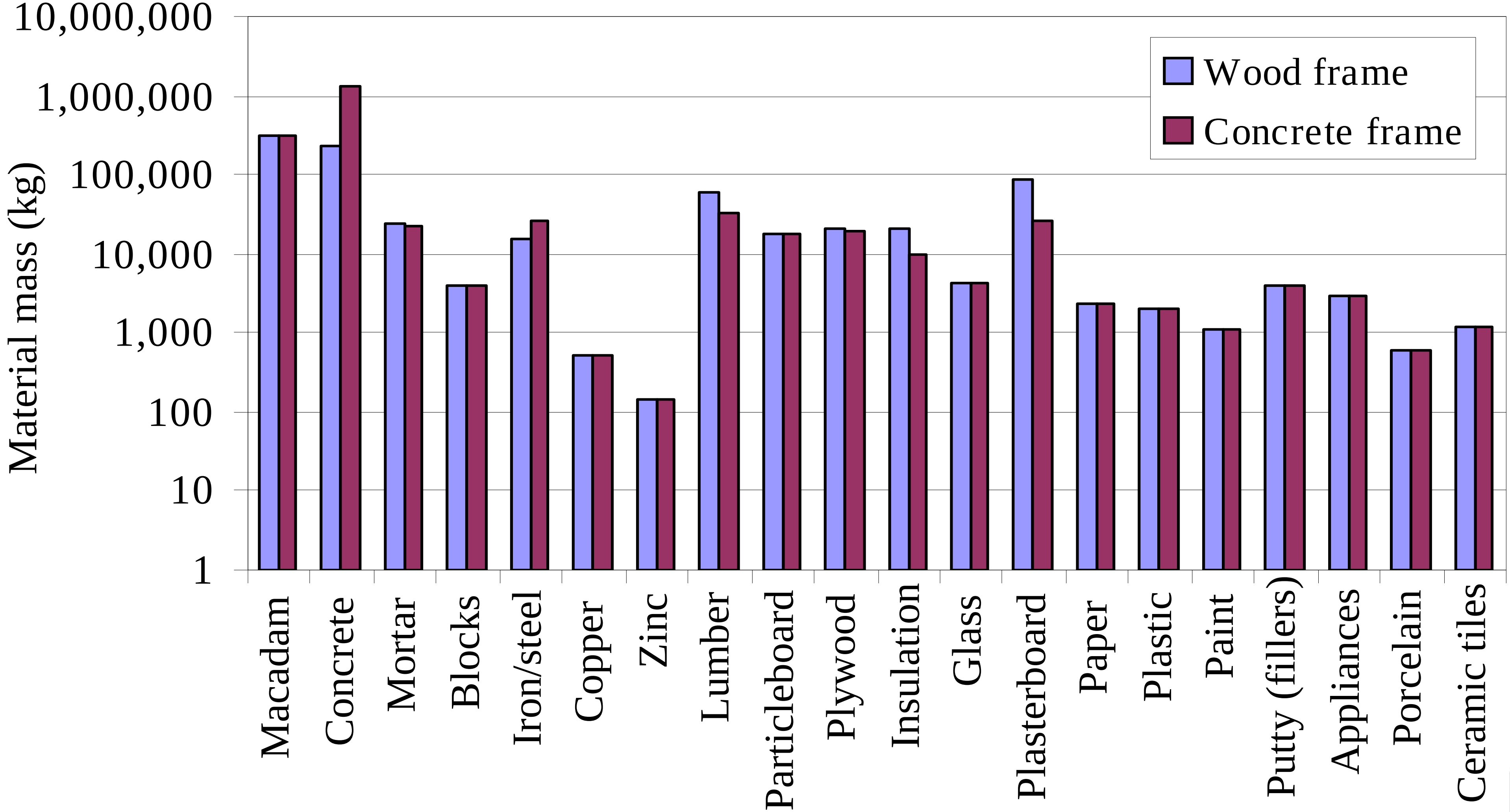
Hypothetical building with identical size and function
Construction cost ≈ 1,231,000 $€_{2004}$

4 stories, 16 apartments 1190 usable m^2

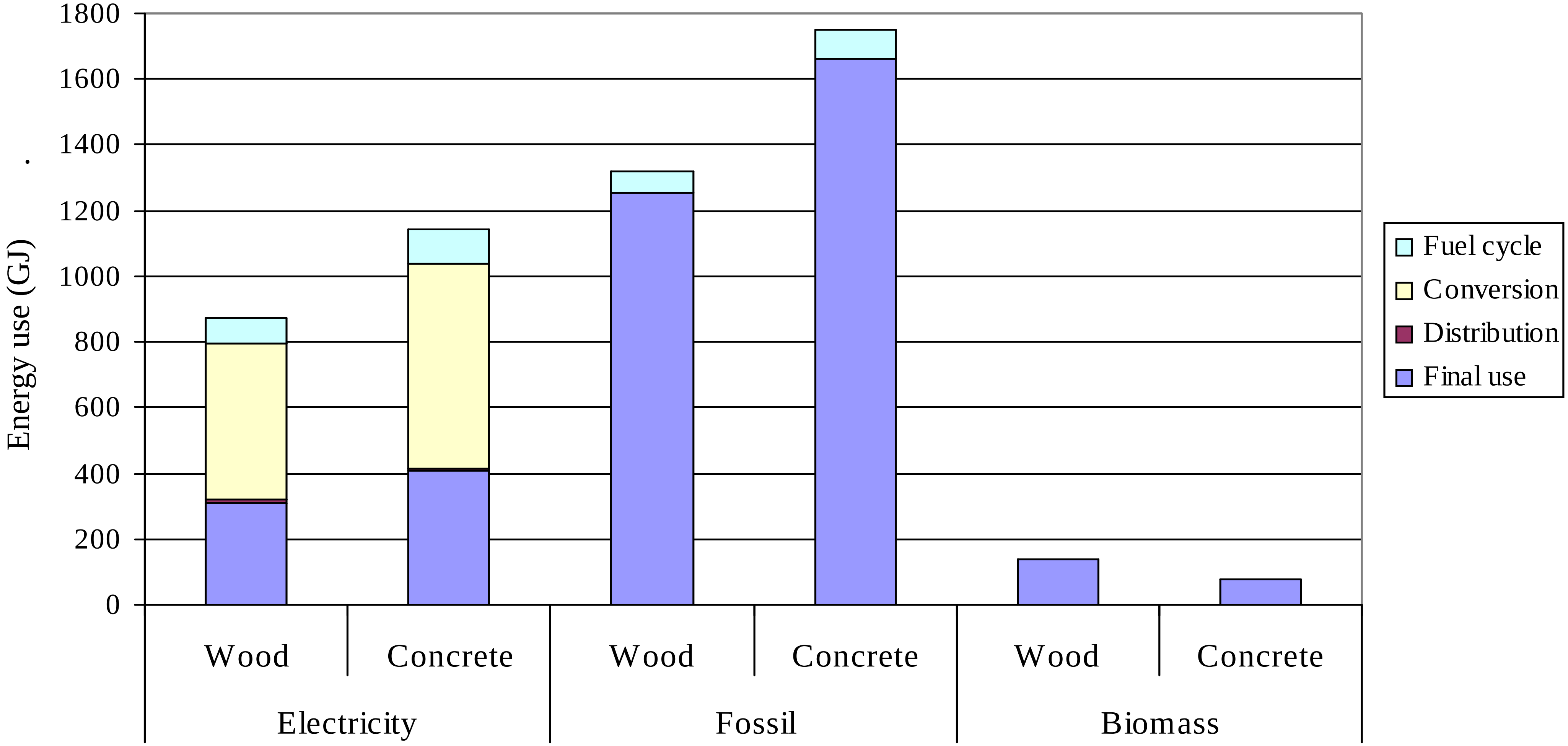
We have considered

- Primary energy use for production of buildings
- Electricity production in fossil condensing plants
- Fossil CO_2 emission from the full fuel cycle
- Substitution of fossil fuels by biomass by-products
- CO_2 balance of cement reactions
- Carbon cycle for wood products

All materials in the building are included



Primary and final energy use for material production



Source: Gustavsson et al. 2006, Sathre and Gustavsson 2007a

Sources of biomass residues

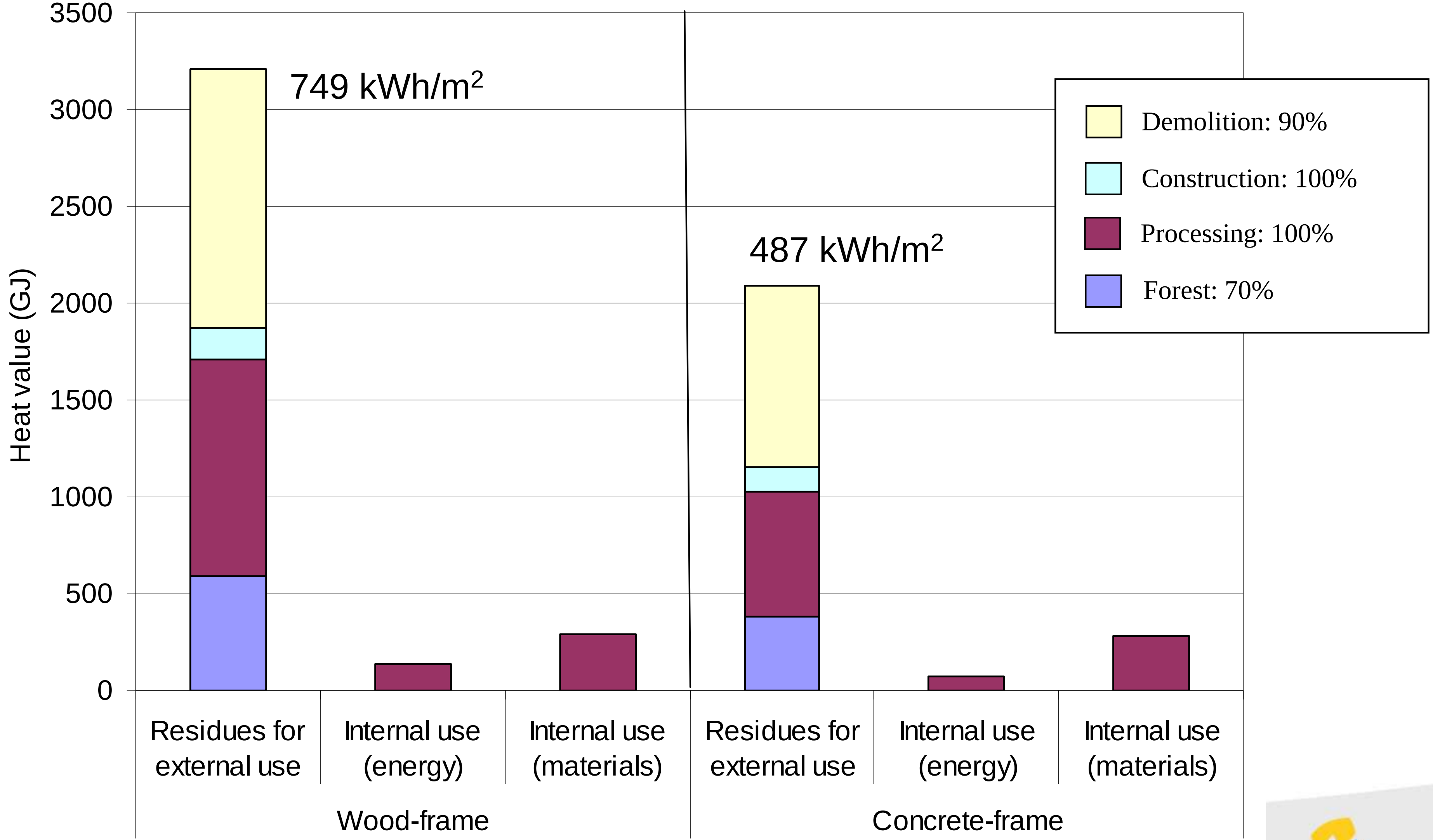
Forest residues

Wood processing residues

Construction residues

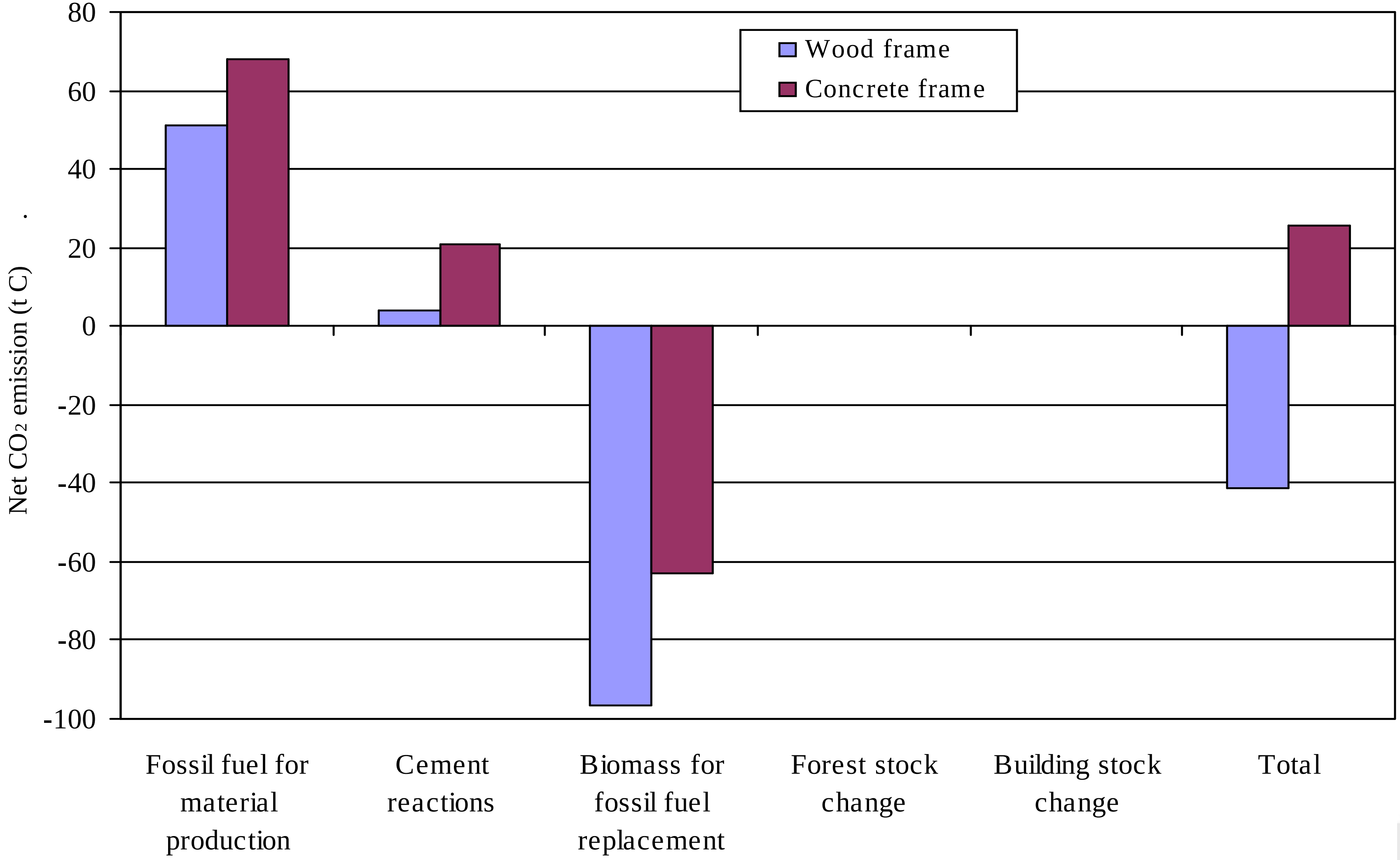
Demolition residues

Potential biomass residue recovery



Source: Gustavsson et al. 2006

Carbon balance of producing the buildings over a 100-year lifecycle



Coal is reference fuel

Source: Gustavsson et al. 2006

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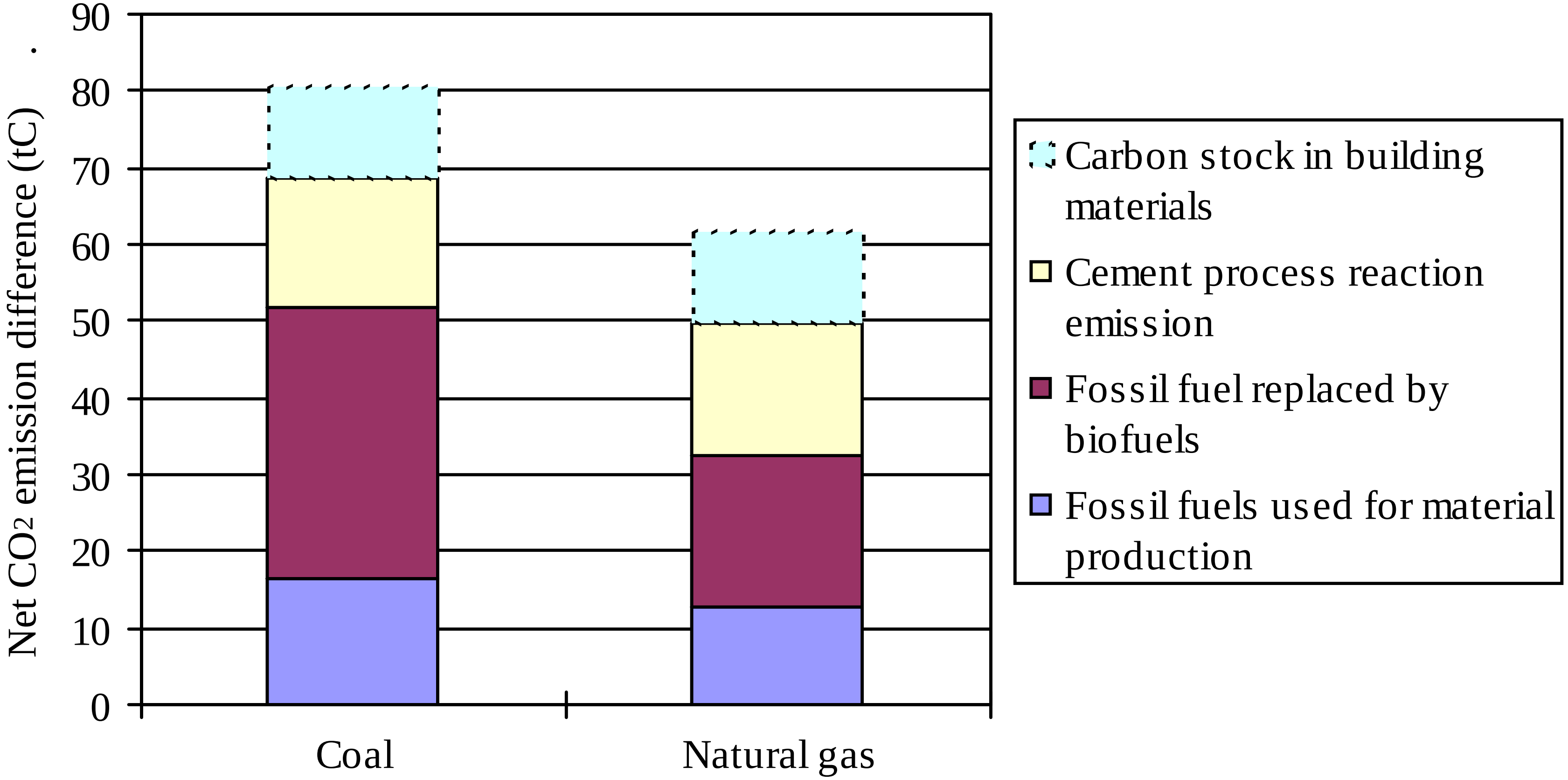
Increased life-cycle net emission of CO_2 if building is built with concrete frame instead of wood frame

Coal or natural gas is reference fuel



Source: Gustavsson et al. 2006

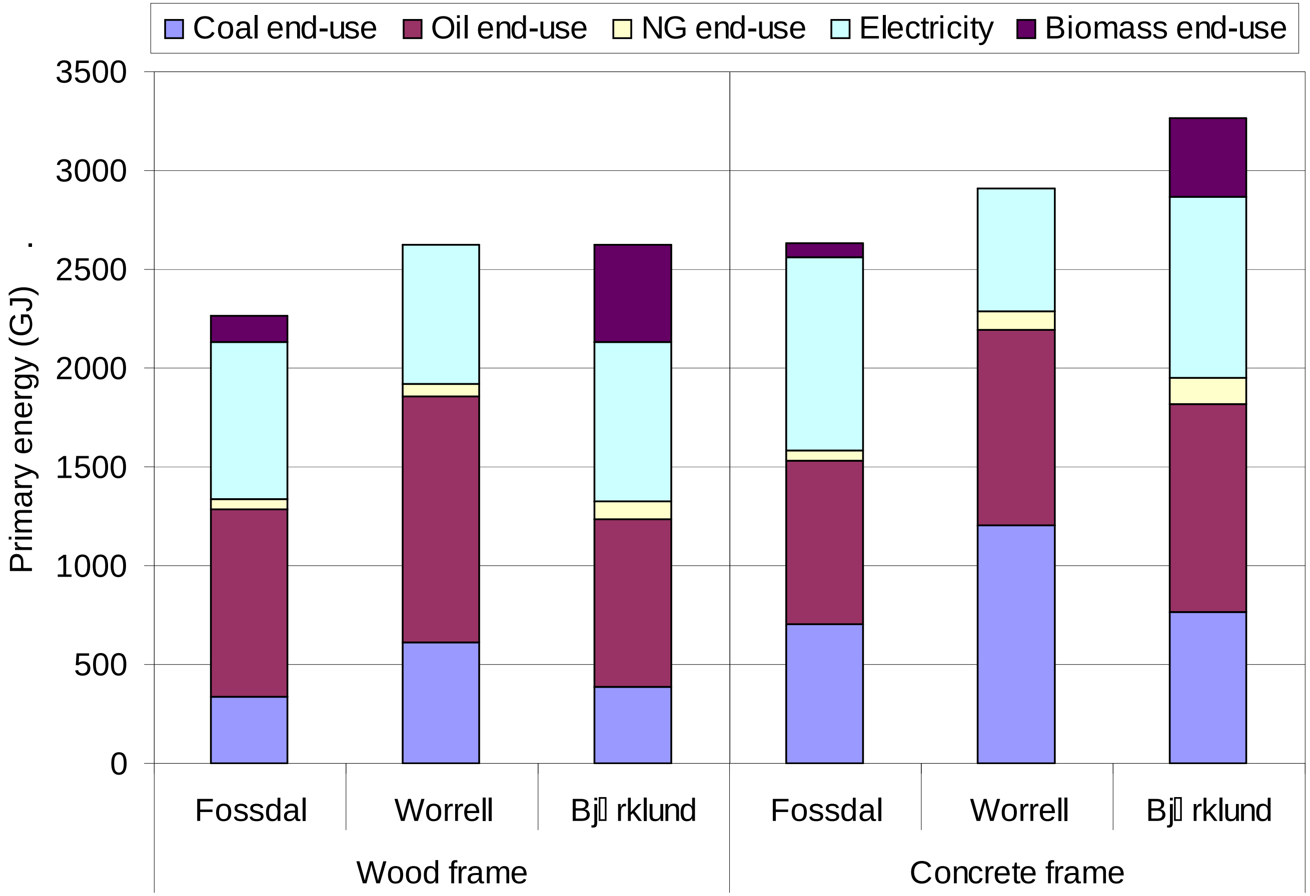
Conclusions

- Production of materials for wood-frame building uses less primary energy than for concrete-frame building
- Use of wood instead of concrete reduces net CO_2 emission
- Recovery of biomass residues to replace fossil fuels is important for the reduction of net CO_2 emission
- In lifecycle perspective, small net change in carbon stocks (forest stand and wood building)

Uncertainties

- Amount of each building material used vary with architectural and engineering design of building
- Primary energy used for the production of building materials varies with time, place, and technology

Primary energy use for material production – Input data from Norwegian, Dutch and Swedish studies



- Fossdal does not specify the type of fossil fuel used. We have disaggregated fossil fuel type using average values from Worrell and Björklund.
- Data for plywood are not included in the studies. We have used data from FAO.

Source: Gustavsson and Sathre 2006

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Variation in CO_2 emission due to different parameters

Parameter	**Base →**	**Variation**
0. Base case		
1. Cement clinker	dry process →	wet process
2. Cement content	Portland cement →	blended cemen
3. Concrete aggregate	crushed stone →	natural gravel
4. Concrete carbonation	8% →	2%
5. Concrete carbonation	8% →	32%
6. Steel material	recycled →	ore-based steel
7. Wood drying	batch kiln →	continuous kiln
8. Material transport	short →	longer distance
9a. Best case for concrete-frame building		
9b. Worst case for concrete-frame building		

Source: Gustavsson and Sathre 2006

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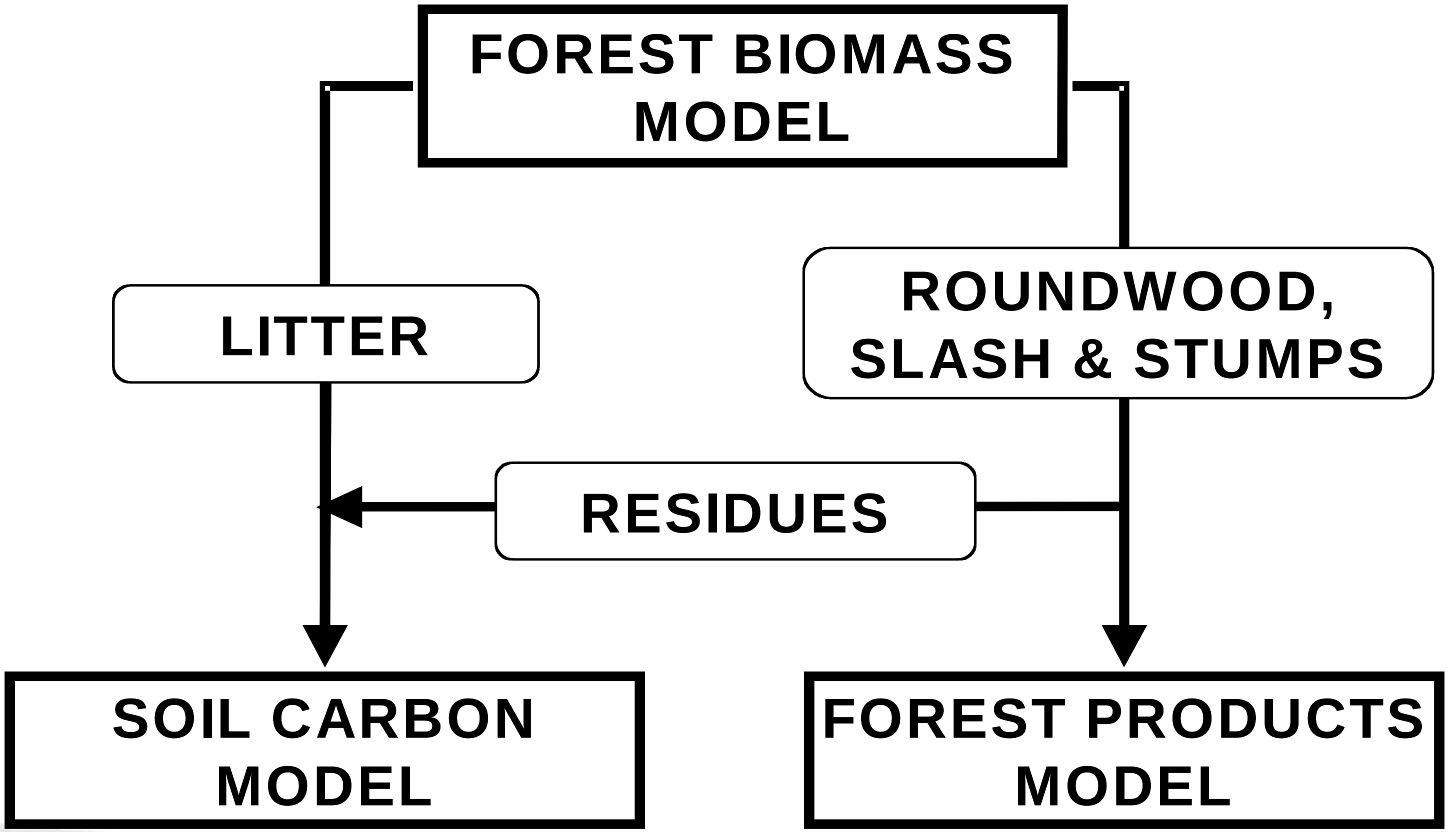
Conclusions

- Variation of system parameters, within practical limits, has moderate effects on the C-balance difference between wood and concrete frame buildings
- Wood-frame building consistently has lower net CO_2 emission: robust result
- Uncertainty remains in e.g. variation in material quantities in different types of buildings: more case studies needed

Different forest management practices and wood substitution: Integrated carbon analysis



Traditional and intensive forest management

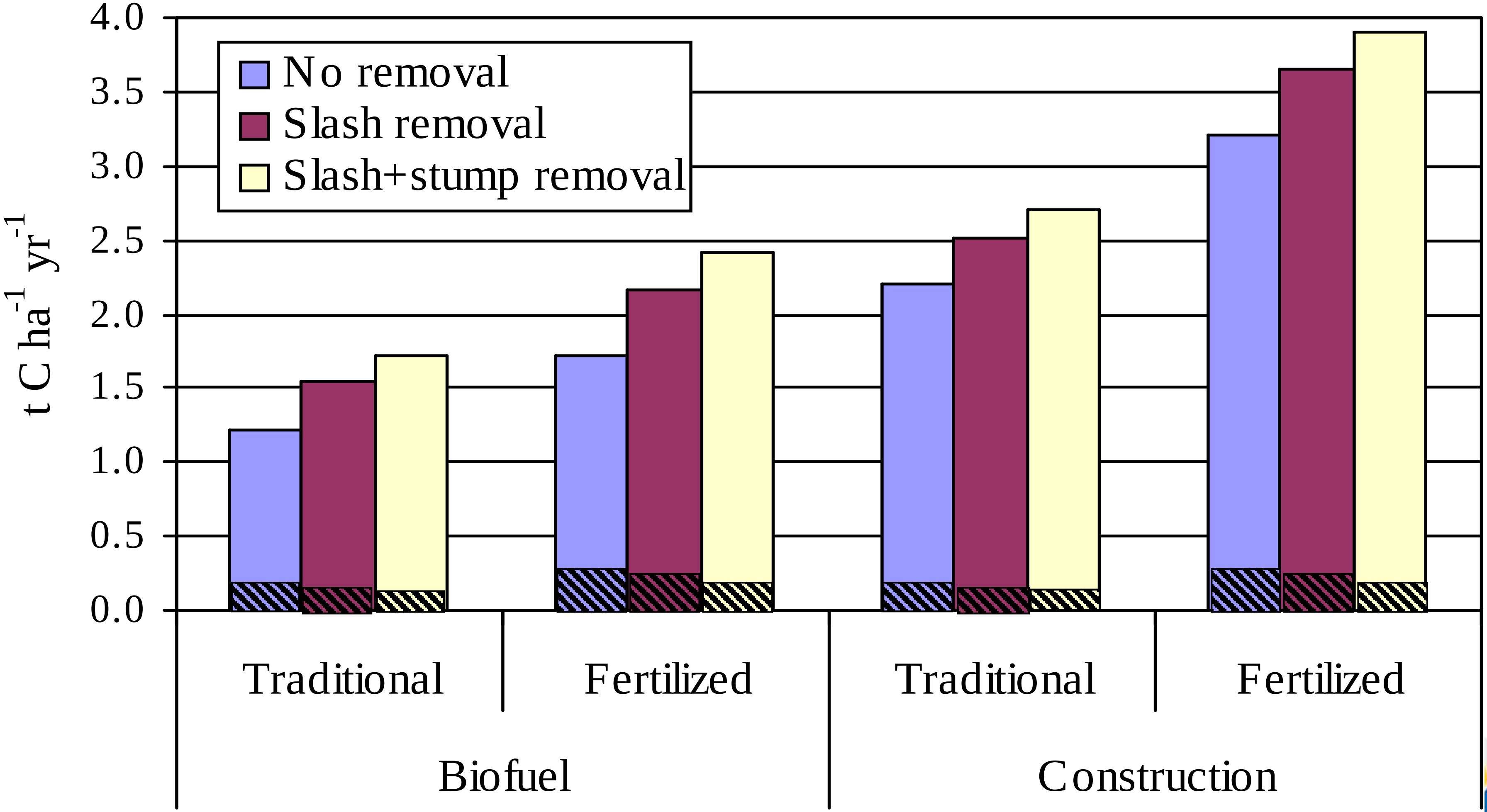
Norway spruce stands in central Sweden. Fertilized regime had 12 applications of CAN (125-150 kg N ha^{-1}) and NPK (125-150 kg N ha^{-1})

Characteristic	Traditional regime	Fertilised regime
Total age (yr) of trees at time of thinnings	37, 47, 62	27, 32, 42
Total age (yr) of trees at time of clear-cutting	92	67
Stem volume production per rotation (m^3 ha^{-1})	669	680
Mean volume production (m^3 ha^{-1} yr^{-1})	**7.3**	**10.0**
Mean biomass production (t d.w. ha^{-1} yr^{-1})	**5.0**	**7.1**

Source: Eriksson et al. 2007

Average CO_2 emission reduction of different forest management scenarios and product uses

tonne carbon per year and hectare of forest land

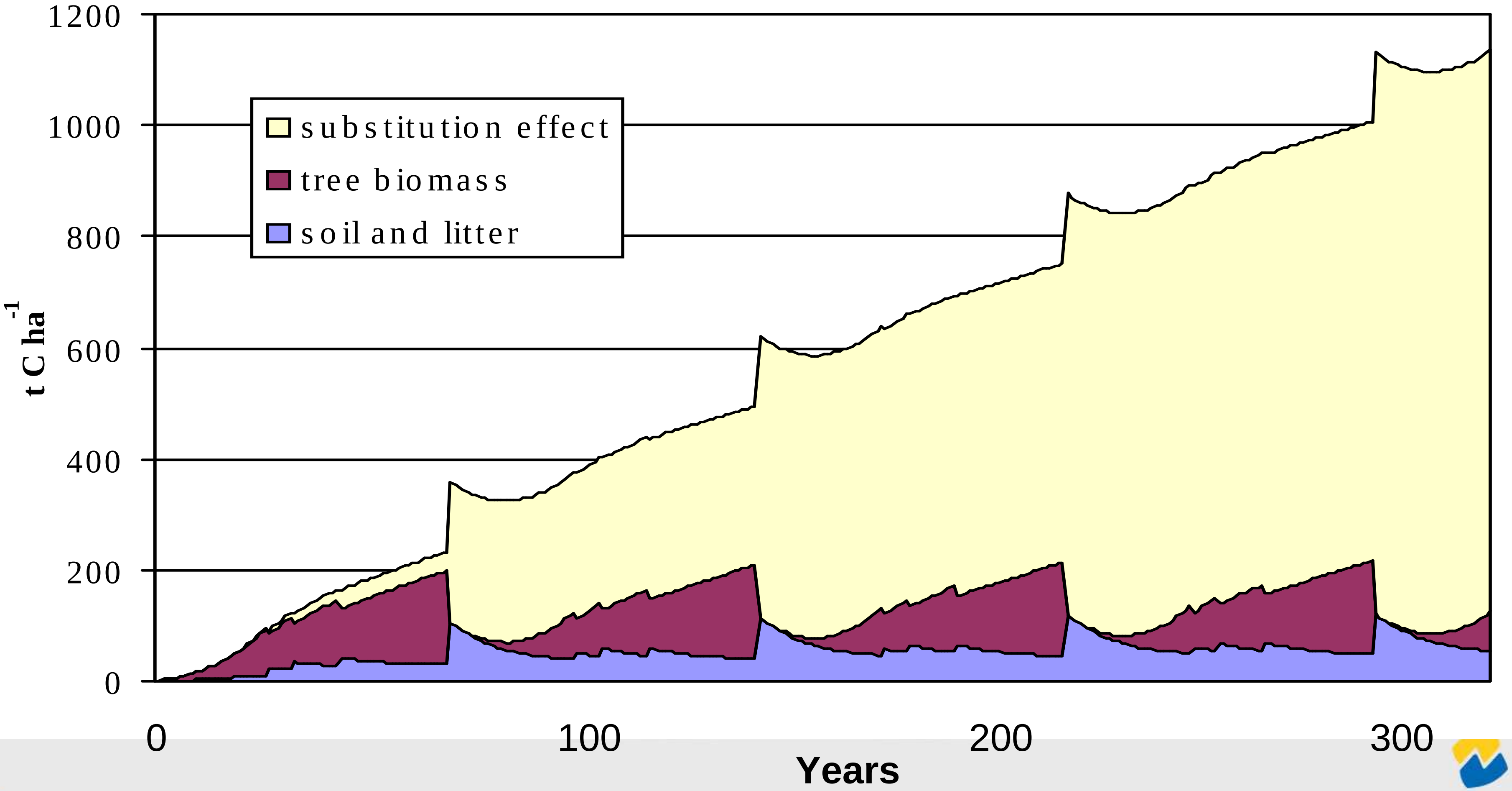


Source: Eriksson et al. 2007

Coal is reference fuel

Accumulated CO_2 emission reduction - maximum

- fertilised forest management
- recovery of slash and stumps
- product used as construction materials and bioenergy
- coal is the substituted fossil fuel



Source: Eriksson et al. 2007

Conclusions

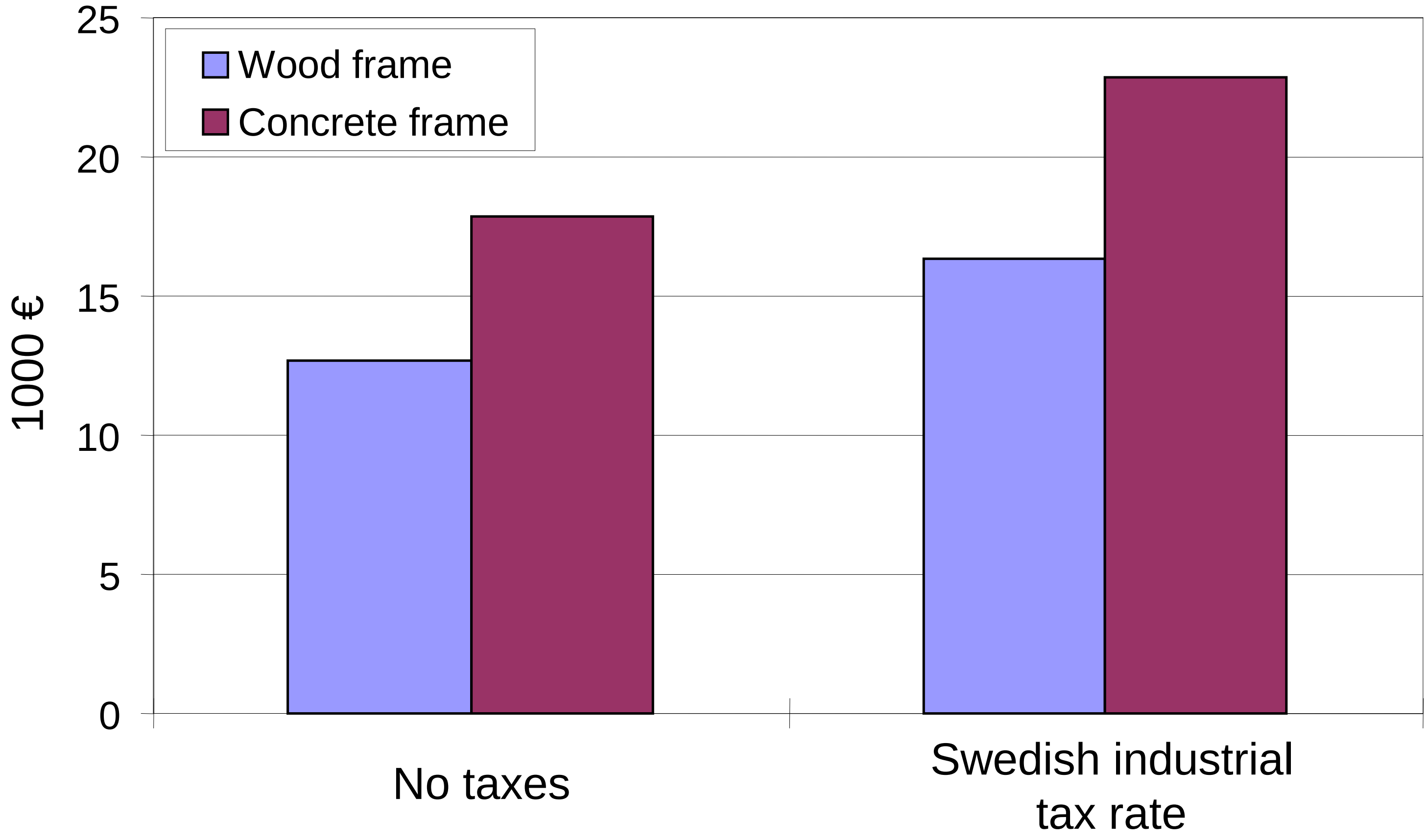
- Product substitution most important for carbon benefits
- More intensive forest management gives greater carbon benefits:
  - More wood production allows more material and fossil fuel substitution
  - Increased soil carbon content because of more litter
- Wood product use for construction and bioenergy gives greater carbon benefit than only for biofuel
- Using forest residues for biofuel more than compensates for soil carbon reduction

Effects of carbon taxes* on building material competitiveness

- Competitiveness is complex: depends on functionality, preferences, traditions, economics, etc.
- We consider two mechanisms that affect relative costs:
  - Energy for material manufacture
  - Use of biomass residues as biofuel

*Or a similar economic instrument used to promote the reduction of CO_2 emission

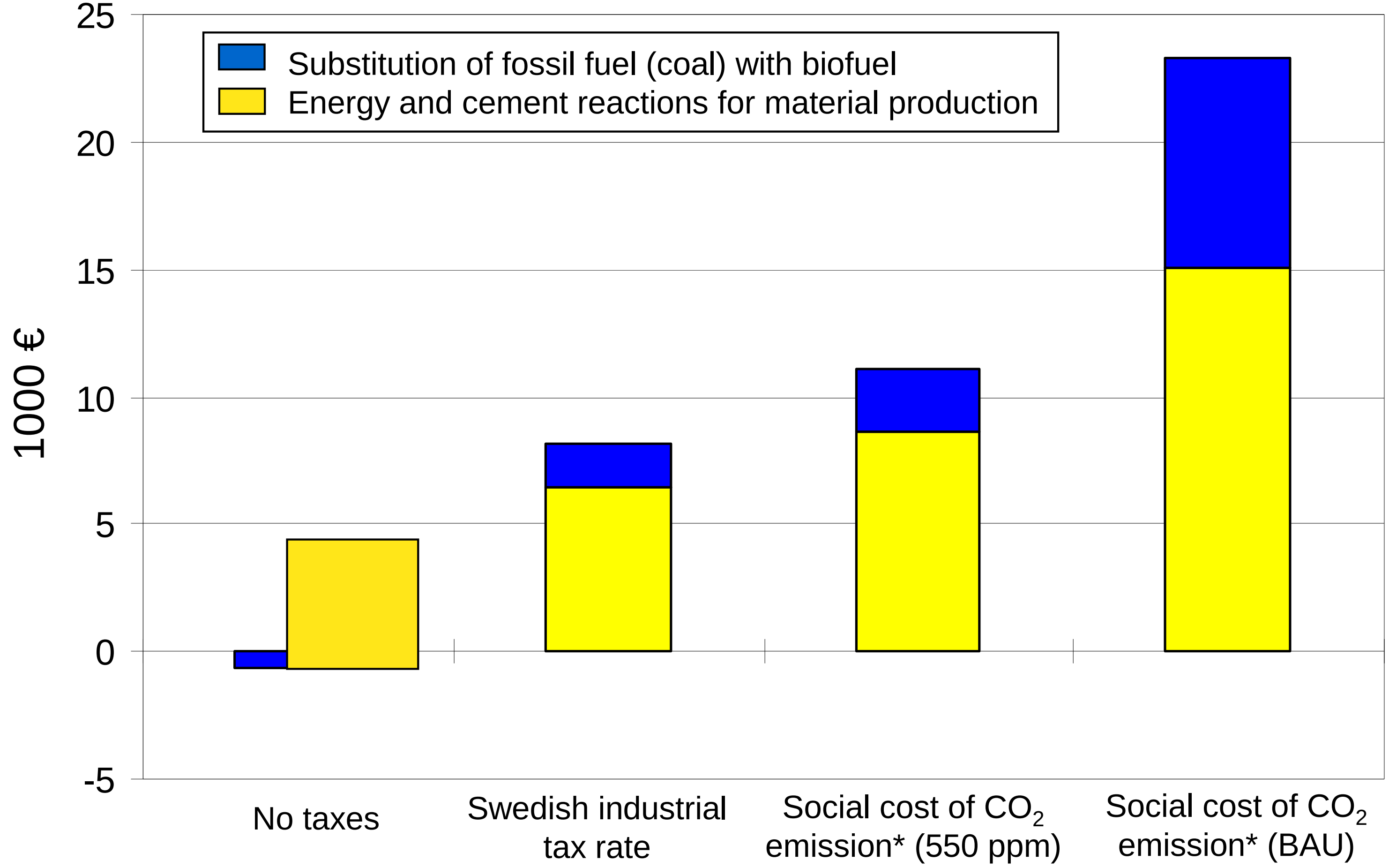
Material production – Cost for energy use and CO_2 emissions



Building cost	($€_{2005}$)
Wood frame:	1,283,000
Concrete frame:	1,338,000

Source: Sathre and Gustavsson 2007a

Cost for energy use and CO_2 emissions – Advantage of wood building compared to concrete building



* *Stern Review on the Economics of Climate Change*, 2006

Source: Sathre and Gustavsson 2007a

Conclusions

- Cost for energy use for material production is 1-2% of building cost, and is lower for wood building
- Without economic policy instruments, it is not profitable to use biomass residues to substitute for fossil coal
- Economic competitiveness of wood construction increases with increased CO_2 taxation
- Social cost of CO_2 emission estimated by Stern Report is higher than current Swedish industrial tax rate

Summarising conclusions …

- Primary energy use and CO_2 emission are lower for producing wood-frame buildings than concrete-frame buildings
- Using biomass by-products to substitute for fossil fuels reduces CO_2 emission
- In a life cycle perspective, the net change in carbon stock (in forest stand and building) is small

Summarizing conclusions

- Wood construction gives high CO_2 emission reduction per hectare of forest land
- Competitiveness of wood construction increases with higher carbon taxes
- Product substitution most important for carbon benefits

References:

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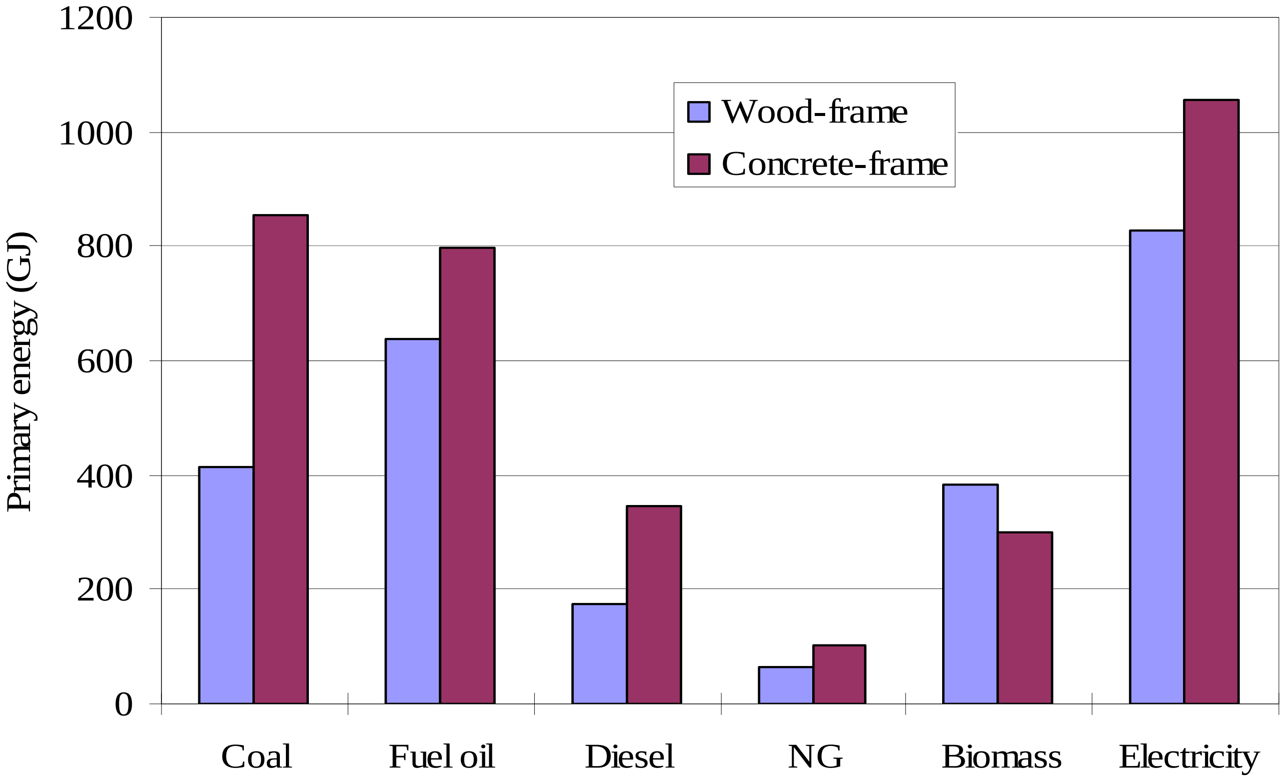
Wood is a limited resource that needs to be used wisely and efficiently

Thank you

Material production energy for a wood-frame and a concrete-frame building

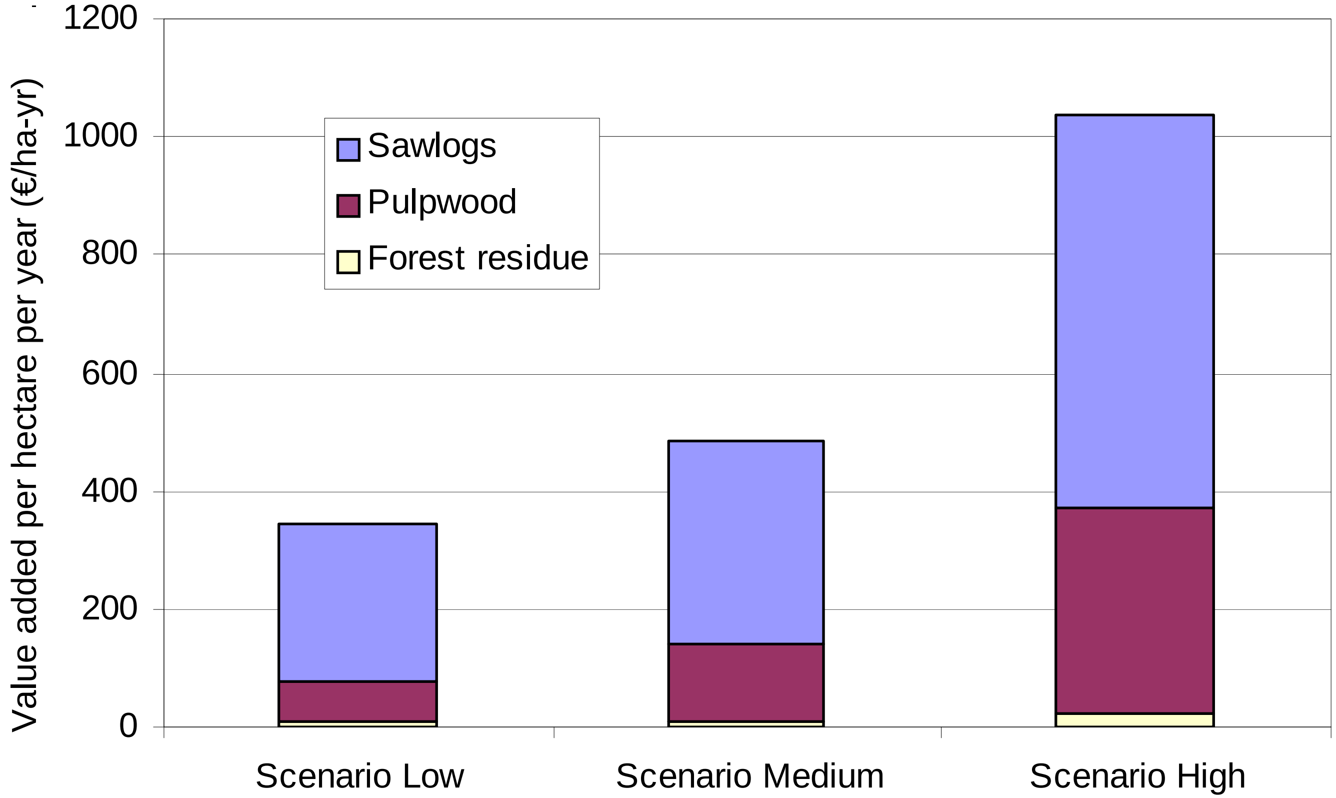
Functionally equivalent wood-frame and concrete-frame versions of multi-storey apartment building



Total primary energy (GJ) used for material production

Source: Gustavsson et al. 2006, Sathre and Gustavsson 2007a

Wood construction gives high value added per hectare of forest land



Scenario	**Slash**	**Pulplogs**	**Sawlogs**
Low	Pellets	Market pulp	Sawn lumber *
Medium	Ethanol	Newsprint	Planed lumber *
High	Methanol	LWC paper	Glu-lam beams and planed lumber *

* By-products valued as biofuel

Source: Sathre and Gustavsson 2007b

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Promoting use of wood in (multi-story) construction

- Implementing policies to internalize the external costs of producing the building materials
- Education of professionals, policy and decision makers, the general public about wood constructions
- Encourage entry of new firms
- Facilitate existing firms to move beyond small-scale experiments
- Co-ordination and collaboration between different sectors and actors
- Harmonize European standard for wood construction

Source: Mahapatra and Gustavsson 2008