Global carbon stocks and stock changes in harvested wood products: a review of current understanding and estimates

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Greenhouse Gas Aspects of Biomass Cascading – Reuse, Recycling and Energy Generation

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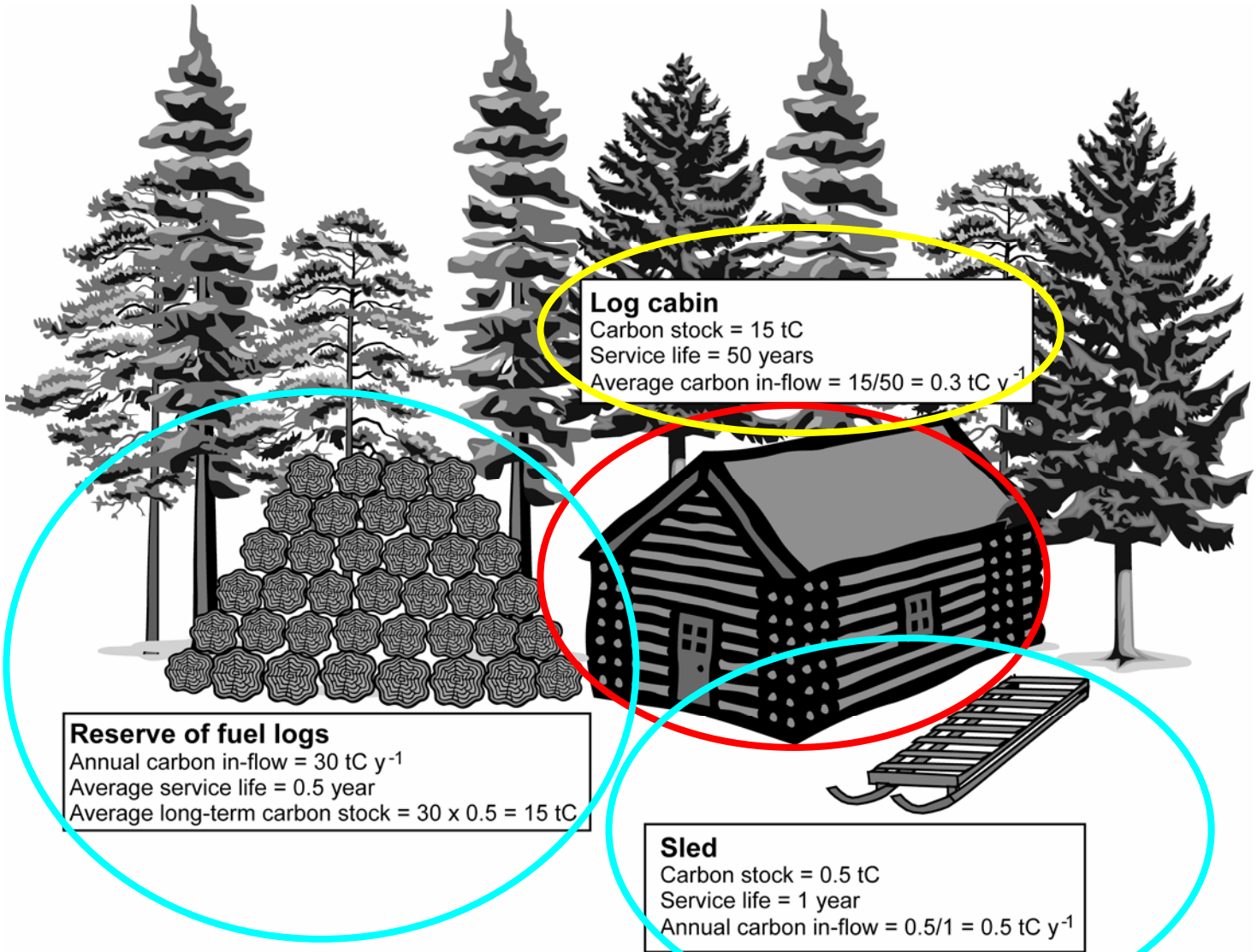
Objectives of our study

- What do we know about **global C fluxes of HWP** based on the **FAO statistics** on forestry?
- **Global C stock / stock change estimates** calculated by a dynamic HWP model using FAO data as input
- Discussion on the results and uncertainties
- What is the **significance of HWP to global C balance?**

Fundamental principles

Basic dynamics of HWP carbon

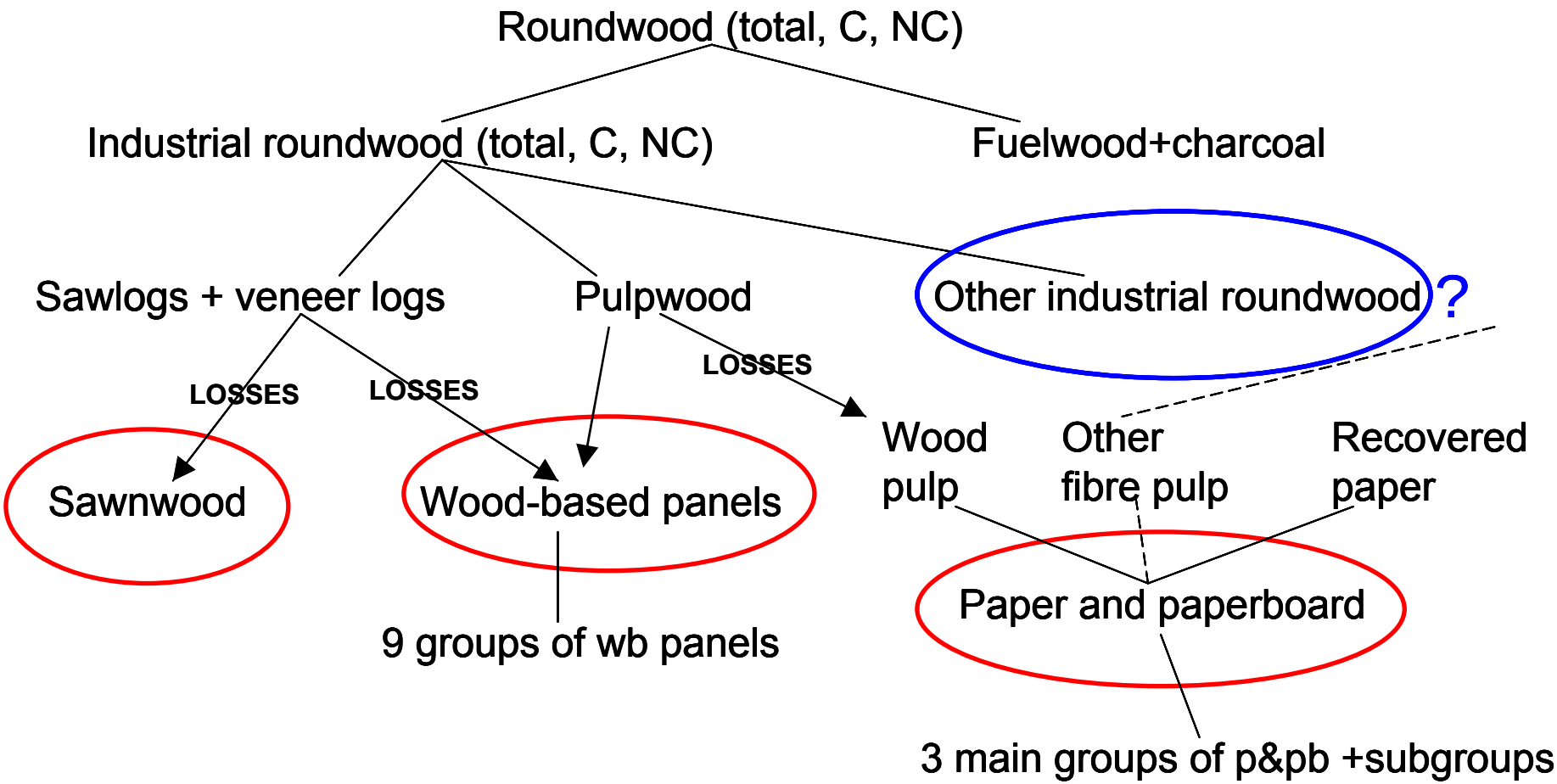


FAO statistics

FAO global statistics on forest products

- Yearly production, export and import rates for most countries, country groups (e.g. EU) + global numbers and for most forest product categories since 1961 until 2003.
- Freely available from web: http://www.fao.org/
- Quality of data varies between different countries and between different forest product categories.

FAO classification of forest products



FAO statistics

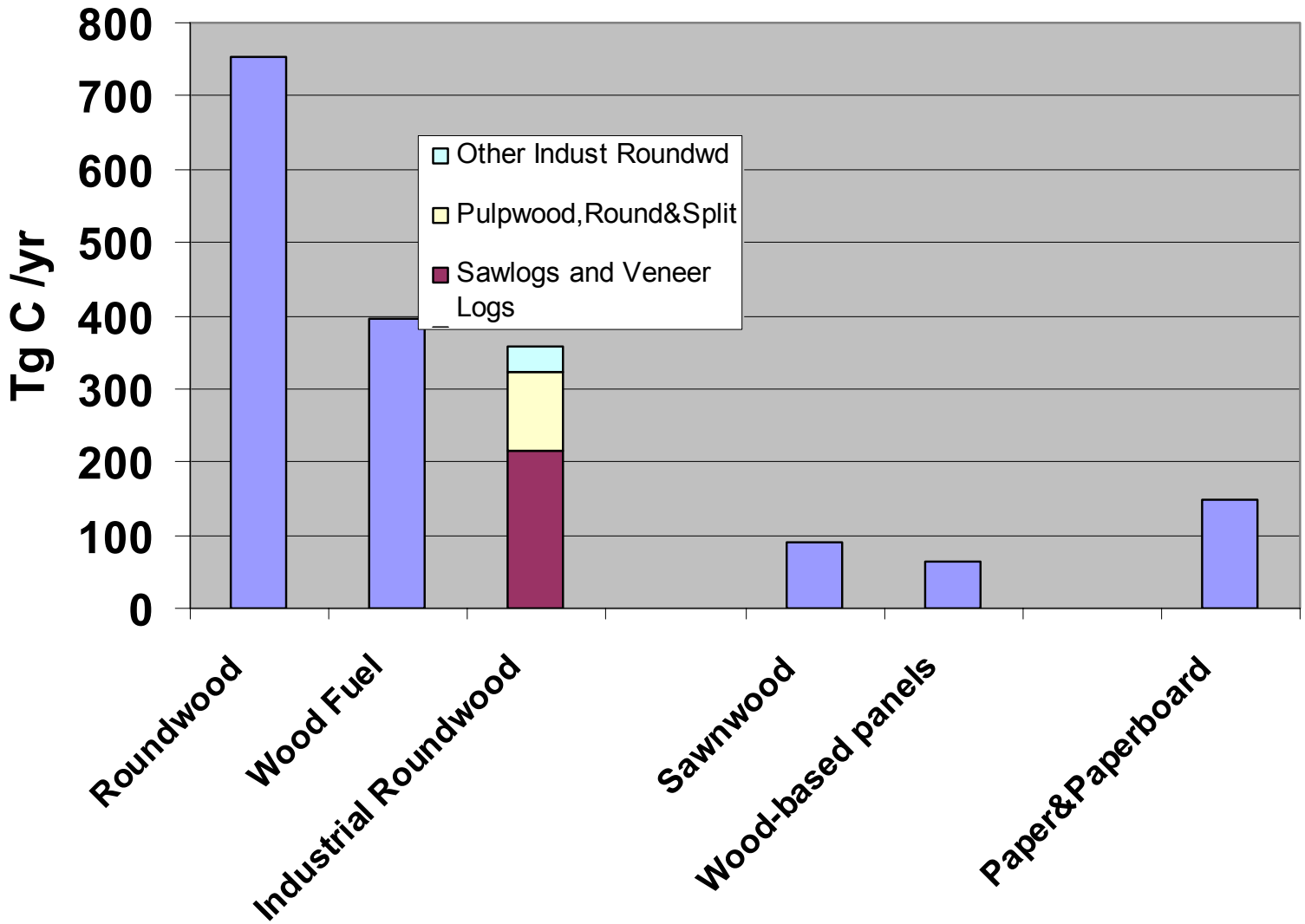
From which FAO classes are long-lived subpools of HWP built up?

- Final products (such as houses, furniture, books) excluded from FAOSTAT, but **comprehensive information on semi-finished ones**.
- A substantial portion of semifinished products such as Sawnwood, Wood-Based Panels and partly also Paper and Paperboard end up in long-term use.
- Other Industrial Roundwood is a mixed class ("Roundwood used for tanning, distillation, match blocks, gazogenes, poles, piling, posts, pitprops, etc."; cited from http://www.fao.org/waicent/faostat/forestry/products.htm) both very short and long-lived components. An **"Other"** type of class, data appear to be **unreliable**.

FAO statistics

Estimated C fluxes in global production of HWP in 2003

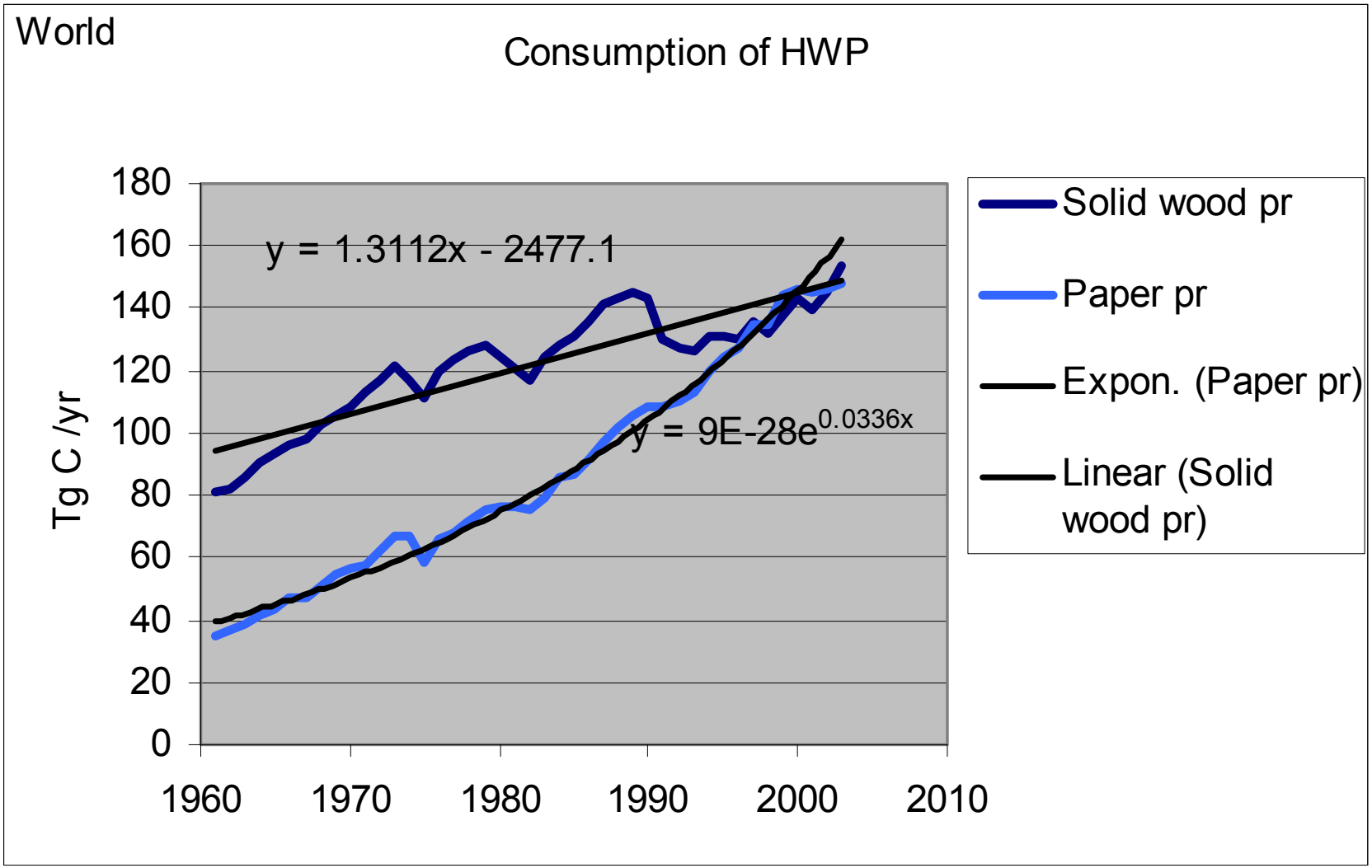
(based on FAOSTAT 2005)



Conversion factors: Wood 0.225 MgC/m3, WB Panels 0.294 MgC/m3, P&Pboard 0.45 MgC/ Mg(air dry)

FAO statistics

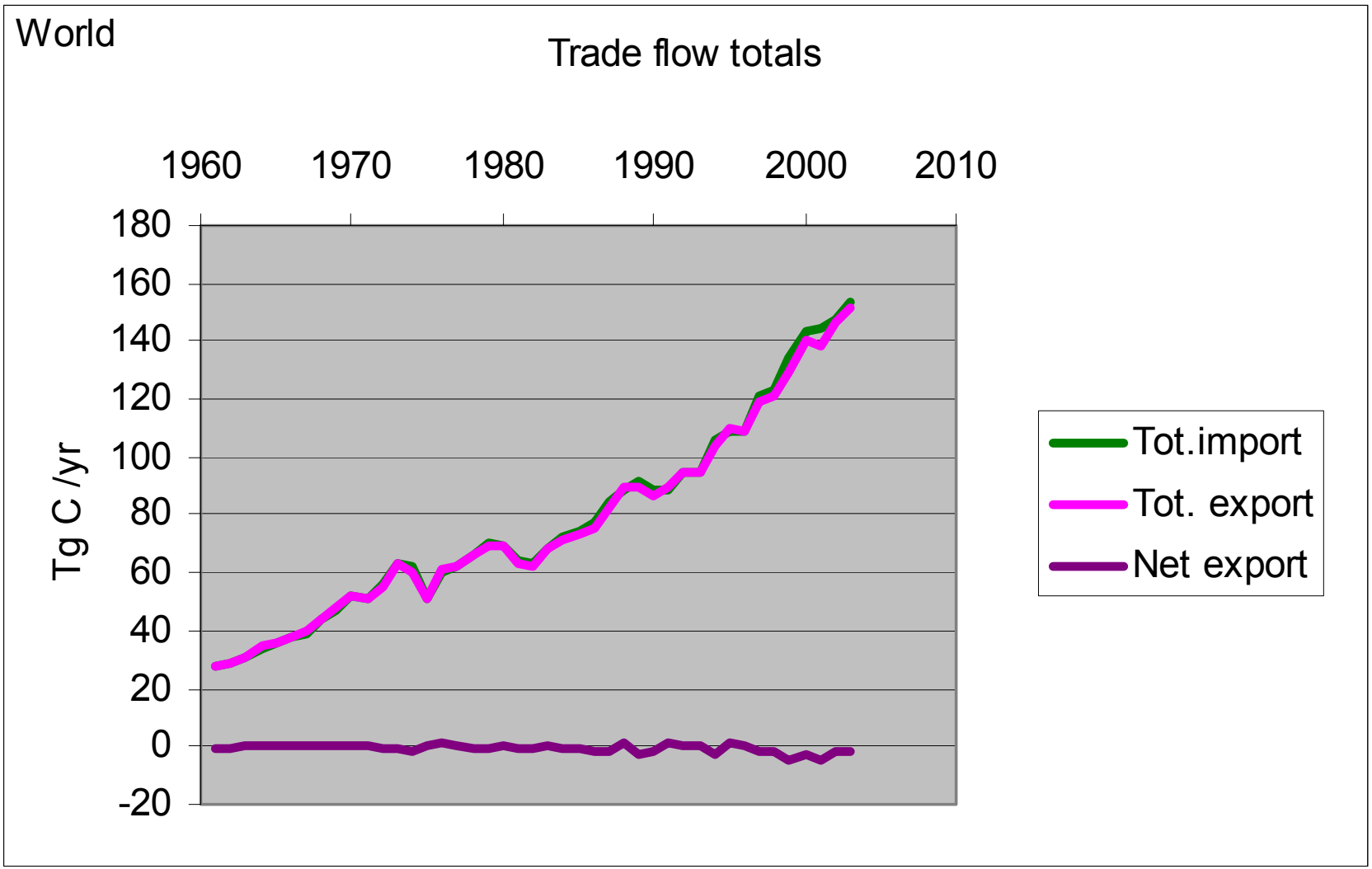
Global consumption of semi-finished HWP converted into C fluxes



Conversion factors: Wood 0.225 MgC/m3, WB Panels 0.294 MgC/m3, P&Pboard 0.45 MgC/ Mg(air dry)

FAO statistics

Global trade flows of all HWP classes converted into C fluxes



Conversion factors: Wood 0.225 MgC/m3, WB Panels 0.294 MgC/m3, P&Pboard 0.45 MgC/ Mg(air dry)

EXPHWP model

- Tool for estimation C stocks in HWP and their changes: **EXPHWP model**
- Originally developed for **national inventories** (3 approaches)
- Input data:FAO statistics on HWP production and trade rates since 1961 (available for most countries) + estimated rates before that.
- In addition: estimates on **HWP lifetimes** and **carbon conversion factors** required.
- Model applied in this study to calculate global estimates.

EXPHWP model

First order decay

- First order decay of HWP pools assumed; basic differential equation:

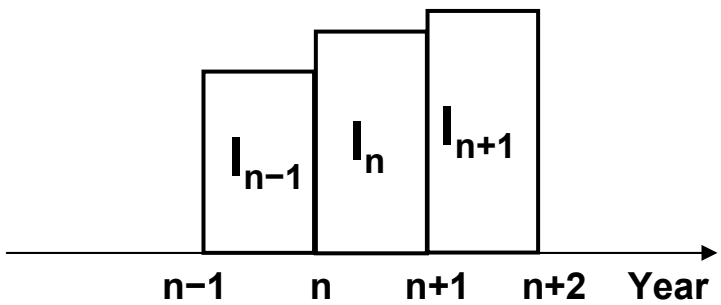
$$\frac{dS(t)}{dt} = I(t) - kS(t) \qquad S(t_0) = S_0$$

where **S(t)** is the carbon stock at time **t**, **I(t)** is the inflow rate to the pool, **kS(t)** is the outflow rate from the pool, where **k** is the decay coefficient, $\mathbf{S_0}$ is the initial stock of the pool in the past at time $\mathbf{t_0}$.

EXPHWP model

First order decay algorithm

- Inflow rate to the C pool of HWP, $\mathbf{I_n}$, is assumed to be **constant <u>within</u> each year n**



- **Analytical solution**: C stock $\mathbf{S_{n+1}}$ in the beginning of year n+1 can be calculated from the recursive formula:

$$S_{n+1} = e^{-k} \cdot S_n + (1 - e^{-k})/k \cdot I_n$$

where k is the decay coefficient (1/yr) of the pool.

Note relationship: Average lifetime = 1 / k Half-life = ln 2 / k

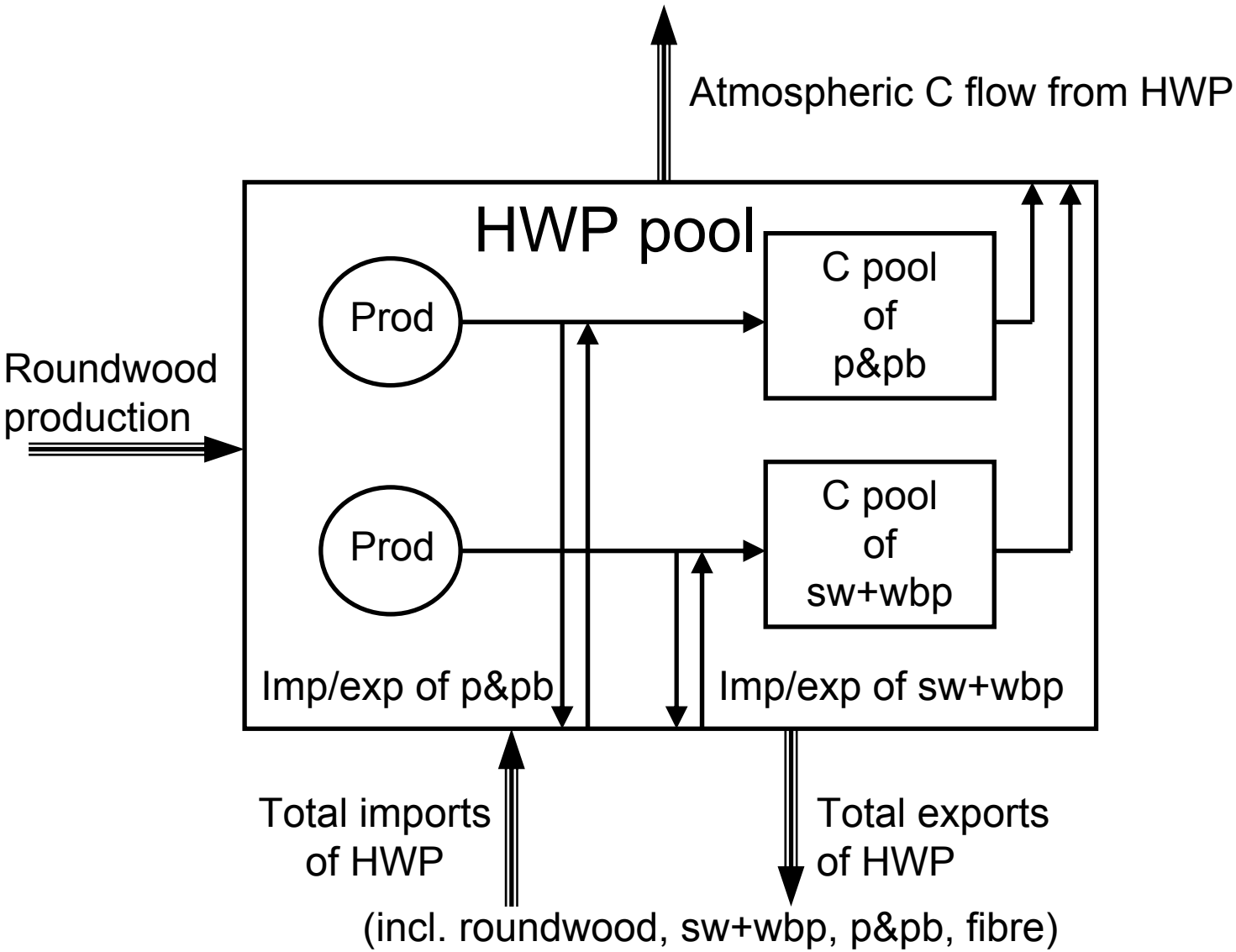
EXPHWP model

What pools are included?

- **Two subpools of semifinished products**: solid wood products (Sawnwood, Wood-Based Panels) and paper products (Paper and Paperboard) with different k-values. Other Industrial Roundwood excluded.
- HWP in landfills not considered in this study.
- Inflow rates to these pools: apparent consumption rates of HWP = production + imports − exports
- Integration of the equations is started from year 1900 assuming a zero initial stock (S_0=0).
- More subpools could be used, if statistics of their inflows and estimates of their k-values were available.

EXPHWP model

Model structure



Global estimates

Additional assumptions:

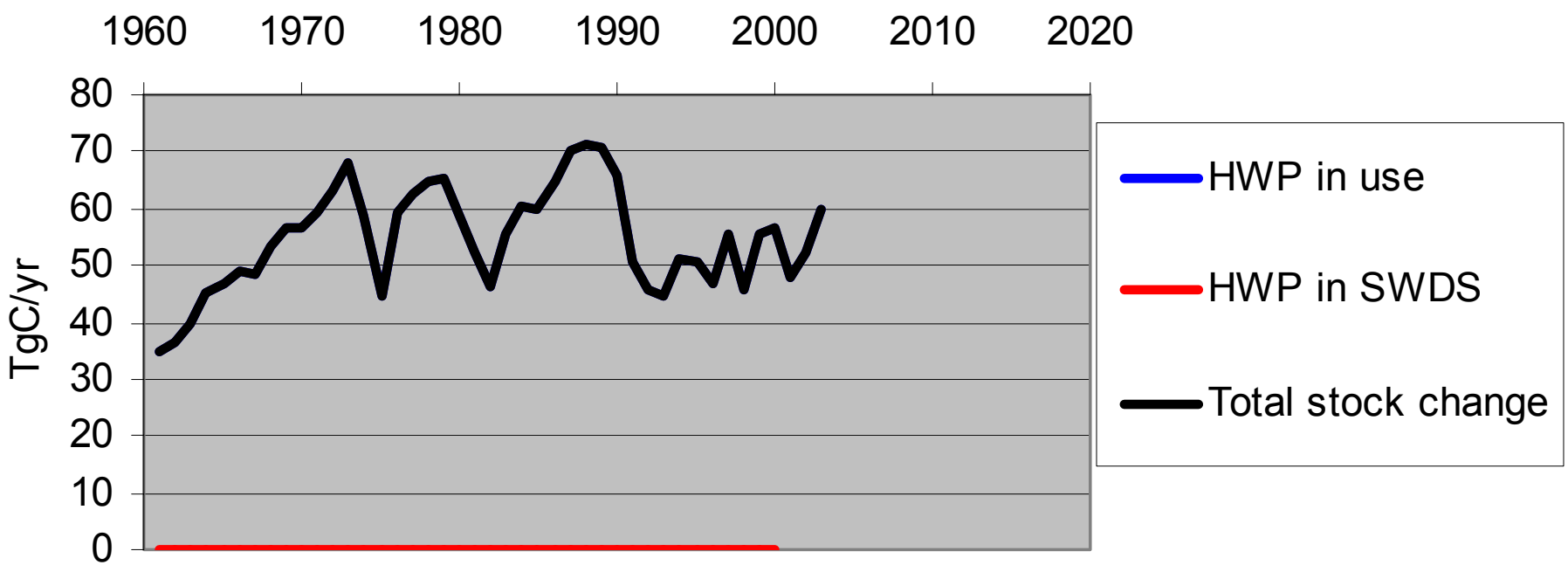
- Estimated annual rates of increase for industrial roundwood production globally **=1.28%** between 1900 and 1961 (K.Skog). Consumption of HWP is assumed to be proportional to rw prod rate.
- Half-life of sawnwood and wb panels is **30 yrs** (or average lifetime = 43 yrs).
- Half-life of paper and paperboard is **1 yrs** (or average lifetime = 1.4 yrs).

Global estimates

Results:

World

Stock change approach:
1) C stock changes

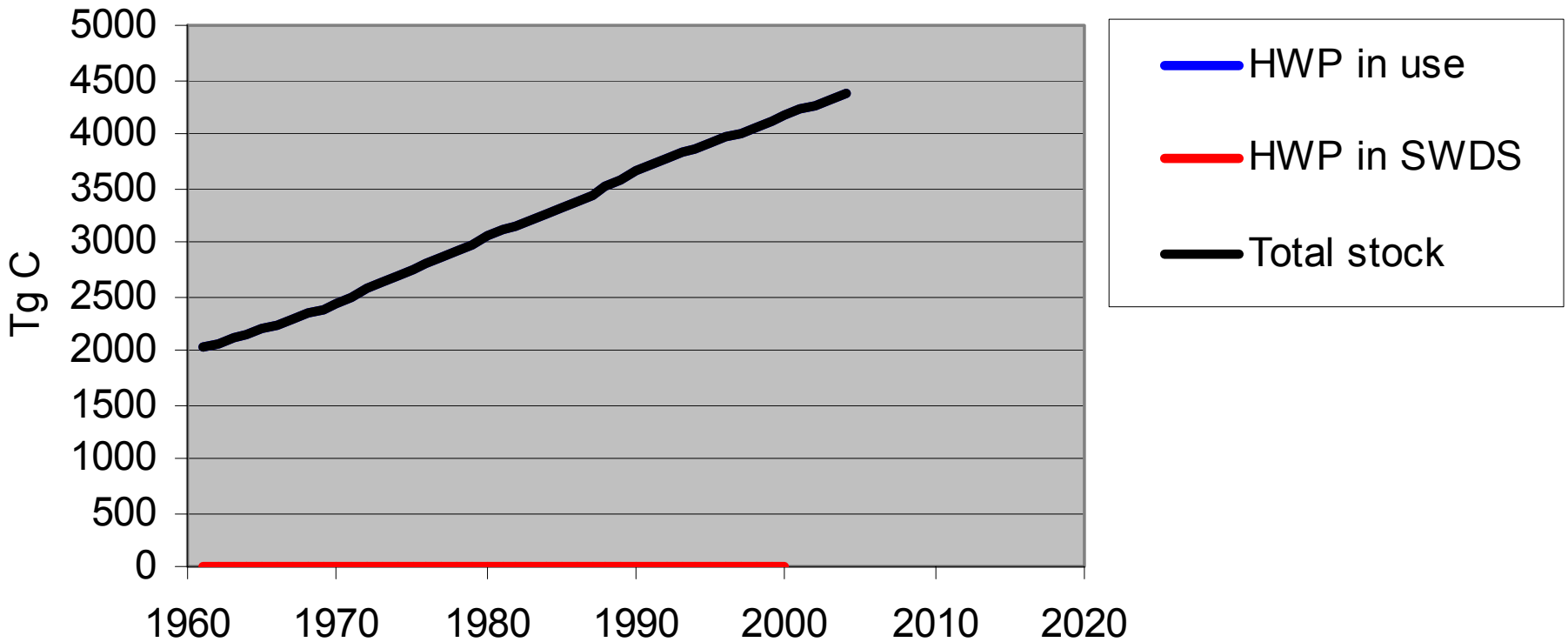


Global estimates

Results:

World

Stock change approach:
2) C stocks



Global estimates

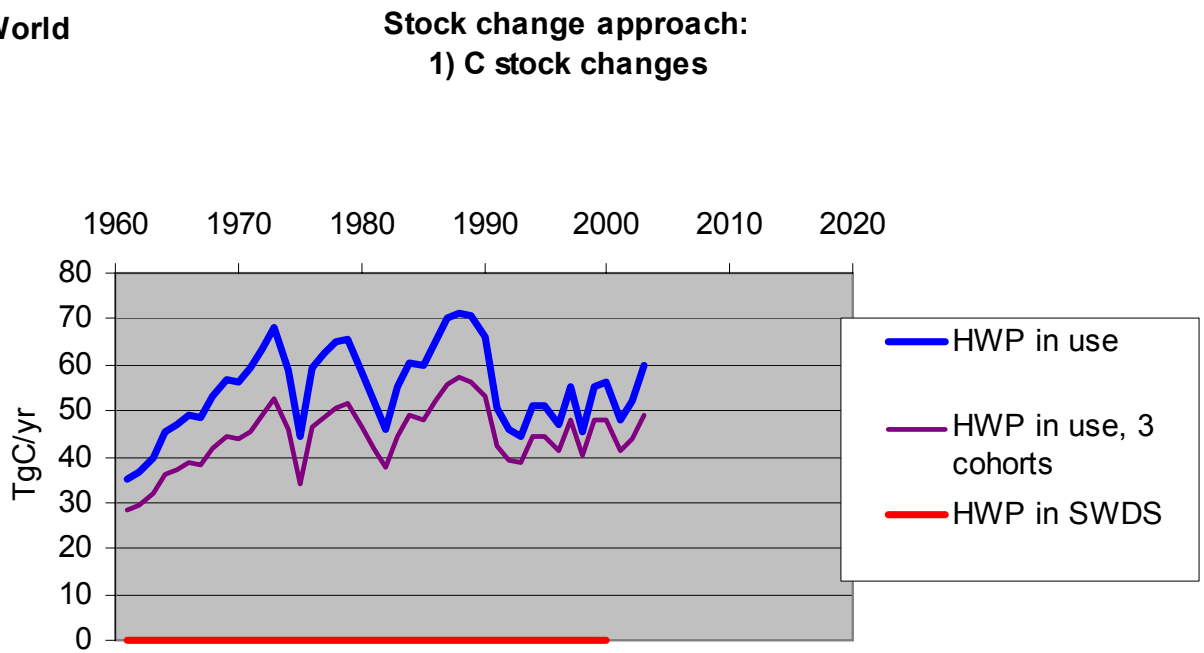
Sensitivity:

- **Initial stock**: increase of Sw+Wbp from 0 to 2000 TgC −> −7% in stock change, +4% in stock
- **Average lifetime** (=1/k): +10% change of Sw+Wbp −> +7% in stock change, +5% in stock
- **Historical growth rate**: +10% change −> +0.7% in stock change, -0.4% in stock
- Influence if k were time-variant??
- Other decay patterns for HWP?

Global estimates

Sensitivity:

- Sw+Wbp: **Division into 3 subpools instead of 1** with same average lifetime of 43 yrs:



- 3 cohorts for sw+wbp: 50% to 80 yrs aver lifetime, 15% to 22 yrs aver lifetime, 35% to 0 yrs aver lifetime
- Tends to give lower stock ch when consumption growing.

Discussion

Remarks:

- Lifetimes of HWP: **no good empirical studies**, based on expert judgments.
- Global C stocks in HWP are evidently **increasing**, but the estimated stock change ≈ +40-60 Tg C/yr **small** compared e.g. with the global terrestrial C sink of 2300 Tg C/yr.
- Global trade flows of 150 Tg C/yr **much larger than stock changes**. (In AFA this would be distributed as additional emission to importers and additional removal to exporters = zero-sum game.)

Discussion

Remarks:

- Unlike HWP in use, a part of HWP disposed into landfills forms **a permanent C sink**, but was not considered in this study.
- However, **energy use** of recovered wood appears to be **more effective** GHG mitigation option **than landfilling**.
- Micro-level case studies in housebuilding (Task 38) indicate that reduced fossil C emissions due to **material substitution** by wood would be much **more important than C sink** itself in wood materials.

Global and national estimates

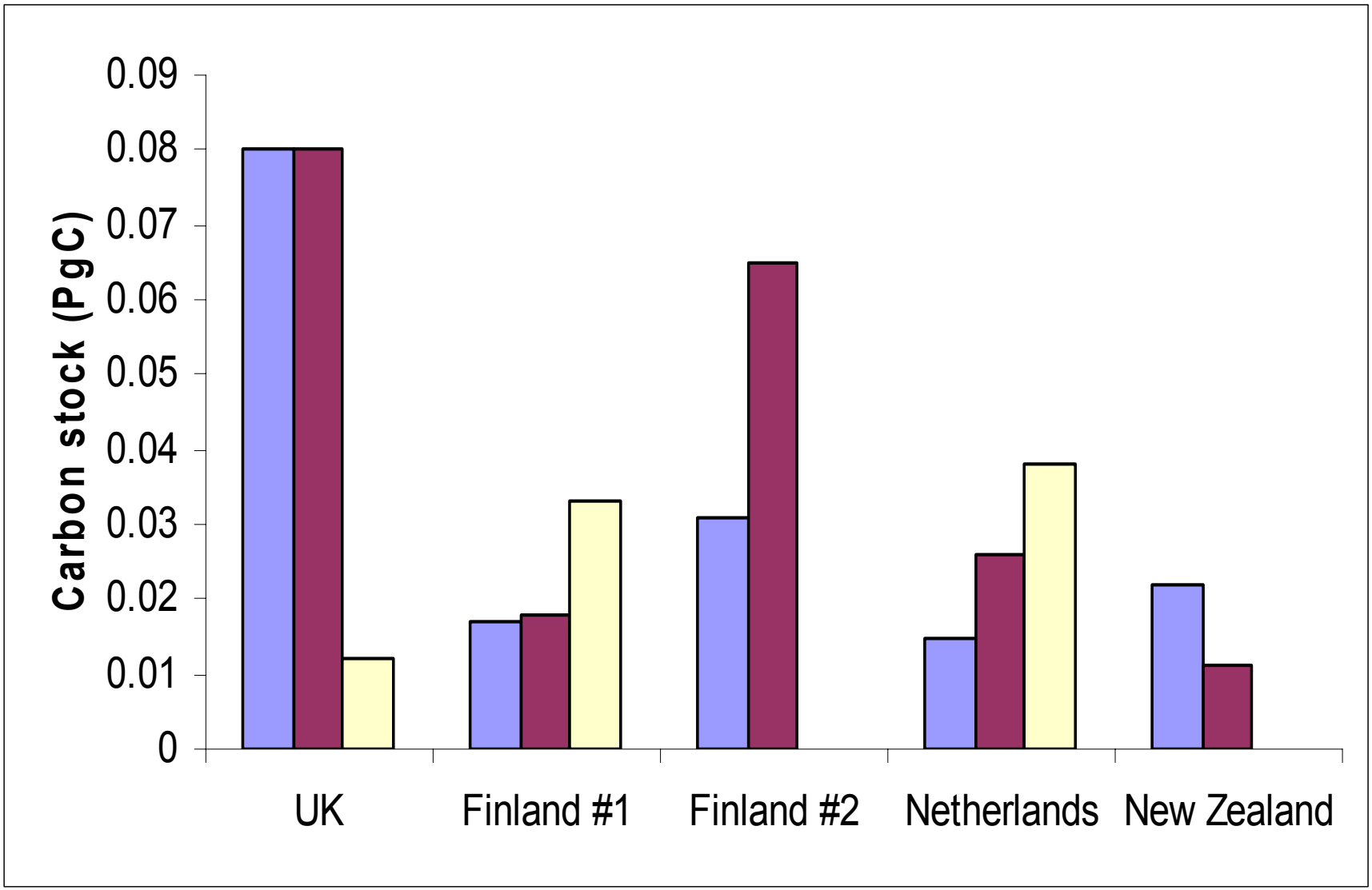
Comparisons with other studies

Locality, country or region	Source	Method of calculation	Pools included[1]			Estimate of Stocks (PgC)		
						From original source	Based on UK and Finnish inventories	
			Primary	Secondary	Landfill		+FAO timber consumption statistics	+ population statistics
UK	Alexander (1998)	Inventory[2]	✓	✓		0.08	-	-
UK	Alexander (1998)		✓	✓	✓	0.29	-	-
Finland	Pingoud *et al.* (2000)		✓	✓		0.017	0.018	0.007
Finland	Pingoud *et al.* (1996)		✓	✓	✓	0.031	*0.065*	*0.025*
Netherlands	Nabuurs and Mohren (1993)	Accounting Model	✓			0.015	0.026	0.021
Germany	Burschel *et al.* (1993)		✓	✓		0.128	-	-
Canada	Kurz *et al.* (1993)		✓	✓	✓	0.282	-	-
Oregon and Washington, USA	Harmon *et al.* (1996)		✓	✓	✓	0.396	-	-
USA	Matthews *et al.* (1996)		✓	✓	✓	2	-	-
USA	Skog and Nicholson (1998)		✓	✓	✓	2.7	*3.01*	*1.25*
Russia	Krankina *et al.* (1996)		✓	✓	✓	2.9	-	-
New Zealand	Maclaren and Wakelin (1991)		✓			0.022	0.011	0.005
World	Matthews *et al.* (1996)		✓	✓		3	3	7
World	Matthews *et al.* (1996)		✓	✓	✓	15	*11*	*25*
World	Buchanan and Levine (2000)		✓			8	*3*	*7*

[1] Wood products carbon pools considered by study
[2] Landfill estimates produced by accounting models.

Global and national estimates

Comparisons with other studies:



Global and national estimates

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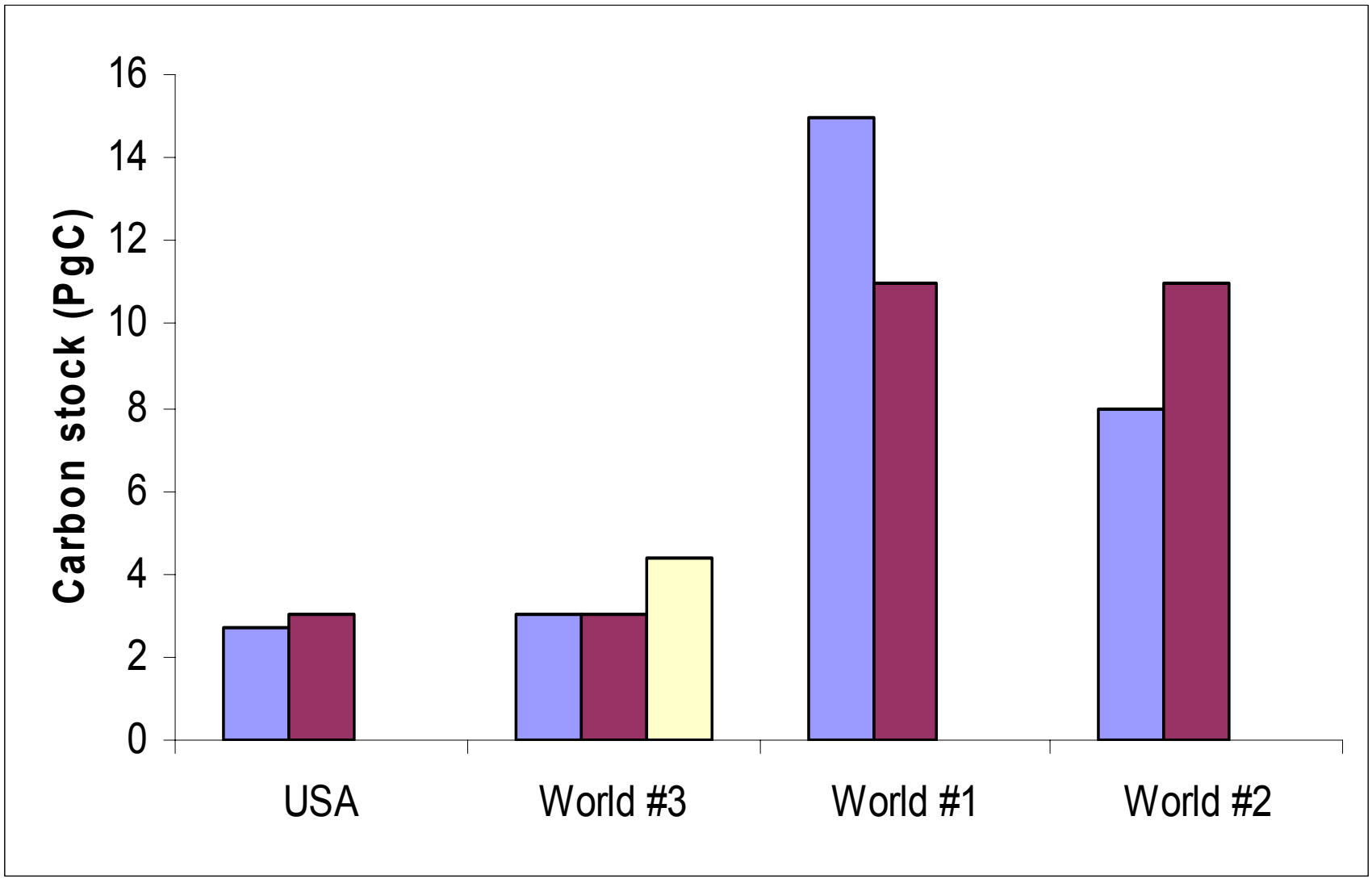

Global estimates

Comparisons with other studies:

- **Pingoud:** **50 to 60 Tg y^{-1}**
- **Matthews and Robertson:** **~10 Tg y^{-1}**
- **Winjum et al. (1991):** **112 Pg y^{-1}**