Rekayasa Industri Pengolahan Hasil Hutan dalam Mengurangi Emisi Karbon

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TEKNOLOGI HASIL HUTAN
Innovation For Efficiency And Sustainability

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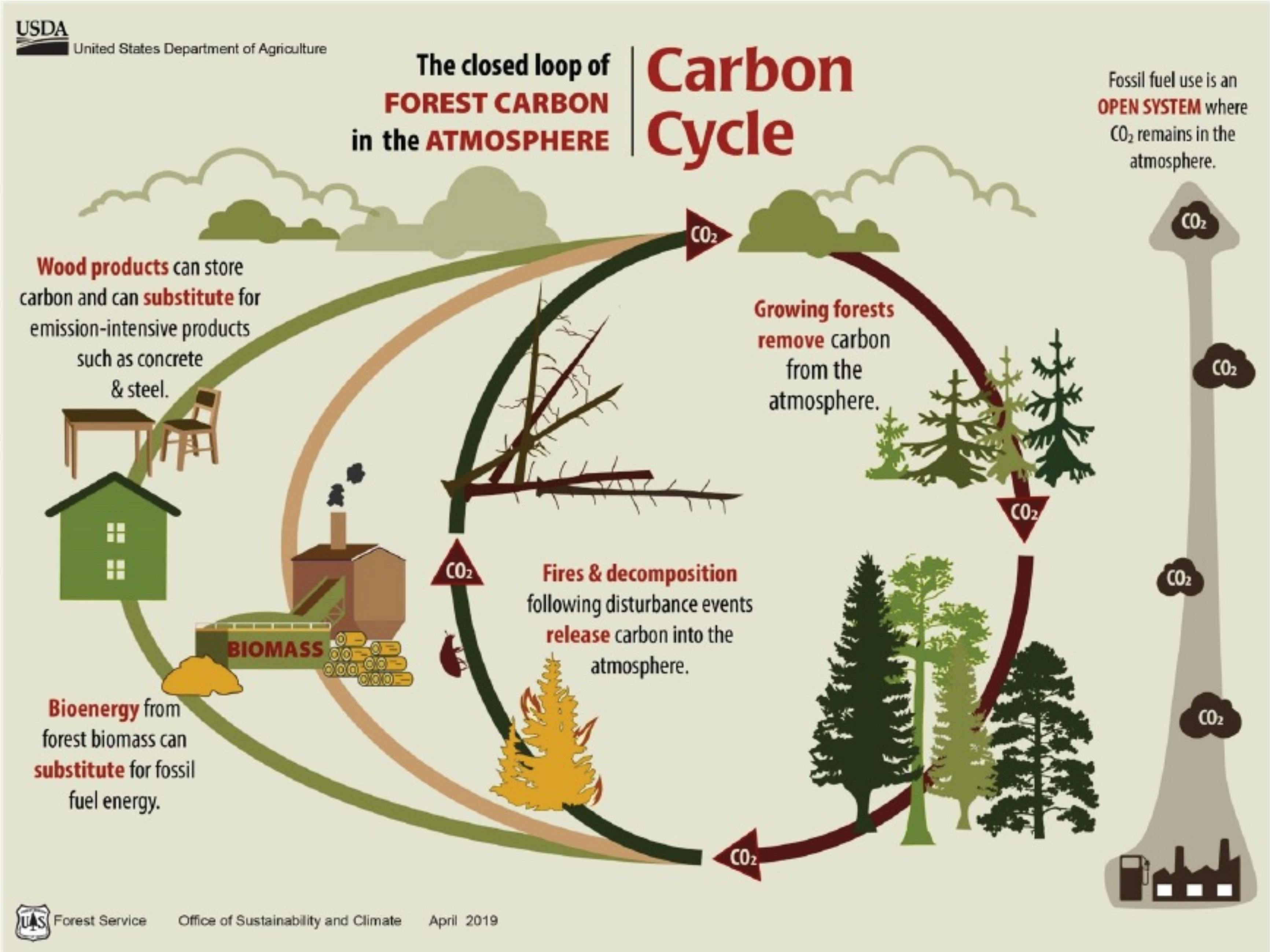
Isu utama:

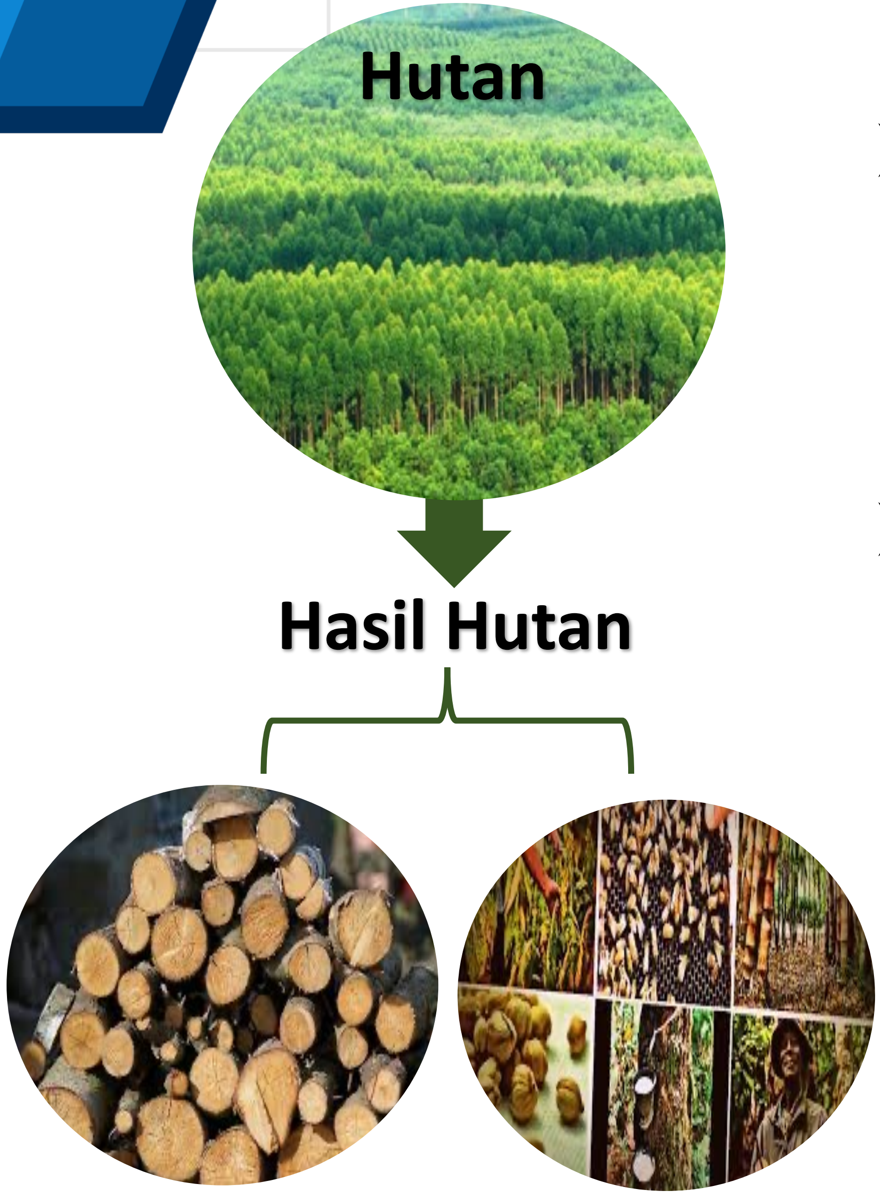
Ada tekanan besar untuk mengurangi jejak karbon (***carbon foot print***) dari kegiatan industri

Isu lingkungan → **Hutan**

- ✓ pengelolaan lahan
- ✓ konversi lahan menjadi penggunaan lain
- ✓ pengolahan bahan baku

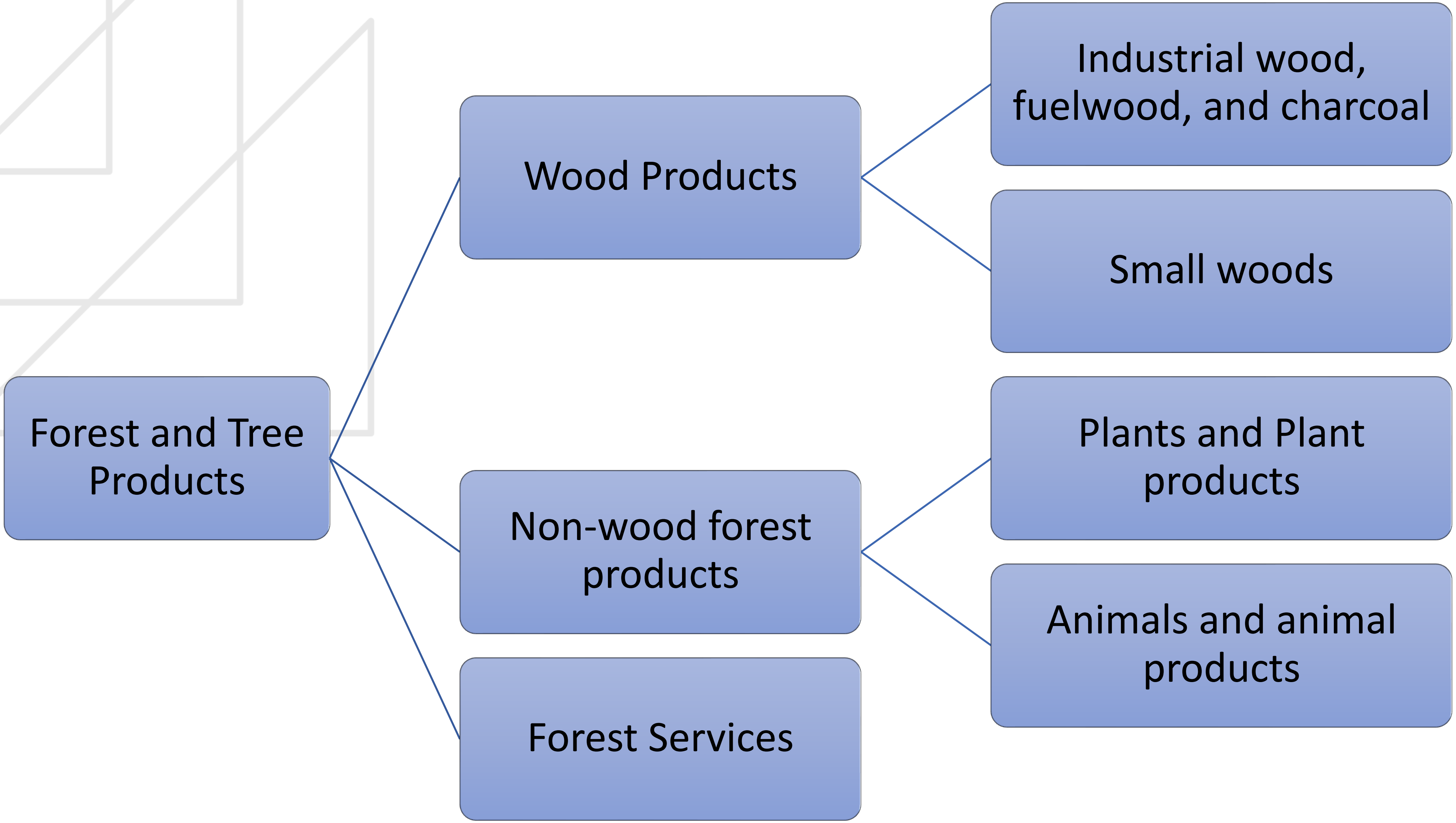


Sumber : Bergman et al. 2021



- Ada hubungan inheren antara **kehutanan** dan **hasil hutan**.
- Salah satu kunci untuk menjaga hutan yang sehat dan hutan tangguh (*healthy and resilient forests*) dengan **memiliki pilihan produk dan pasar** semua bahan baku
- Koneksi pasar sangat penting dalam mendukung pengelolaan hutan. Penjualan kayu dan hasil hutan lainnya yang didukung oleh lembaga strategis menjadi penting untuk **mendorong ekosistem yang tangguh dan adaptif** terkait mitigasi risiko kebakaran hutan dan perubahan iklim, penyimpanan karbon, dan memperkuat komunitas

Klasifikasi Produk-Produk Kehutanan



Kontribusi Sektor Kehutanan terhadap Perekonomian Nasional

Produksi Kayu Bulat

2020 11,56 Juta m^3
2021 12,8 Juta m^3
↑ 10,74%

Produksi Kayu Olahan

Peningkatan 5,94% dari tahun 2020

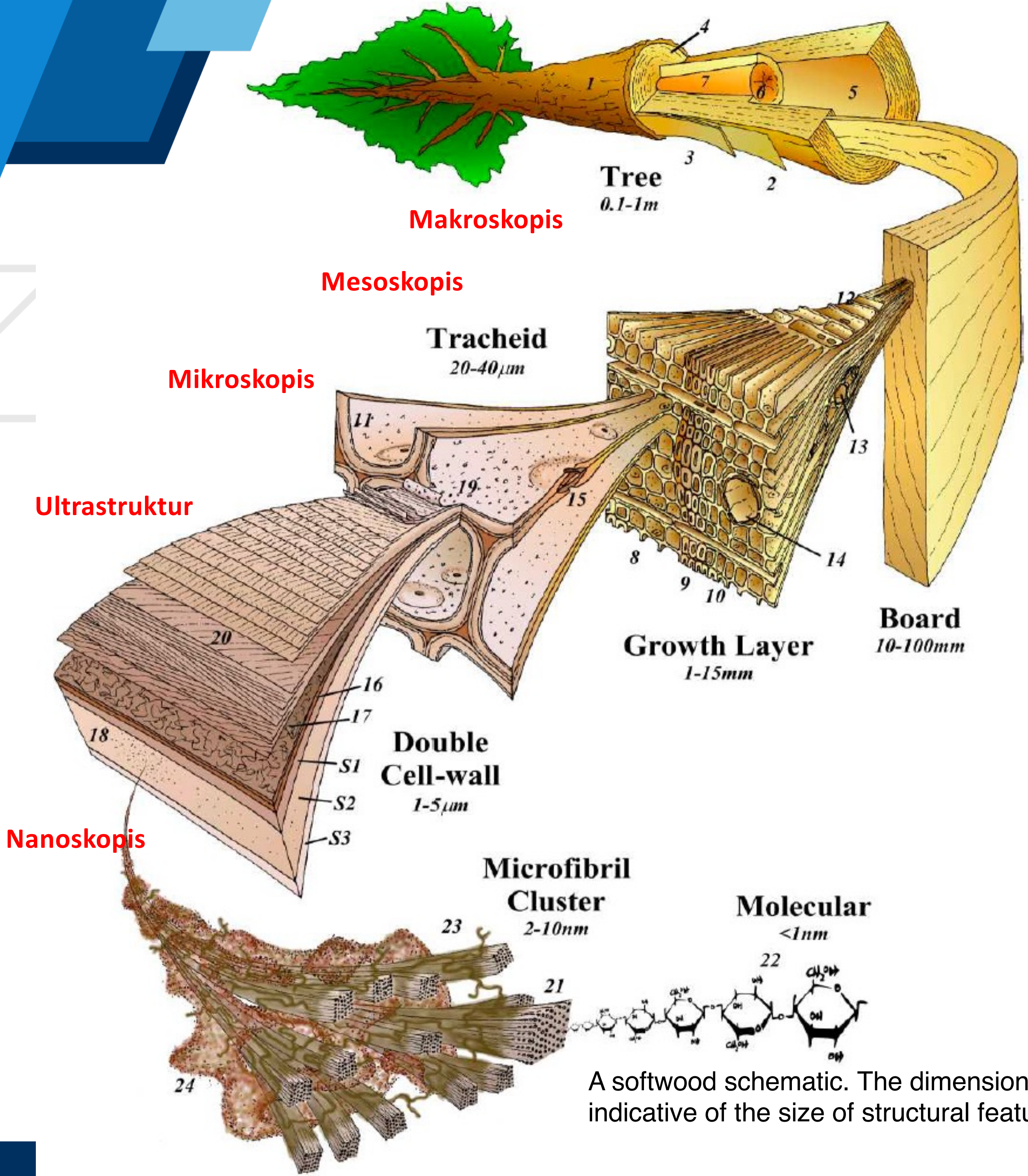
Hasil Hutan Bukan Kayu (HHBK)

2020 130 Juta ton
2021 192 Juta ton
↑ 47,60%

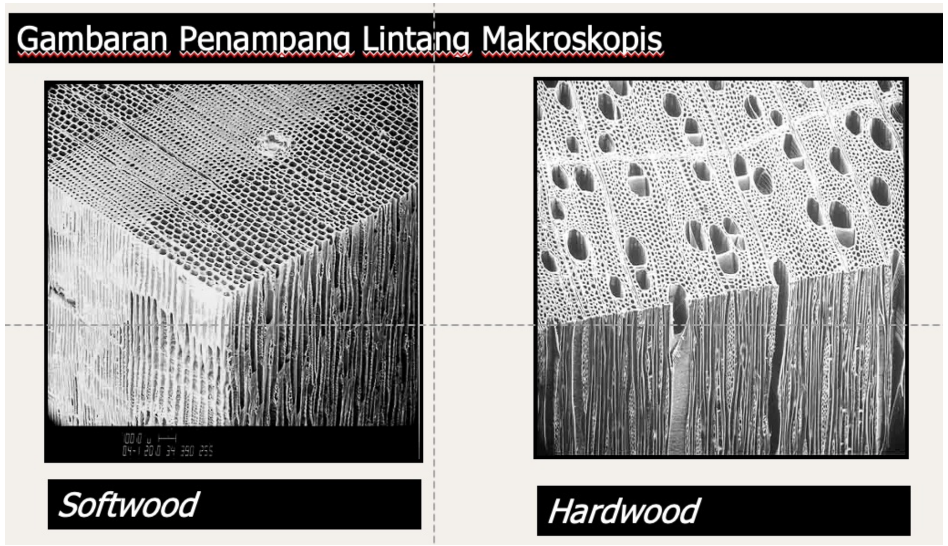
Ekspor

2020 2,59 Juta USD
2021 4,41 Juta USD
↑ 70,33%

Sumber : KLHK 2021



A softwood schematic. The dimensions below each of the scale labels are indicative of the size of structural features at that scale (Harrington 2012)



Logs → Lumber → Veneer → Long flakes → Chips → Flakes → Excelsior → Particles → Fiber bundles → Paper fiber → Wood flour → Cellulose

1-20 m

1-20 cm

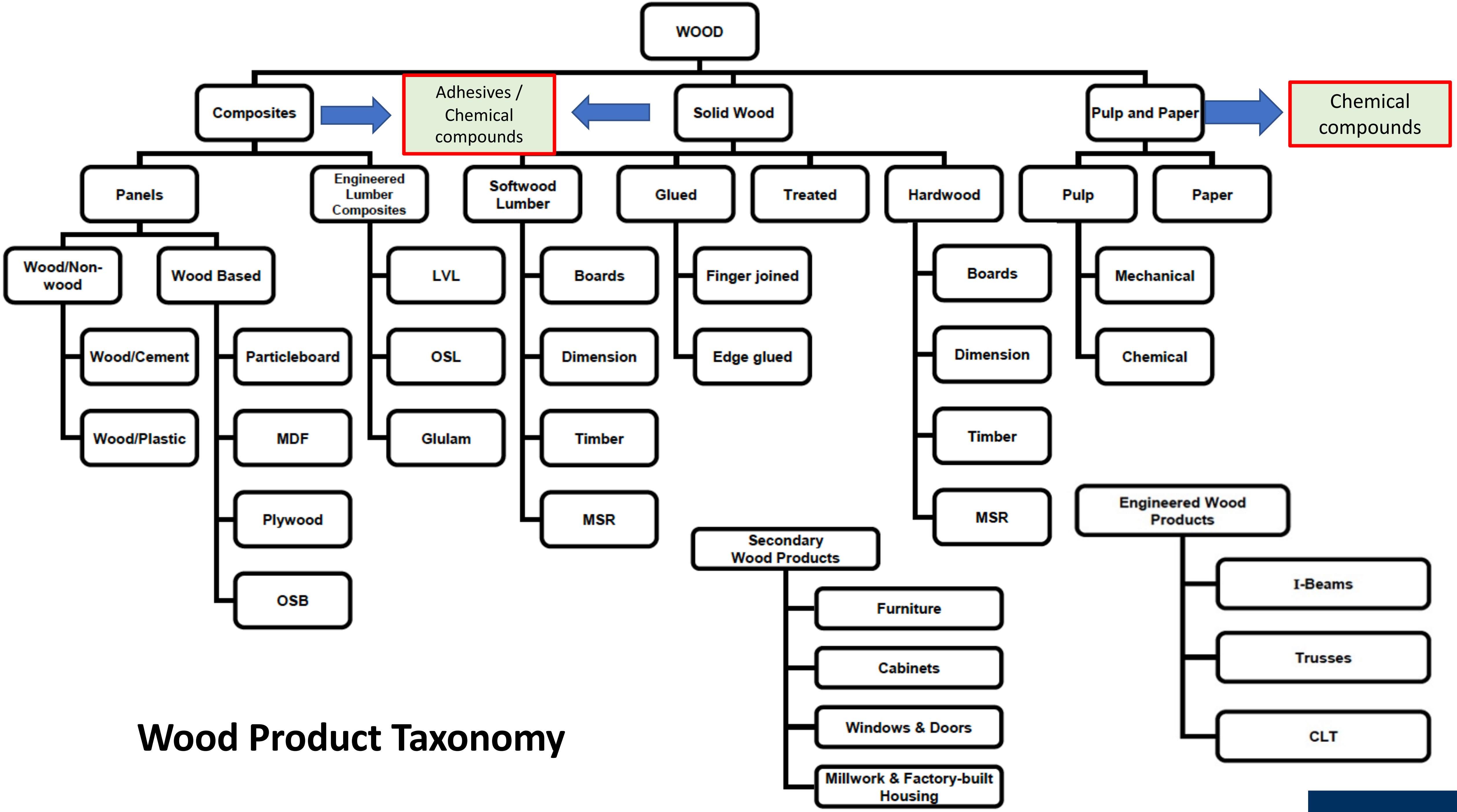
1-20 mm

1-20 µm

< 1 nm

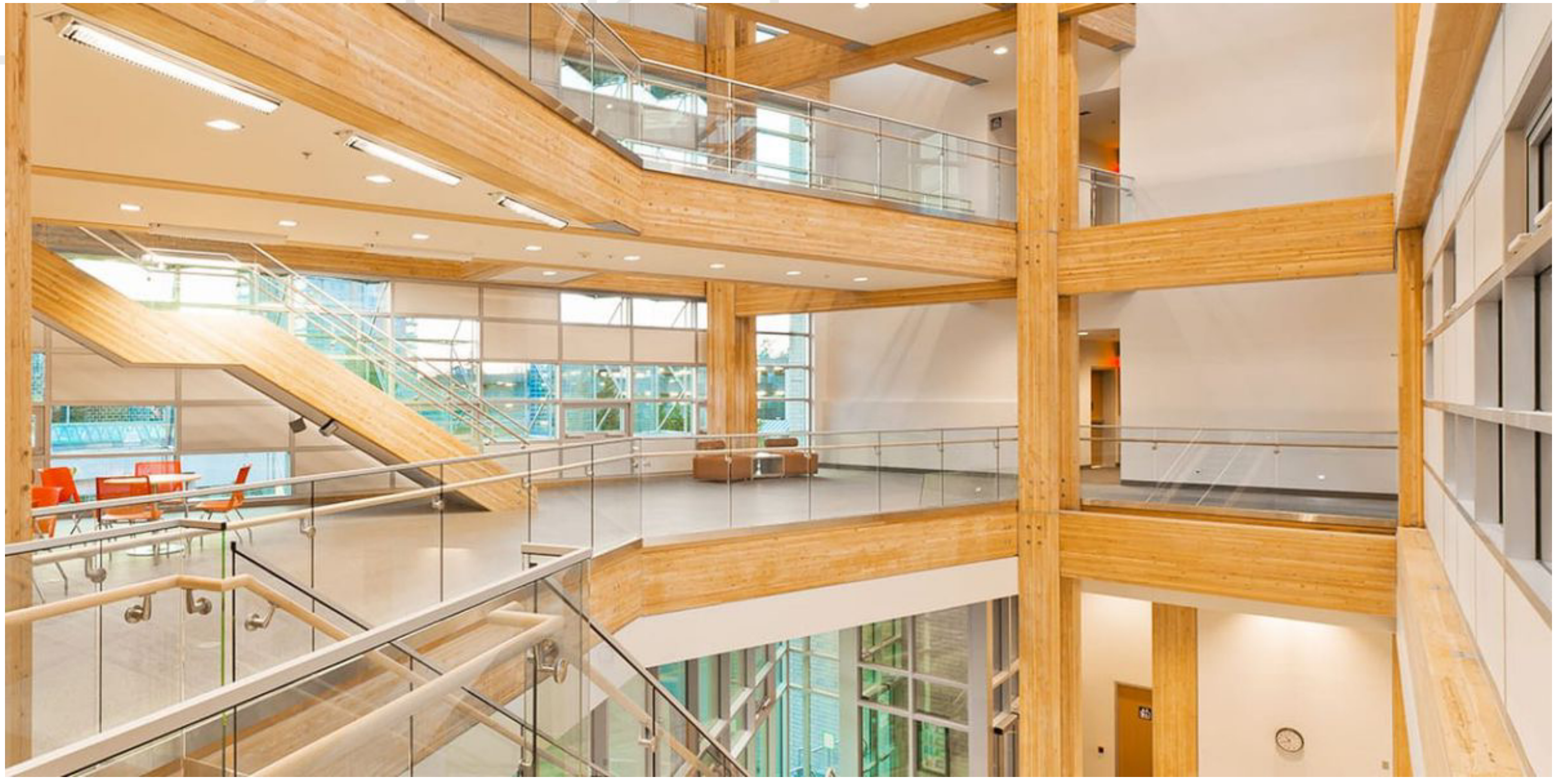
Basic wood elements,
from largest to smallest
(Kretschmann and others 2007).

Wood Handbook (2021)



Wood Product Taxonomy

Produk Rekayasa Kayu

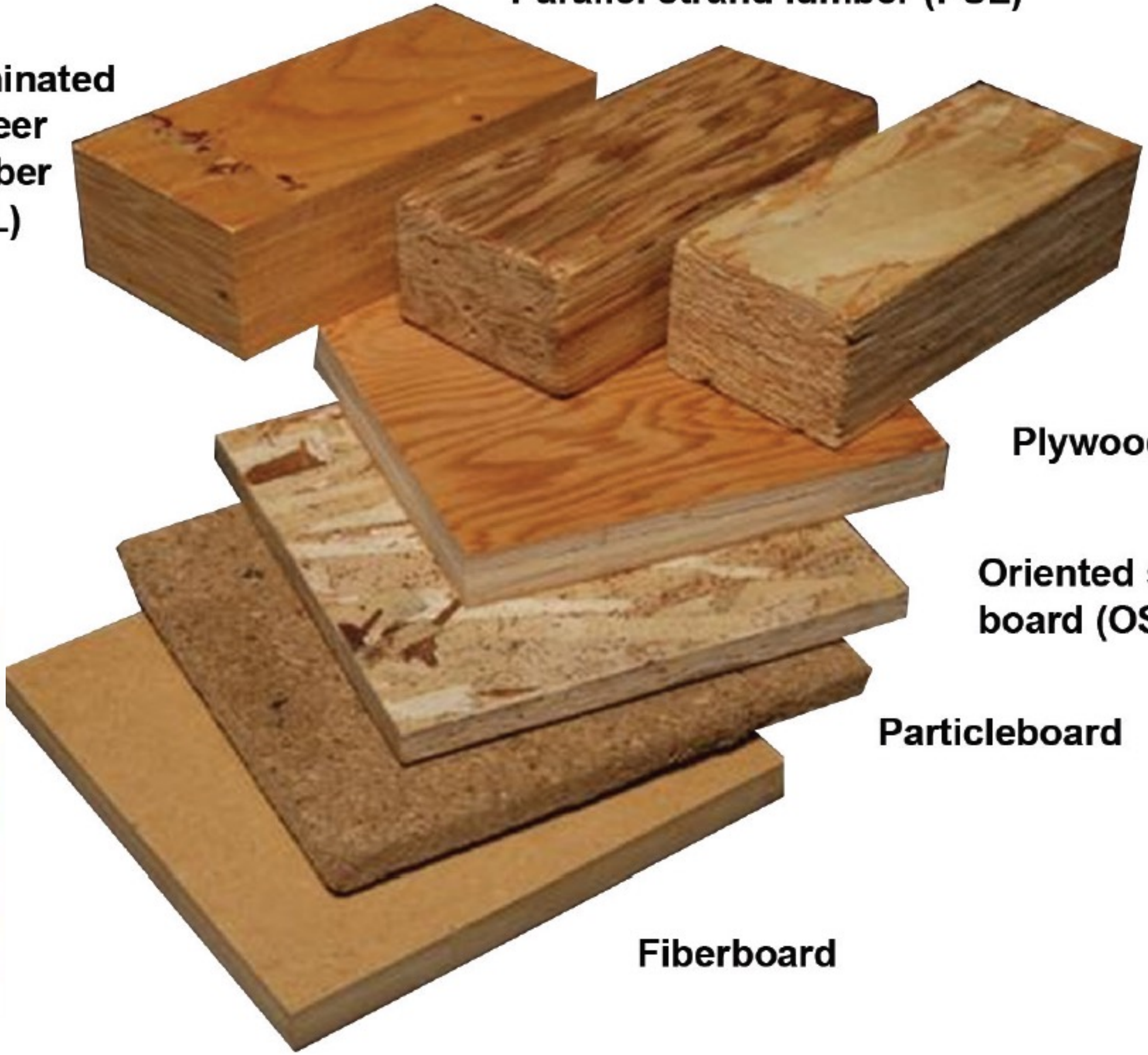


Konstruksi bangunan:

- Konstruksi bangunan **menghabiskan banyak sumber daya**, yang mengakibatkan konsekuensi lingkungan
- ***Kayu****, beton, dan baja* adalah bahan bangunan utama. Dari ketiganya, konstruksi kayu bertindak sebagai strategi **pengurangan emisi gas rumah kaca (GRK)** dan berasal dari sumber yang terbarukan dan berkelanjutan.

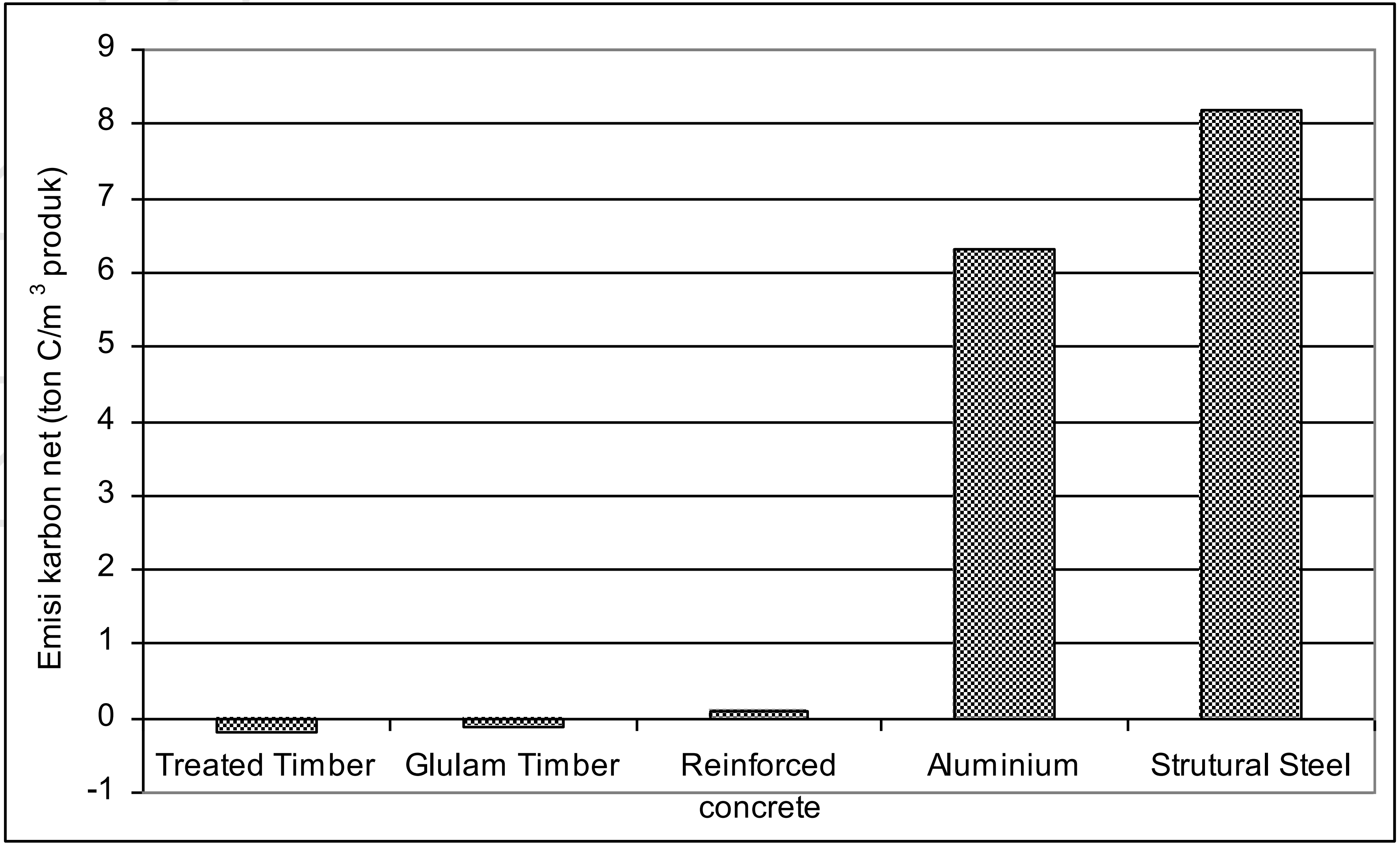
CLT

Glulam

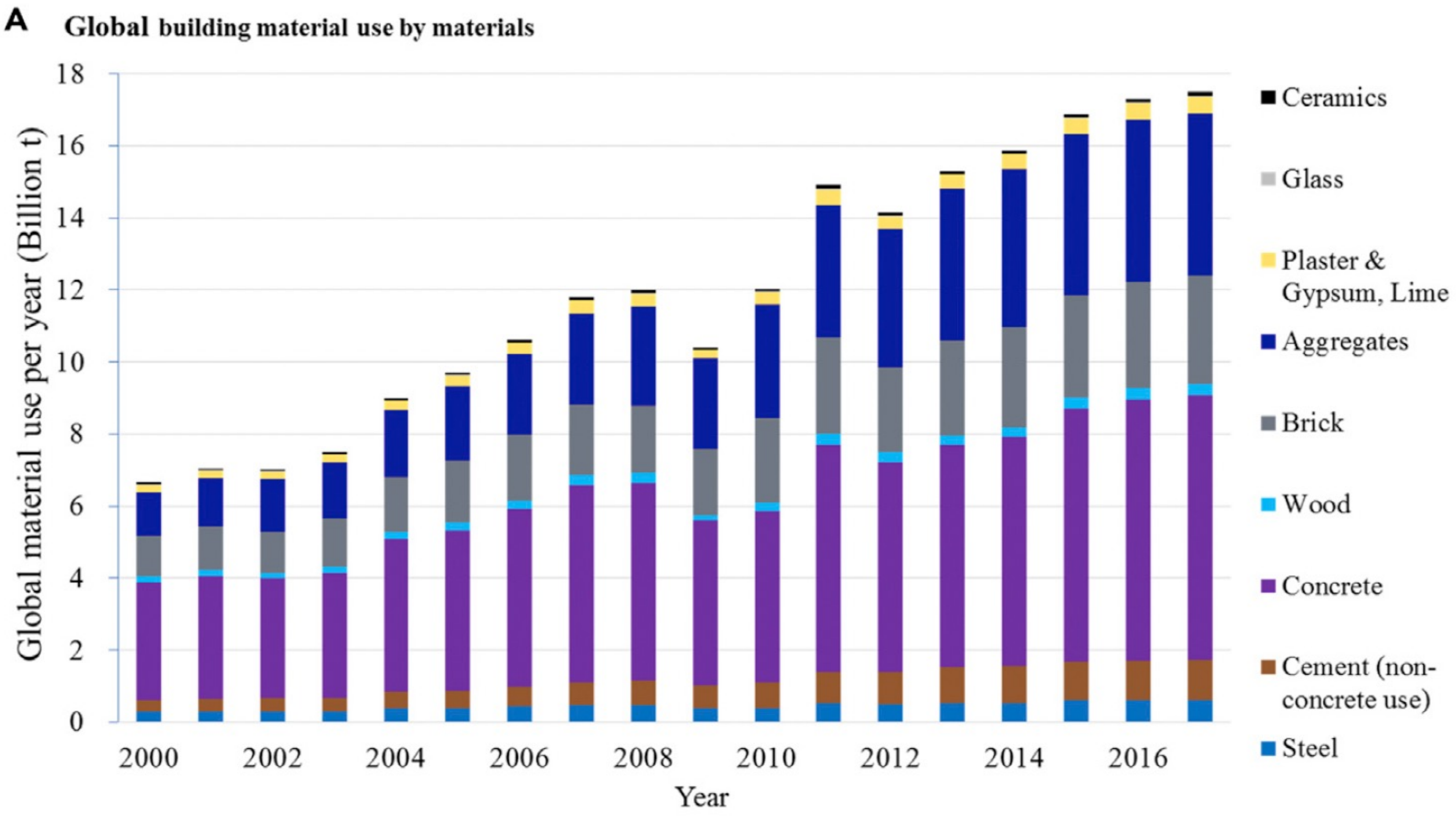


Examples of various composite products

Wood Handbook (2021)



Emisi karbon net pada bahan bangunan
(Sumber: Buchanan 1993)



Annual Global Building Material Use during 2000–2017 by Material

Sumber: Huang et al. 2020: A Life Cycle Thinking Framework to Mitigate the Environmental Impact of Building Materials

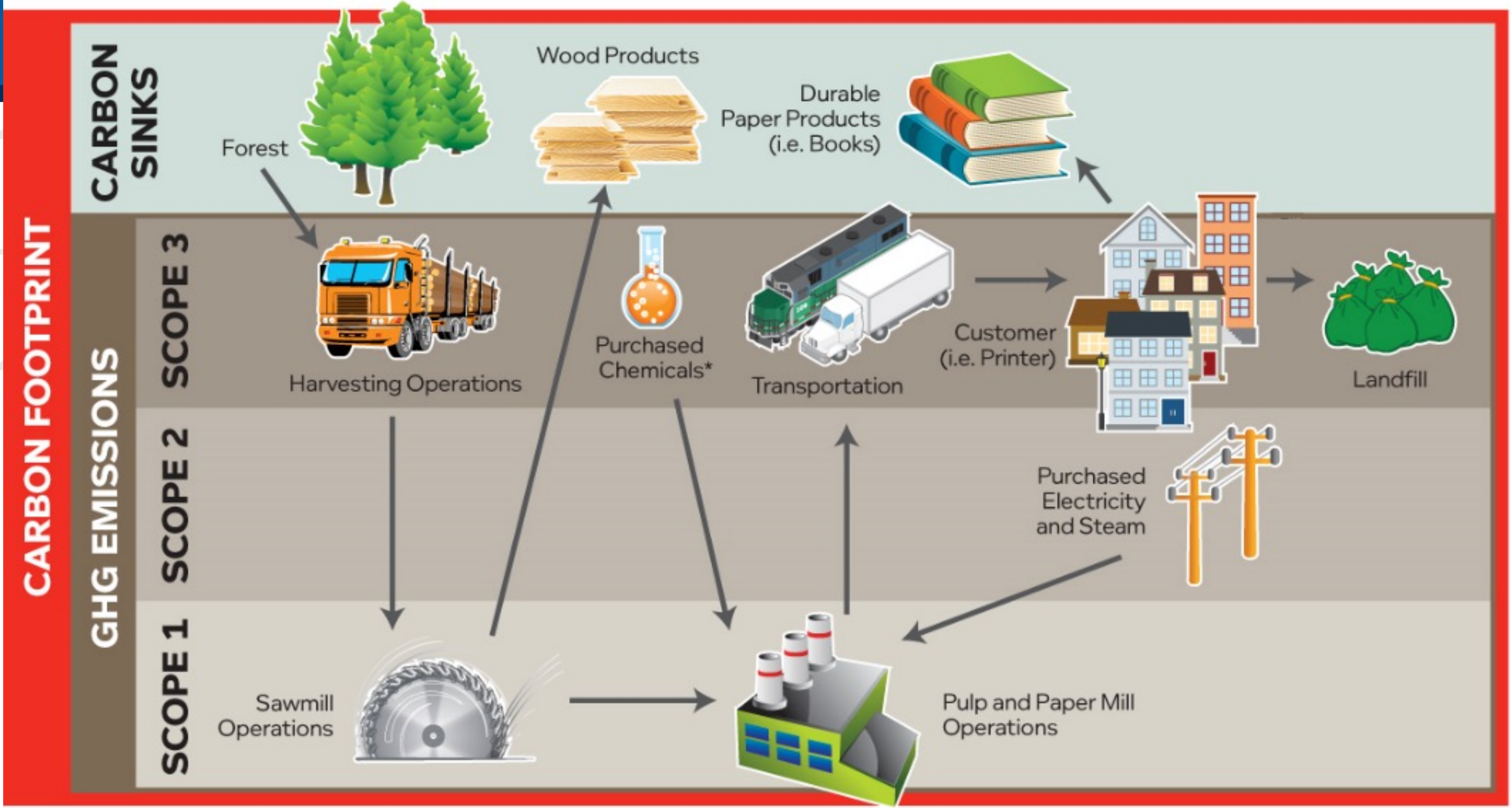
Table 1–1. Environmental performance indexes for residential construction[a]

	Wood frame	Nonwood frame	Difference	Change[b] (%)
Minneapolis design[c]				
Embodied energy (GJ)	651	764	113	–17
Global warming impact (CO_2 kg)	37,047	46,826	9,779	–26
Air emission index (index scale)	8,556	9,729	1,173	–14
Water emission index (index scale)	17	70	53	–312
Solid waste (total kg)	13,766	13641	–125	1
Atlanta design[d]				
Embodied energy (GJ)	398	461	63	–16
Global warming impact (CO_2 kg)	21,367	28,004	6,637	–31
Air emission index (index scale)	4,893	6,007	1,114	–23
Water emission index (index scale)	7	7	0	0
Solid waste (total kg)	7,442	11,269	3,827	–51

[a] Lippke and others (2004).
[b] Percentage change = [(Wood frame – Nonwood frame)/(Wood frame)] × 100.
[c] Steel frame.
[d] Concrete frame.

Sumber : Brashaw dan Berman 2021 (Wood Handbook: Chapter 1)

Operational Boundaries – from Cradle to Grave



*A portion of the emissions from energy used to produce any purchased chemicals

***Life cycle assessment* (LCA)** – Metode untuk penilaian lingkungan produk yang meliputi siklus hidup dari ekstraksi bahan mentah ke pengolahan limbah

***Life cycle inventory* (LCI)** – Studi LCA yang mencakup analisis inventaris, tetapi tidak termasuk penilaian dampak.

***Life cycle impact assessment* (LCIA)** – Fase studi LCA selama dampak lingkungan produk dinilai dan dievaluasi

Mengikuti standar internasional seperti ISO 14040 dan 14044 (ISO 2006a,b), analisis ini dapat mencakup masa pakai produk mulai dari ekstraksi bahan mentah hingga titik produksi produk ("**cradle-to-gate**") atau melalui pengiriman produk, konstruksi, penggunaan, dan terakhir titik pembuangan ("**cradle-to-grave**")

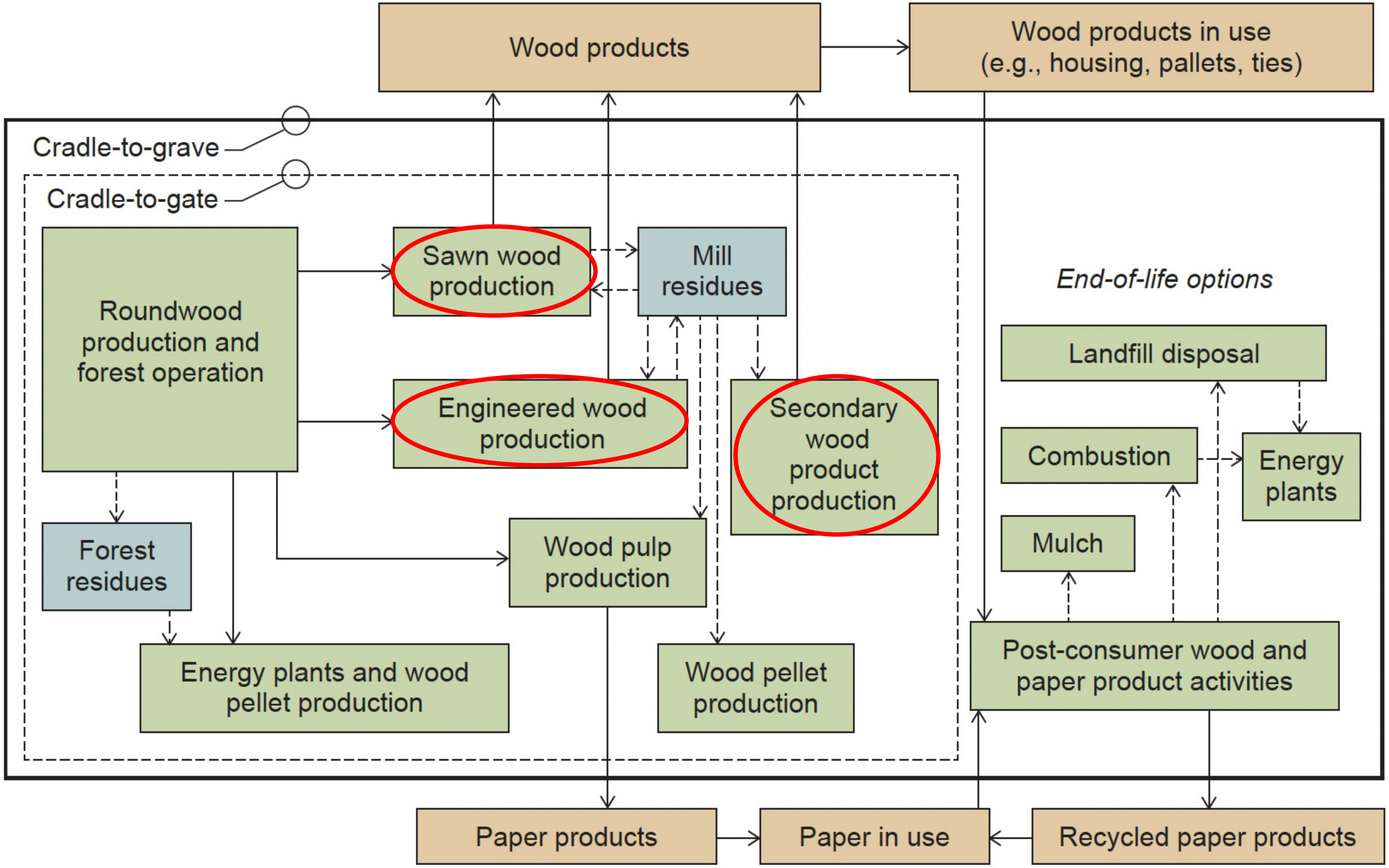


Figure 1–5. Broad view of harvested wood product carbon flow. (From Bergman and others (2014b) and Bais-Moleman and others (2018).)

Cradle-to-gate LCA results for 1 m^3 Wood Product

	Unit	Forestry Operations	Glulam Production	PB	MDF	Hardboard /EWST	Cement	Steel	Plastic	Glass
Impact Category										
Global Warming Potential (GWP)	kg CO2 eq	12.19	206.48	402	759	572	4311	13599	1672	2563
Acidification Potential	kg SO2 eq	9.18	104.19	6.34	5.52	6	21.73	53.12	3.90	21.37
Eutrophication Potential	kg N eq	0.0324	0.1096	1.39	3.42	1	0.505	51.666	1.125	2.095
Ozone Depletion Potential	kg CFC-11 eq	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0004	0.0000	0.0002
Smog Potential	kg O3 eq	4.61	25.29	134	70	78	276	670	49	243
Total Primary Energy Consumption										
Non-renewable fossil	MJ	189.18	3325.58	5,940	10,578	9,340	16,485	181,837	69,934	27,864
Non-renewable nuclear	MJ	1.81	436.89	634	1371	6	0	15,998	1,131	1,350
Renewable (solar, wind, hydroelectric, and geothermal)	MJ	0.20	16.96	418	551	145	0	1,039	246	274
Renewable biomass	MJ	0.00	2213.25	1936	5046	18627	0	102	28	308

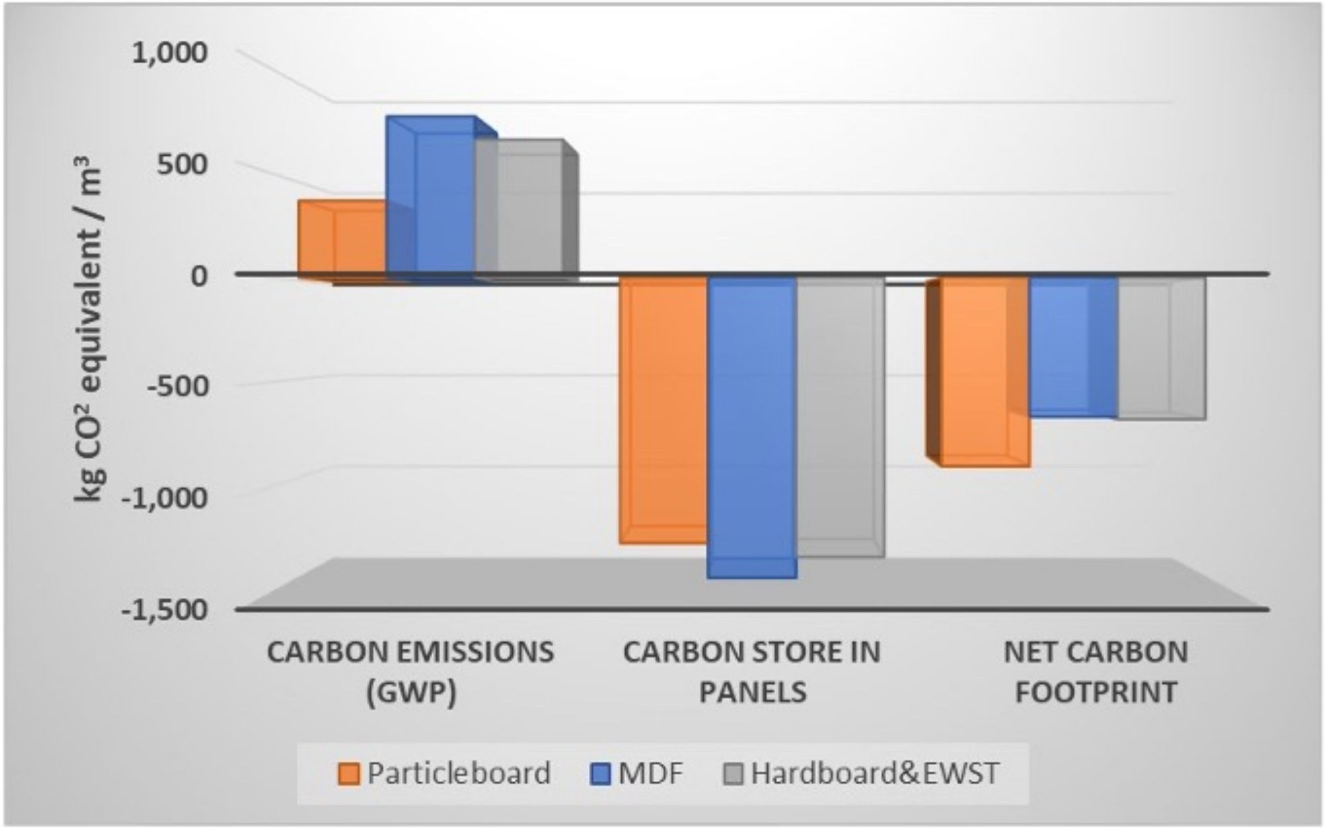
Sumber : Puetmann 2013; 2016

Cradle-to-gate LCA results for 1 m^3 Wood Product

	Unit	Forestry Operation	Glulam Production	PB	MDF	Hardboard/ EWST	Cement	Steel	Plastic	Glass
Material Resources Consumption										
Non-Renewable materials	kg	0,00	4,86	29,00	50,00	4,00	5.119,00	9.080,00	21,00	3.177,00
Renewable materials	kg	0,00	587,80	799,00	1.050,00	1.302,00	N.A	5,00	1,00	15,00
Waste Generation										
Solid Waste	kg	0,19	37,18	N.A	N.A	N.A	N.A	N.A	N.A	N.A
Hazardous waste generated	kg	N.A	N.A	N.A	N.A	N.A	N.A	3,36	0,07	0,09
Non-hazardous waste generated	kg	N.A	N.A	9,00	12,00	109,00	292,00	29,40	488,00	972,00

Sumber : Puetmann 2013;2016

Cradle-to-gate carbon emissions (GWP), carbon stored in final product, and net carbon footprint (emissions minus storage)



Every 1.0 kg of carbon stored in WCP to 3.67 kg of CO s 2 is equivalent not in the atmosphere.

Sumber : Puetmann 2016 ; Life cycle assessment of Density Fiberboard , and Hardboard Wood Siding & Trim

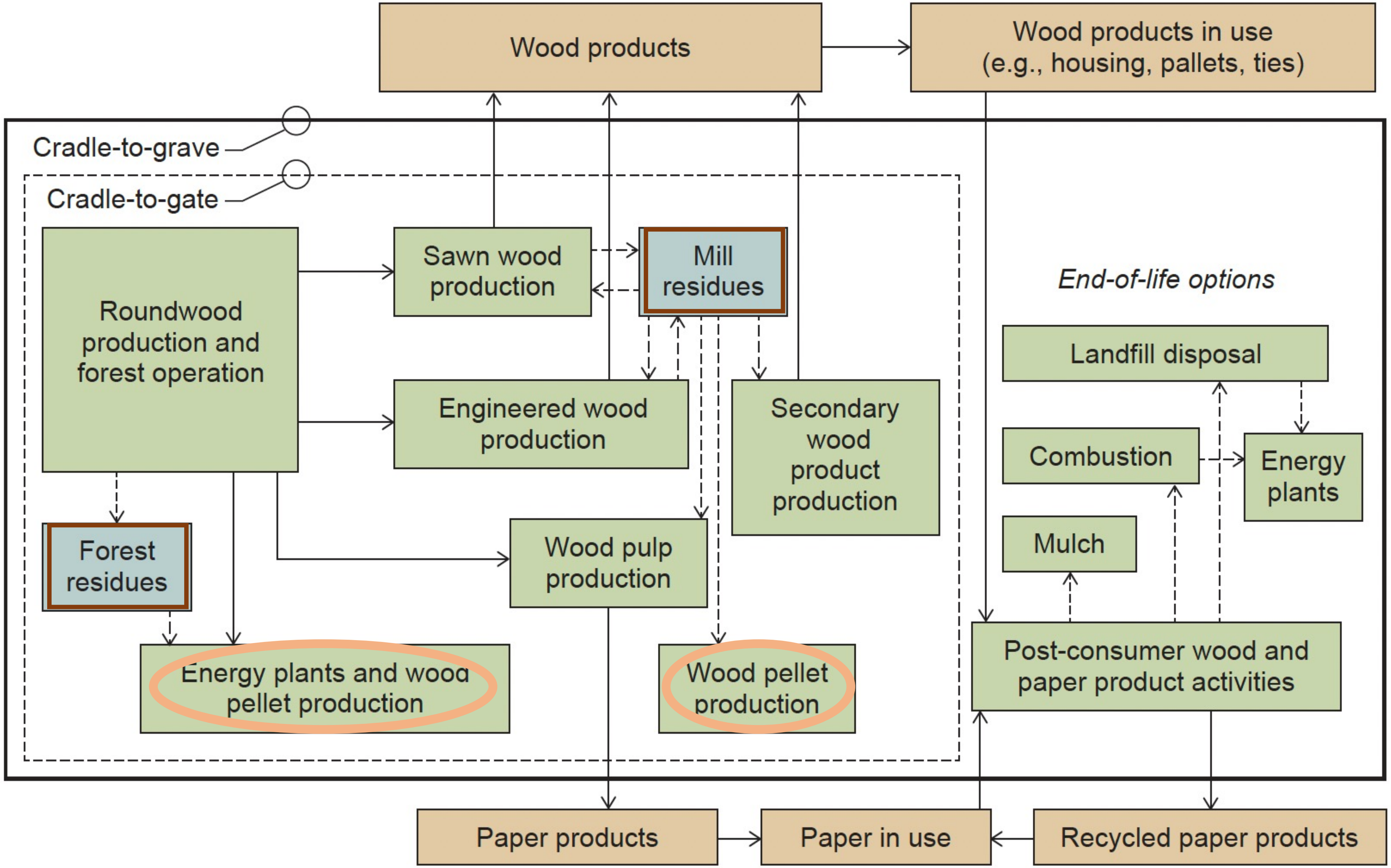


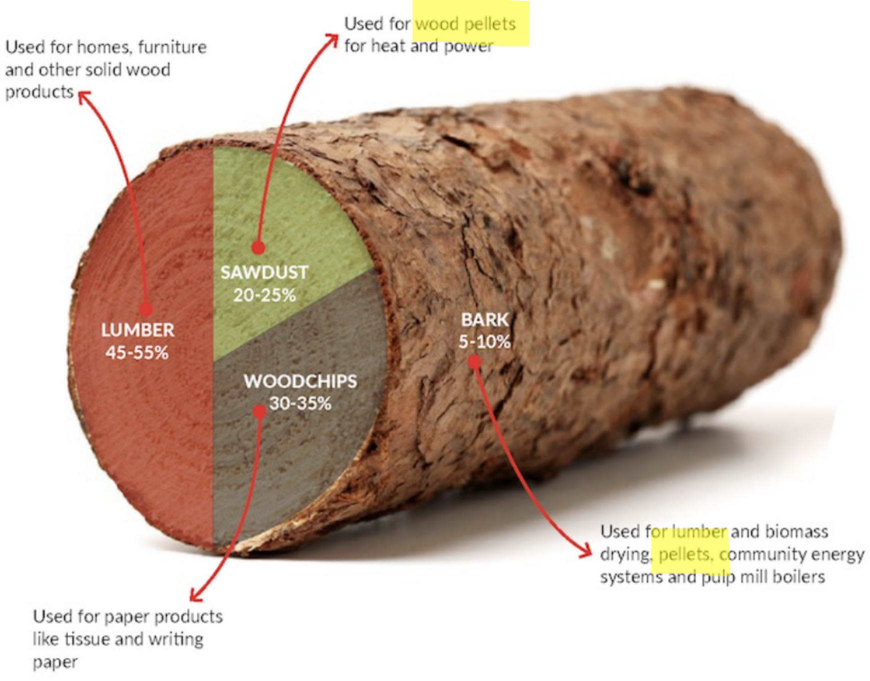
Figure 1–5. Broad view of harvested wood product carbon flow. (From Bergman and others (2014b) and Bais-Moleman and others (2018).)

Environmental load over the entire Life Cycle of wood pellet

Parameter	Total	Unit
Use of resources		
Timber	0.9	g
Copper ore	23.8	g
Iron ore	0.8	g
Lead ore	0.3	g
Bauxite	0.002	g
Uranium ore	13.8	g
Coal	0.005	kWh
Oil	0.4	kWh
Natural gas	0.001	kWh
Energy use		
Fossil fuel	251	MJ
Electricity *(internal parameter)*	22.5	kWh
Biofuel	176	MJ
Emission to air		
CO_2	13,936	g
CO	162	g
NO_x	129	g
HC	21	g
N_2O	1.3	g
SO_2	69	g
CH_4	3.4	g
Particles	19	g
Emission to water		
N-tot	0.03	g
Waste		
Ash	1811	g
Waste oil	1.8	g
Building waste	0.8	g
Highly active radioactive waste	0.5	g
Low active radioactive waste	0.3	g
Hazardous waste	1.1	g
Other waste	16.3	g

Sumber : Chen 2009

Woodl pellet menjadi sumber energy



Siklus bioenergi kayu dari hutan tanaman energi

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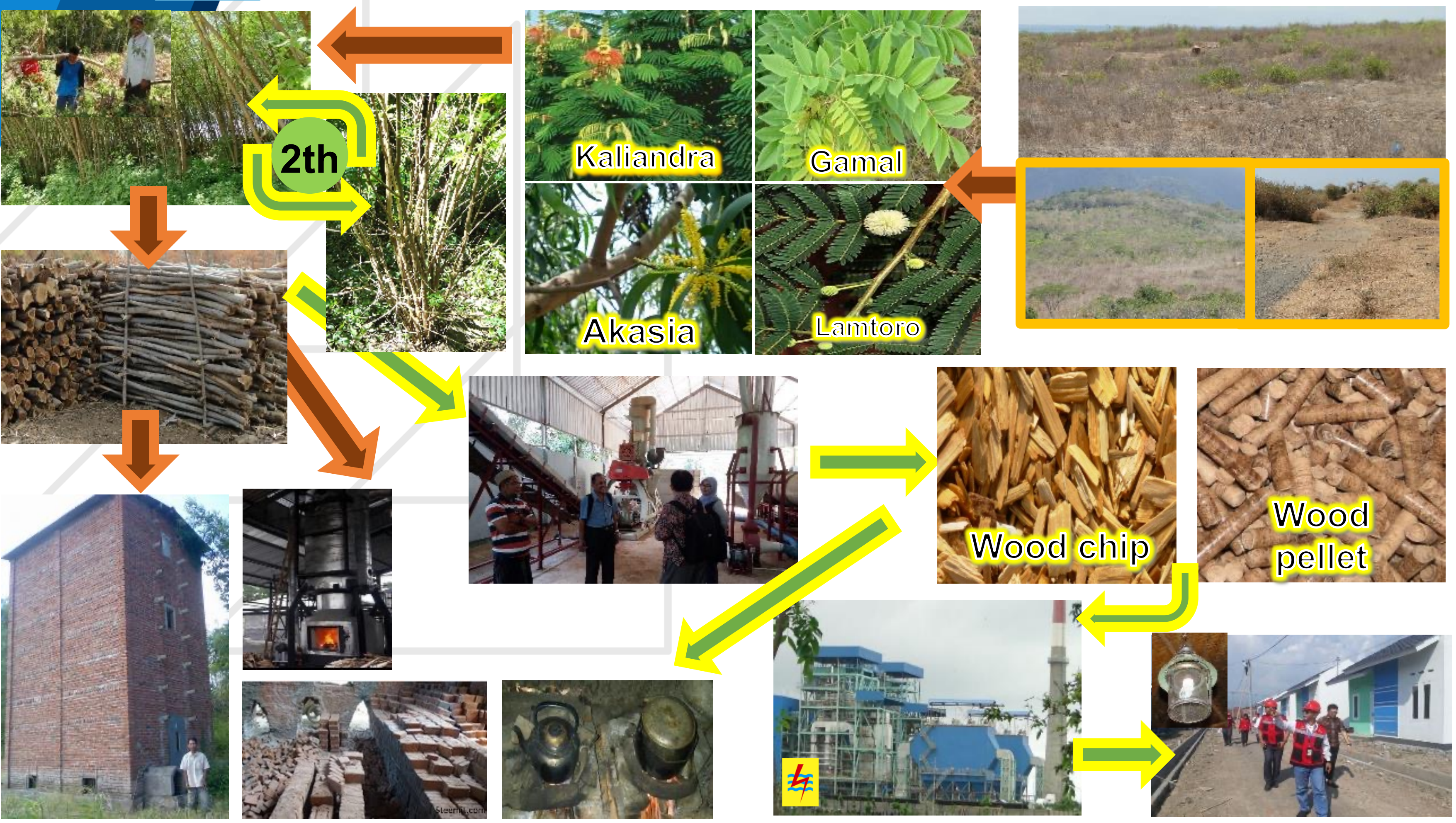
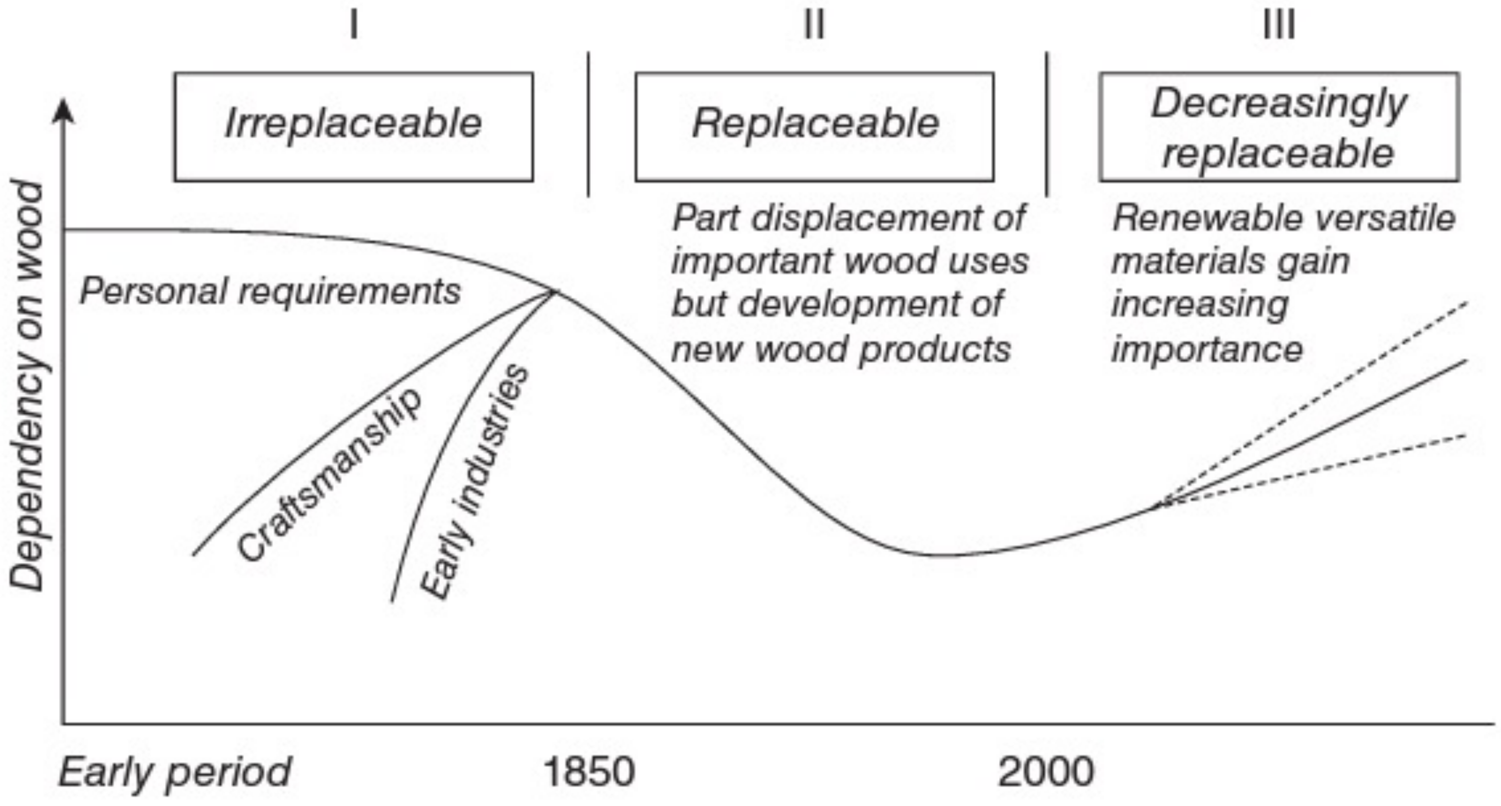


Produksi wood pellet dari hutan tanaman energi di Lombok Timur

Sumber: Disertasi Budi Narendra (2019)

- Status keberlanjutan HTE : cukup berkelanjutan
- **Faktor pengungkit**: keragaman spesiesnya, luasan hutan yang dikelola, dan efektifitas penyuluhan
- Pengembangan HTE pada lahan kritis dengan skenario optimis:
  - Menekan luasan lahan kritis sebesar 16%
  - Terbangun HTE seluas 17.277 ha di tahun 2040
  - Mengurangi pengangguran dari 10.197 menjadi 2.422 orang
  - Menghasilkan kayu energi 848.291 m^3/th → listrik 873.992 rumah tangga
  - Keuntungan Rp 108.628.116/ha.

Relative importance of wood material in past, present, and future



Kenaikan **trend penggunaan kayu** kembali terjadi akibat permasalahan dan kendala pasokan bahan baku dan bahan bakar yang tidak terbarukan (batu bara, minyak, dan gas alam)

Sumber : Sathre and Gustavsson 2009:3 ; Using wood products to mitigate climate change: external costs and structural change

Peningkatan Mutu Kayu

Rekayasa → **Inovasi**

Pemilihan jenis kayu

Kayu cepat tumbuh

Pengeringan

Pengerjaan

Pengawetan

Pengawet non-biosidal

Modifikasi Kayu

Asetilasi, polipropilen, *thermal wood*

- Proses yang digunakan dalam upaya **memperbaiki sifat material kayu**, dengan tetap menghasilkan material yang dapat didaur ulang sehingga produk akhirnya ramah lingkungan

Kebutuhan perekat

Penggunaan bio-based adhesive → Inovasi

Motivations	Ways to introduce bio-based content
• Customer environmental awareness	• Natural macromolecules with adhesive properties (proteins, natural rubber, polysaccharides, lignin)
• Regulations, *i.e.* classification of formaldehyde as a carcinogen	• Synthesis of polymers from renewable monomers (succinic acid, itaconic acid, 1,3-propanediol *etc.*)
• Oil shortage & associated price volatility	• Use of renewable compounds as additives (rosin, fats, oils)
• Differentiation through the development of customised/ specialty products	

Advantage	Example
Higher adhesive strength	Polyurethane from palm oil polyol,[104] polyurethane from partially bio-based isocyanate and castor oil,[38] polyurethane based on castor oil,[106] polyether-polyester based on canola oil,[37] protein-urea formaldehyde mixture for particle boards[109]
Better chemical resistance	Polyurethane from canola oil and 1,3-propanediol polyol[73]
Lower volume reduction	Isosorbide-based dental adhesive[108]
Low cost	Soy flour protein adhesive for oriental strand board,[110] starch – polyvinyl alcohol – melamine adhesive[27]
Easier handling due to lower press temperatures and higher moisture tolerance	Protein adhesives[111]
Avoiding solvents due to lower viscosity	Cardanol-benzoxazine resin[112]

Sumber : Heinrich 2019 ; Future opportunities for bio-based adhesives – advantages beyond renewability

Pemanfaatan Hasil Hutan selain Kayu

Bio-Pellet Fuel from Oil Palm EFB:(Brunerová *et al*. 2018)

Bio komposit

Sumber energi

reinforce

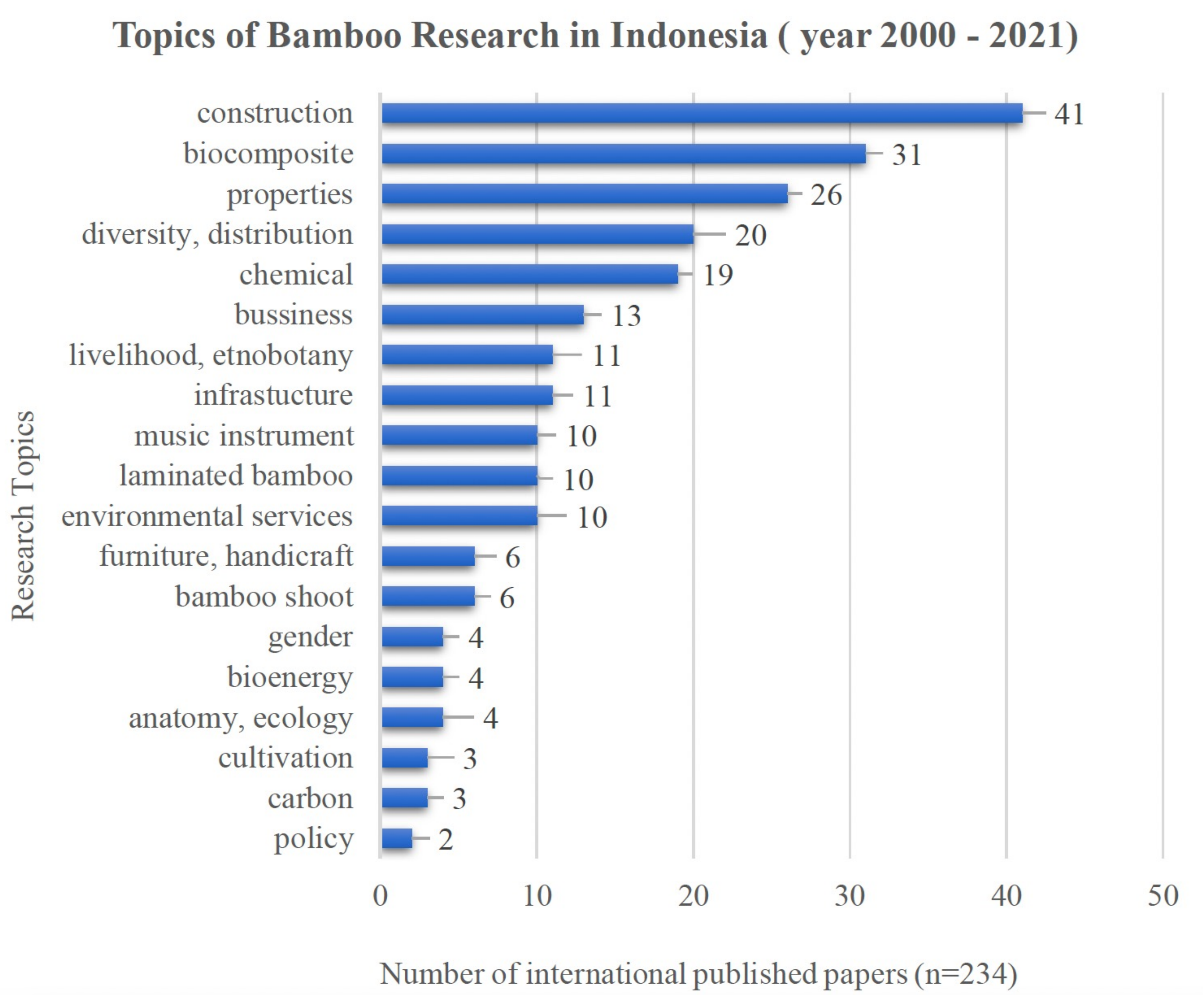
Bambu

Sawit

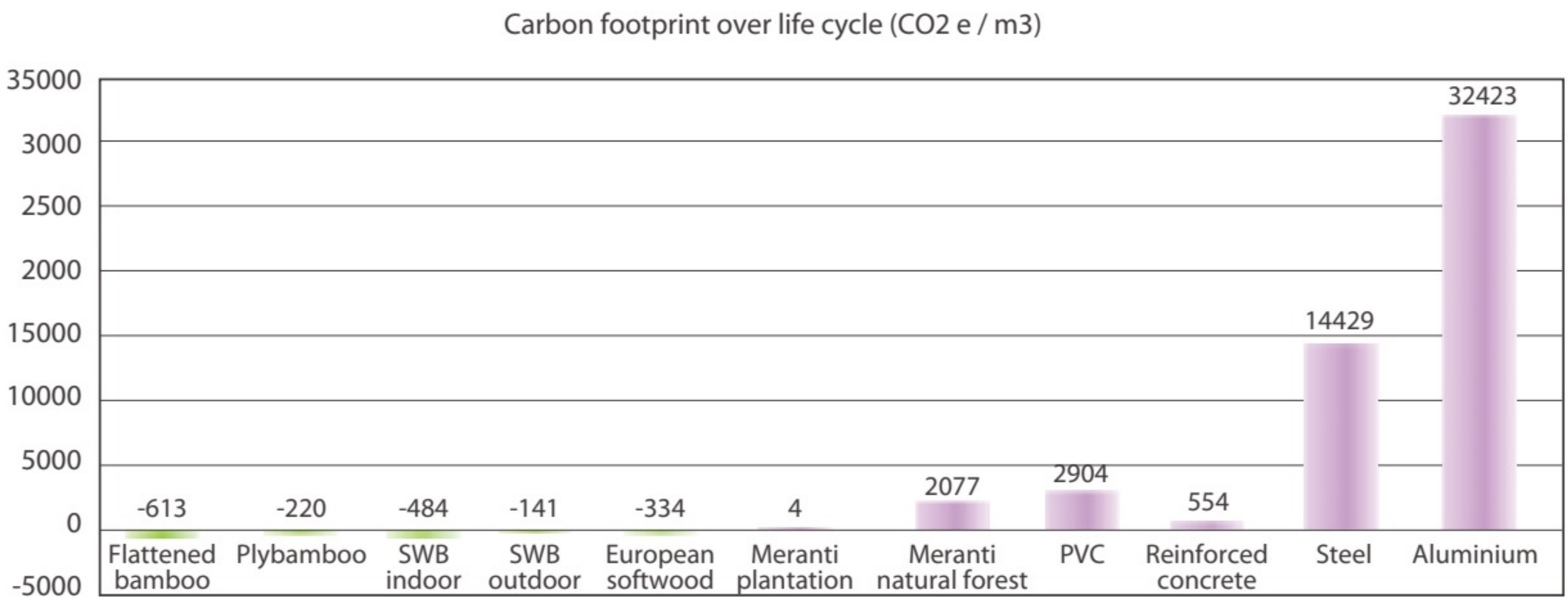
reinforce

Bahan berligno-selulosa lain

Beton ringan berpenguat serat kenaf (Sadir *et al*. 2022)

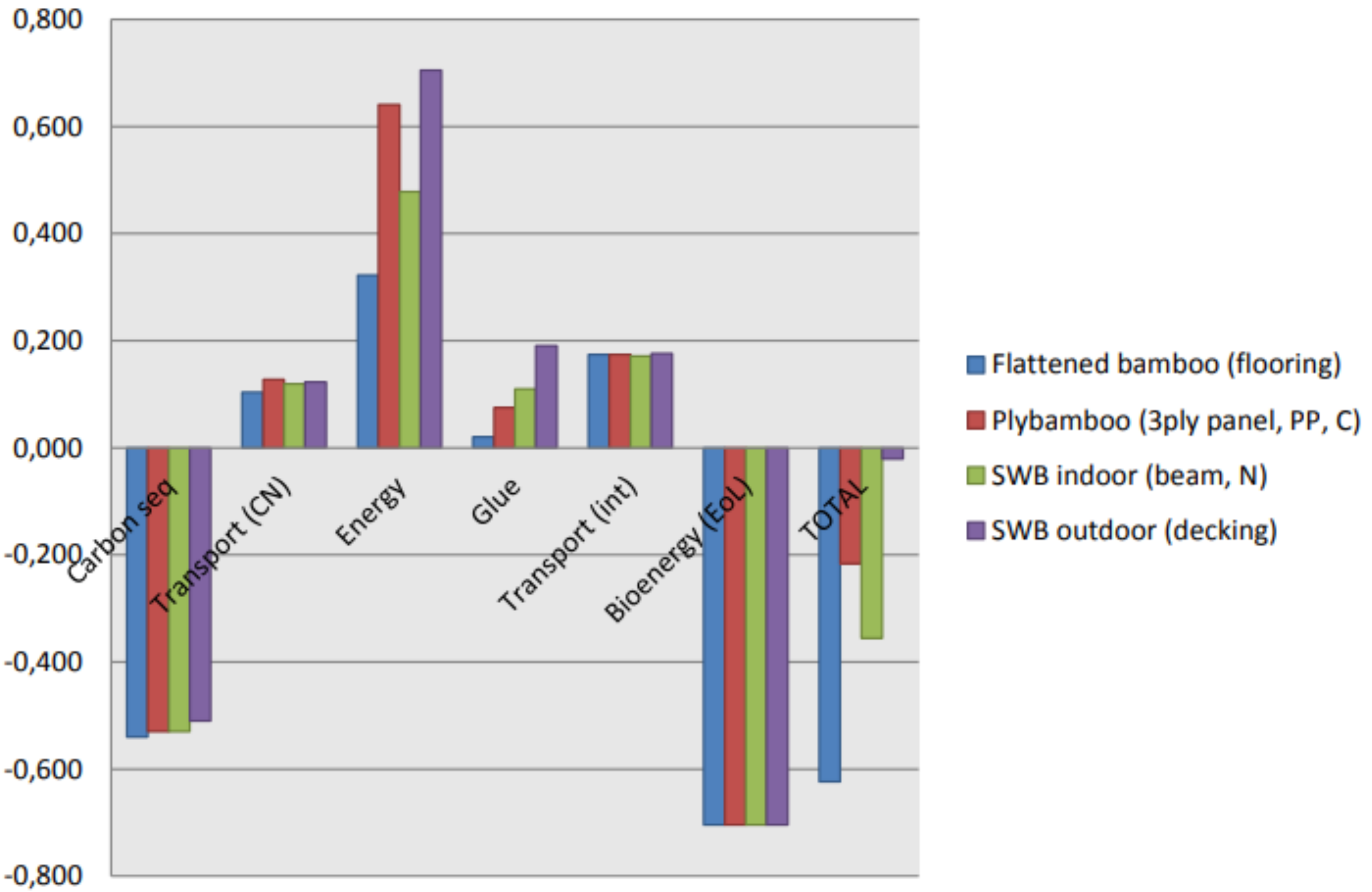


Sumber: Ekawati et al. 2022: The status of bamboo research and development for sustainable use in Indonesia: A systematic literature review



Sumber: der Lug dan Vogtlander. 2022T: The environmental impact of industrial bamboo product

Carbon Footprint over life cycle (CO_2 eq/kg produk)



Sumber: Lugt et al. 2015; Environmental Assessment of Industrial Bamboo Products - Life Cycle Assessment and Carbon Sequestration

Tantangan

Ramah lingkungan **vs** Jejak karbon (*carbon foot print*)

Inovasi

Sertifikasi legalitas kayu dan kelestarian

Penutup

- ✓ Rekayasa Industri pengolahan hasil menjadi tantangan dan tanggung jawab bersama
- ✓ Berbagai produk rekayasa hasil hutan perlu didorong bersinergi dengan dengan industry untuk memperoleh pasar
- ✓ Potensi energi alternatif berupa *wood pellet* sangat menjanjikan
- ✓ Upaya pengurangan emisi karbon perlu **inovasi** dan harmonisasi produk hasil hutan ramah lingkungan yang didukung oleh regulasi yang tepat

Terimakasih

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