Fossil C emissions associated with C flows of wood products

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Motivation of the study:

- Harvested wood products (HWP) are basically a renewable non-fossil C resource, which can act as **C sink** and **substitute** for other fossil-fuel intensive products.

- However, during the life cycle of HWP **fossil fuels** are used in harvesting, manufacture, transportation etc.

- These **side effects** in the form of fossil C emissions determine e.g., how effective tools various HWP can be in GHG mitigation.

Aims of the study:

- Consider the **manufacture part** of the HWP life cycle

- Average specific **fossil C emissions** and **primary energy use** associated with manufacture of wood products in Finland

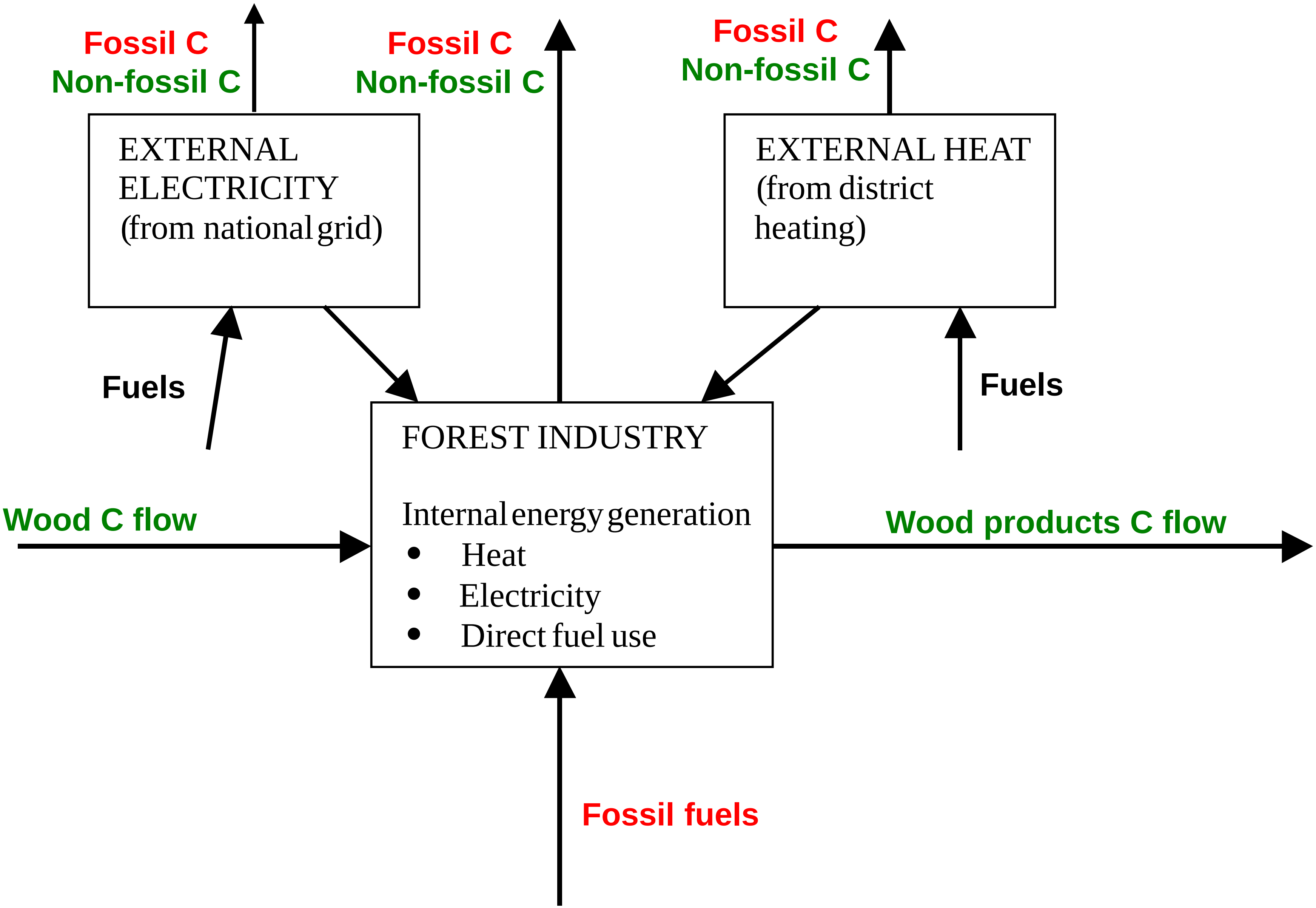
- Expressed in terms of emission or energy **per C in wood material flow** (**raw material** flow and **end product** flow)

- Approximate comparison with fossil C emissions of **harvesting and transportation**

Aims of the study:

• Development of a model for C emissions of manufacture of HWP in Finland, used in a more comprehensive study (Liski et al.), where the **influence of rotation length on the different C pools (vegetation, soil, and HWP)** of the forest sector was considered.

C emissions associated with manufacture of wood products



Methods:

C emission and energy model of the Finnish forest industries in 1995

- C emissions and primary energy consumption **allocated to main product groups** in mechanical wood processing and pulp&paper manufacture.

- ‘Lumped’ product groups: **sawn wood, plywood, particle board, wood fibre board,** and *production lines* based on **mechanical pulping, chemical pulping, and recycled fibre**.

Basic parameters of the C emission and energy model

Mechanical wood processing:

Specific consumption of heat and electricity

	Production 1995 1000 m^3/a	**Heat MWh/m^3**	**Electricity MWh/m^3**
Sawnwood	9400	**0.22**	**0.078**
Plywood, block board	778	**1.10**	**0.30**
Particle board	485	**0.49**	**0.18**
Wood fibre board (1000 t/a and MWh/t)	79	**2.11**	**0.64**

Reference: Lehtilä, VTT Energy, 1995

Basic parameters of the C emission and energy model

Mechanical wood processing:

Energy supply

	Sawn wood	Plywood	Particle board	W. fibre board
Internal energy generation				
Assumed efficiency of heat production = 80 %				
Fuels:				
Coal	6 %	0 %	0 %	1 %
Oil	14 %	16 %	40 %	5 %
Peat	1 %	1 %	0 %	7 %
Gas	29 %	1 %	0 %	0 %
Biomass	50 %	82 %	60 %	86 %
Selfgenerated electricity				
% of internal energy generation	13 %	3 %	0 %	7 %
External energy (share of total supply)				
Heat (district h. + pulp&paper i.)	20 %	20 %	20 %	20 %
Electricity (national grid)	60 %	90 %	100 %	77 %

Reference year: 1995.

References: Finnish Environment Institute, Statistics Finland (unpublished databases); A. Lehtilä, VTT Energy, pers.comm.

Basic parameters of the C emission and energy model

Mechanical wood processing:

Energy supply

- Allocation principle: process by-products (like wood residues of saw milling), used in other processes (like pulping or particle-board manufacture) for **raw material** and/or **energy**, are not accounted for the primary process.

- Only the actual reported use of **by-product biofuels** of the considered manufacture process is included in the above numbers.

Basic parameters of the C emission and energy model

Pulp and paper industry:

Modelling principles

• Lumped representation of pulp&paper industry, which means that the branch is divided into **three pulp-type based production lines** (incl. pulping+papermaking), based on:

mechanical and chemical pulping and recycled fibre.

• The emissions/primary energy of manufacture paper grades are **allocated** to the pulp-type based production lines according to the paper **recipe mix** and added to the emissions/primary energy of pulping.

Basic parameters of the C emission and energy model

Pulp and paper industry:

• **Paper recipes in 1995**

		Mechanical pulp					Chemical pulp			Recycled pulp		
Main paper grades	**t paper / t pulp**	GWP, NB	GWP, B	TMP, NB	TMP, B	SCP .	HSUP, B	SSUP, NB	SSUP, B	REC, NB	REC, B	*SUM*
Chemical pulp board	**1.02**	0	0	0	0	0	0.527	0.000	0.473	0	0	*1.00*
Mechanical woodpulp containing board	**1.01**	0.347	0	0.183	0	0	0.216	0	0.165	0.089	0	*1.00*
Fluting	**0.96**	0	0	0	0	1.000	0	0	0	0	0	*1.00*
Liner	**0.99**	0	0	0	0	0	0.107	0.731	0.106	0.056	0	*1.00*
Other papers (tissue etc)	**0.98**	0.113	0	0	0	0	0.148	0.105	0.215	0.127	0.293	*1.00*
Other papers (kraft etc)	**0.97**	0	0	0	0	0	0.107	0.731	0.106	0.056	0	*1.00*
Newsprint paper	**0.99**	0.292	0.024	0.530	0.032	0	0	0	0.059	0	0.062	*1.00*
Fine grade paper, coated	**1.59**	0	0	0	0	0	0.680	0	0.292	0	0.028	*1.00*
Fine grade paper, uncoated	**1.22**	0	0	0	0	0	0.680	0	0.292	0	0.028	*1.00*
Mechanical woodpulp paper, coated	**1.49**	0	0.354	0	0.242	0	0	0	0.395	0	0.010	*1.00*
Mechanical woodpulp paper, uncoated	**1.24**	0	0.354	0	0.242	0	0	0	0.395	0	0.010	*1.00*

Reference: Lehtilä, VTT Energy, personal communication

Basic parameters of the C emission and energy model

Pulp and paper industry:

Specific consumption of heat, electricity and direct fuels

- **Pulping**

Main pulp grades	Production 1995 1000 t/a	Direct fuels MWh/t	Heat MWh/t	Electricity MWh/t	
Groundwood, unbleached	801		**0**	**1.55**	**MECHANICAL PULP**
Groundwood, bleached	1167		**0**	**2.10**	
Thermomechanical pulp, unbleached	943		**-0.75**	**2.40**	
Thermomechanical pulp, bleached	818		**-1.17**	**3.37**	
Semi-chemical pulp	509		**1.06**	**0.40**	
Hardwood sulphate pulp, bleached	2174	**0.39**	**3.07**	**0.69**	**CHEMICAL PULP**
Softwood sulphate pulp, unbleached	680	**0.52**	**2.77**	**0.57**	including drying of
Softwood sulphate pulp, bleached	2928	**0.52**	**3.33**	**0.75**	51% of produced pulp*
Recycled pulp, unbleached	180		**0**	**0.10**	**RECYCLED PULP**
Recycled pulp, bleached	272	**0.25**	**0.17**	**0.40**	
Total pulp production	*10472*				
	*Pulp drying		**0.97**	**0.14**	

Reference: Carlson and Heikkinen, Jaakko Pöyry, 1998

Basic parameters of the C emission and energy model

Pulp and paper industry:

Specific consumption of heat, electricity and direct fuels

• **Paper manufacture**

Main paper grades	Production 1995 1000 t/a	Direct fuels MWh/t	Heat MWh/t	Electricity MWh/t
Chemical pulp board	600	**0.03**	**1.92**	**0.85**
Mechanical woodpulp containing boarc	979		**1.94**	**0.70**
Fluting	475		**1.56**	**0.52**
Liner	317		**1.64**	**0.54**
Other papers (tissue etc)	372	**0.86**	**0.89**	**0.84**
Other papers (kraft etc)	484		**1.97**	**0.89**
Newsprint paper	1425		**1.44**	**0.57**
Fine grade paper, coated	729	**0.17**	**1.97**	**0.86**
Fine grade paper, uncoated	1200		**1.89**	**0.66**
Mechanical woodpulp paper, coated	2496	**0.17**	**1.44**	**0.78**
Mechanical woodpulp paper, uncoated	1889		**1.44**	**0.63**
Total paper production	*10966*			

References: Carlson and Heikkinen, Jaakko Pöyry, 1998; Lehtilä, VTT Energy, personal communication

Basic parameters of the C emission and energy model

Pulp and paper industry:

Energy supply

PROCESS BYPRODUCT FUELS

Pulp grade	Wood waste MWh/t	Black liquor MWh/t
Groundwood, unbleached	**0.45**	**0**
Groundwood, bleached	**0.45**	**0**
Thermomechanical pulp, unbleached	**0.49**	**0**
Thermomechanical pulp, bleached	**0.49**	**0**
Semi-chemical pulp	**0.46**	**0.69**
Hardwood sulphate pulp, bleached	**1.00**	**4.47**
Softwood sulphate pulp, unbleached	**0.93**	**5.44**
Softwood sulphate pulp, bleached	**0.93**	**5.44**
Efficiency of heat production	*86 %*	*82 %*

References: Carlson and Heikkinen, Jaakko Pöyry, 1998; Lehtilä, A., VTT Energy, pers.comm.

Basic parameters of the C emission and energy model

Pulp and paper industry:

Energy supply

- Allocation principle: **by-product biofuels** utilised in those production lines where they build up.

- The rest of energy supply for self-generated heat and electricity is satisfied by bought fossil fuels, and in addition electricity is bought from the markets.

- **Direct fuels**: natural gas used in paper drying, oil or gas in drying of recycled pulp and in lime sludge reburning kiln.

Basic parameters of the C emission and energy model

Pulp and paper industry:

Energy supply

EXTERNAL FOSSIL FUELS	
% of total fuel use	**33 %**
Efficiency of heat production	**89 %**
Fuel mix (% of external fuels)	
Natural gas	**49 %**
Heavy fuel oil	**18 %**
Peat	**17 %**
Coal	**15 %**
Other	**2 %**
SELFGENERATED ELECTRICITY	
% of total heat+electricity generation	**19 %**
Efficiency of back-pressure turbines	**95 %**
EXTERNAL ELECTRICITY	
% of total electricity use	**60 %**

References: Carlson and Heikkinen, Jaakko Pöyry, 1998; Statistics Finland, unpublished data, A. Lehtilä, VTT Energy, personal communication.

Basic parameters of the C emission and energy model

Specific emissions of fuels and of bought electricity and heat

Specific C emissions of main fuels

(1 kg C = 3,67 kg CO_2)

	kgC / MWh
Fossil C emissions	
Natural gas	**52**
Heavy fuel oil	**76**
Peat	**108**
Coal	**91**
Non-fossil C emissions	
Wood waste	**119**
Black liquor	**108**

Basic parameters of the C emission and energy model

Specific C emissions and primary energy of **external electricity** from national grid

C emissions **(kg C /MWh)**	Average el.	Base load el.
Fossil C emissions	**68**	**51**
Non-fossil C emissions (wood)	**5**	**5**
Primary energy **(MWh / MWh)**		
Fossil	**0.78**	**0.58**
Non-fossil (wood)	**0.04**	**0.05**
Other	**1.38**	**1.77**

Reference: Statistics Finland.

- The specific emissions calculated on the basis of the mix of electricity generated in Finland, which means that we assumed the imported electricity to have a similar mix.

Basic parameters of the C emission and energy model

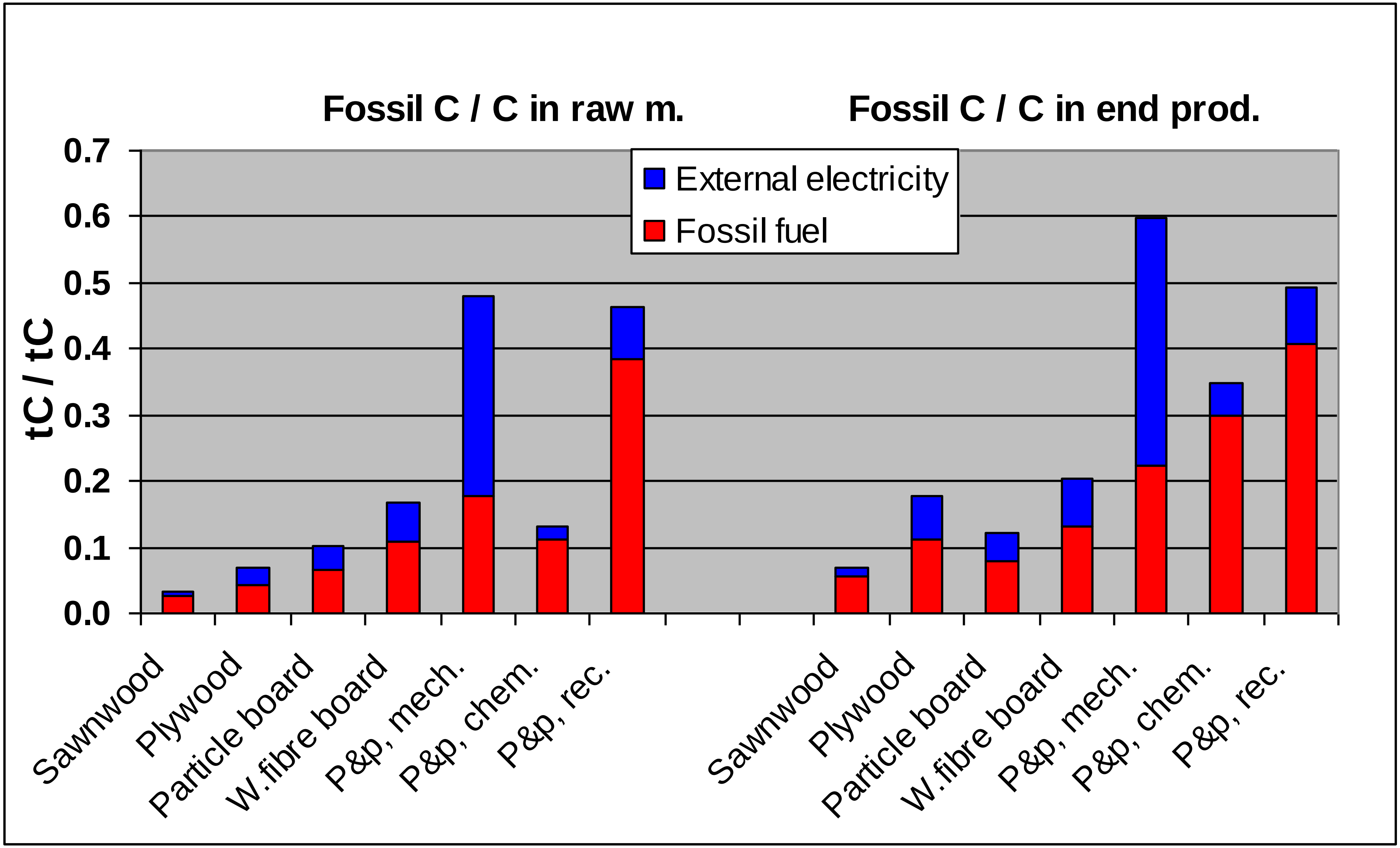
Specific C emissions of **external heat** from district heating systems

C emissions	kgC / MWh
Fossil C emissions	**96**
Non-fossil C emissions (wood)	**7**
Primary energy	**MWh / MWh**
Fossil	**1.16**
Non-fossil (wood)	**0.06**

Reference: Statistics Finland.

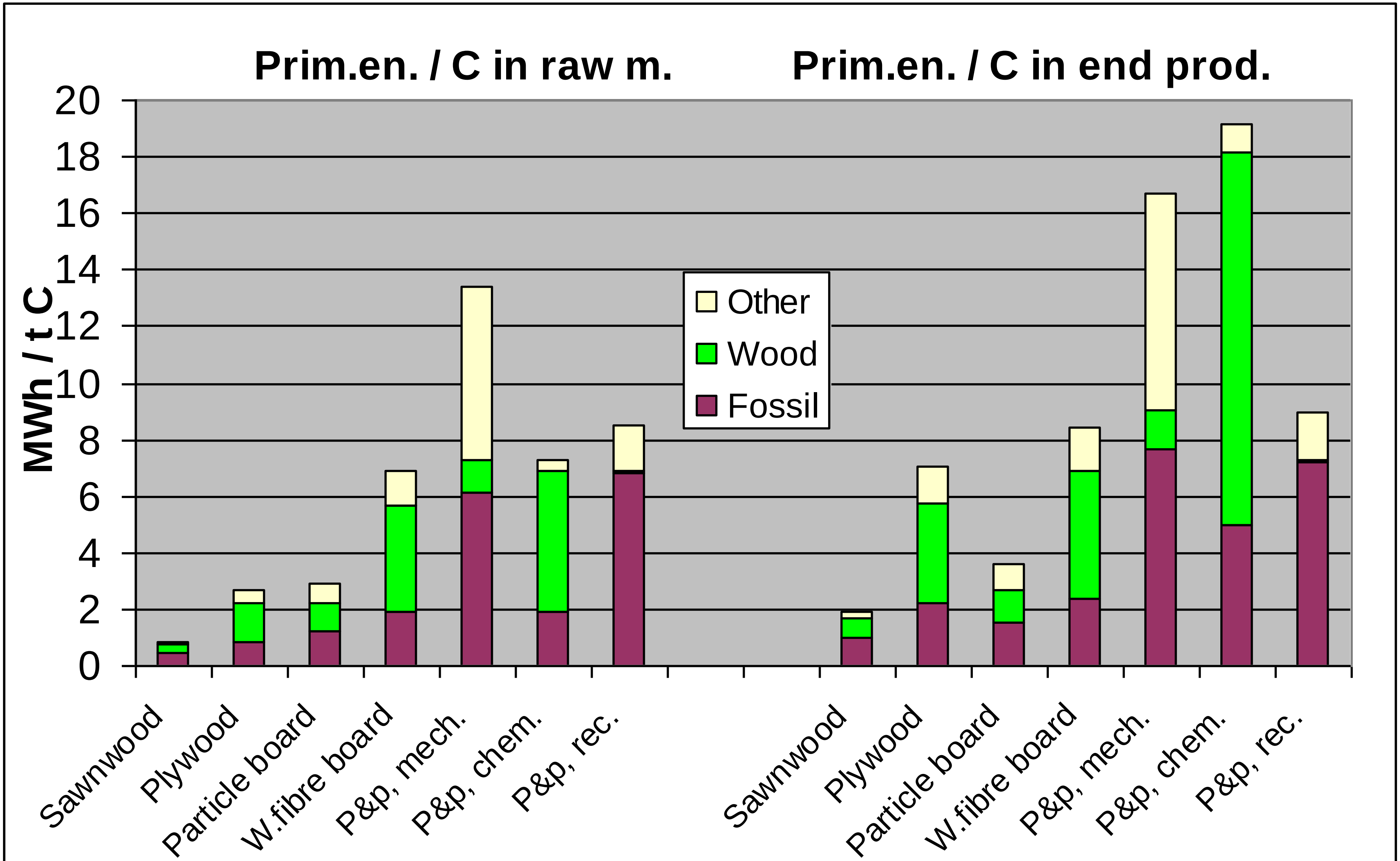
Results

Fossil C emissions of manufacture in proportion to C flow in material (Finnish forest industry in 1995)



Results

Primary energy of manufacture in proportion to C flow in material (Finnish forest industry in 1995)



Results

Fossil C emissions of harvesting and transportation compared with the emissions of manufacture:

- **Case example**: a big Finnish company importing about 20 % of its raw wood and exporting about 84% of its sawn wood production, reference year 1997.

- The estimated **fossil C emissions** of **harvesting + raw wood transportation + sawn wood transportation** **=** **average fossil C emissions** of **saw milling**

- These emissions were divided as follows: harvesting **16%**, raw wood transportation **44%**, sawn wood transportation **40%**

Discussion

- Results are a snapshot of the year 1995 in Finland representing the prevailing product mix, technology, and energy sources.

- The allocation of C emissions between different production lines within pulp&paper industry is problematic, as the manufacture is really very integrated.

- The specific C emissions are case-dependent, e.g. due to various energy sources from country to country, but characteristic are the significant differences in energy-intensity of various harvested wood products (HWP) groups.

Discussion

- Fossil C emissions in chemical pulping lower, due to use of by-product biofuels, but pulp&paper manufacture generally very energy intensive (chemical pulping: waste of biomass and bioenergy?).

- One possible criteria for burdens could also be emissions/energy divided by value added in the final product?

- Emissions of *manufacturing* appear to dominate the emissions of wood products' life cycle (with the exception of sawn wood).

- The transportation emissions are understandably even more case-dependent, but the numbers of the big company presented above represent an upper estimate for Finland, with long transport distances for round wood and big share of exported sawn wood.

Conclusions

- Fossil C emissions of the life cycle of HWP **diminish their applicability as C sink and GHG mitigation option**.

- There are **continuos fossil C emissions of maintaining any C stock of HWP**. The shorter the life time of the HWP the larger maintenance flow is required. The emissions are proportional to the maintenance C flow multiplied by the specific fossil C emissions of the flow (manufacture+transport etc of HWP).

Conclusions

- **Focusing barely on C balances of HWP stocks** (reported under the LUCF sector) is **insufficient** when assessing GHG mitigation options of HWP.

- The **life-cycle view** of GHG impacts is **helpful** and complementary to the sectoral view of national emission inventories.