Circular use of oil palm residues "Circular use of residues is not a goal but a journey"

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WFBR: Adding value to biomass

So many residues that can turned from a problem into a valuable product!

What is the most circular application?



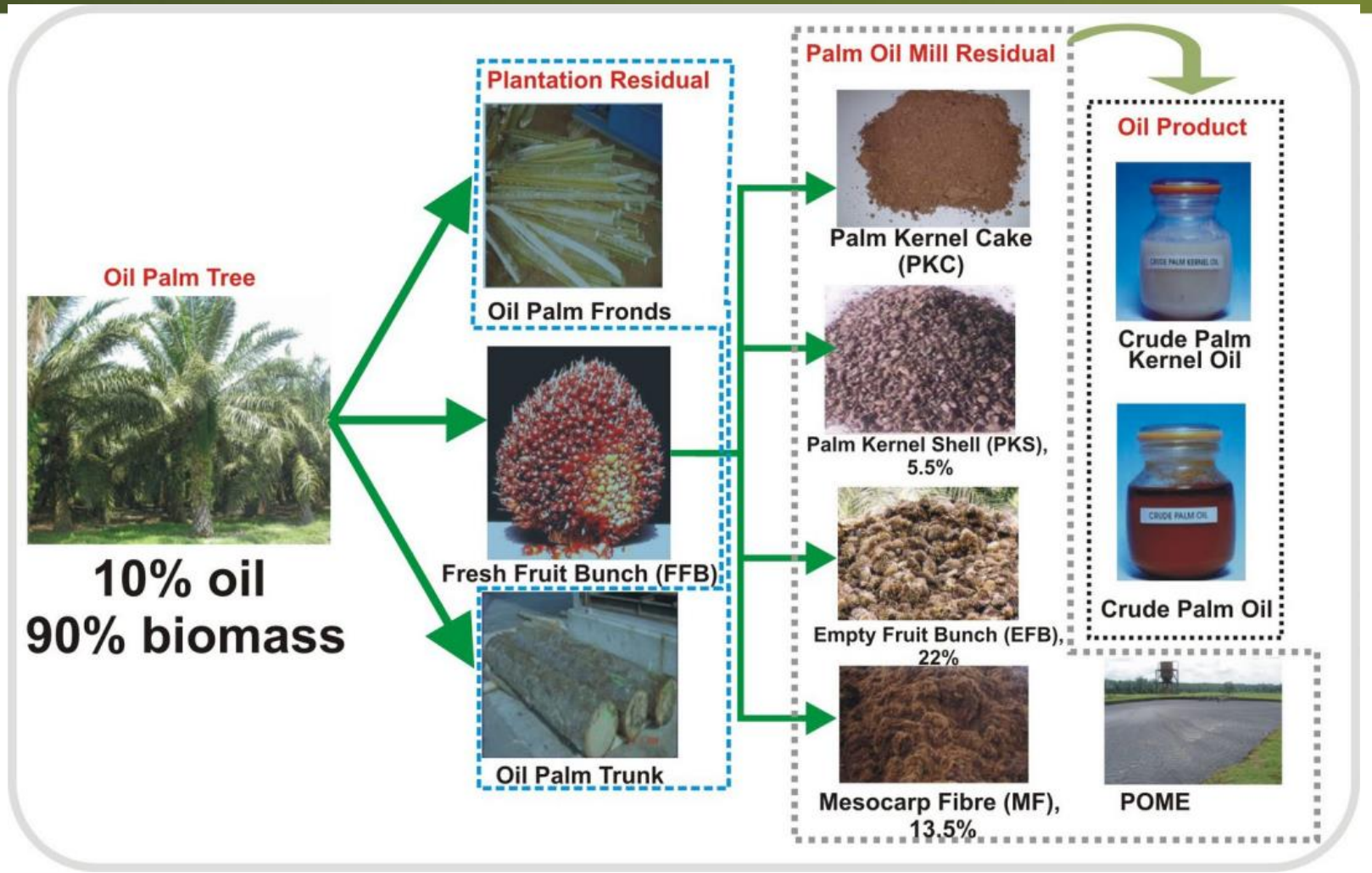




90% (FW) of oil palm production is not oil

Residues are underutilized

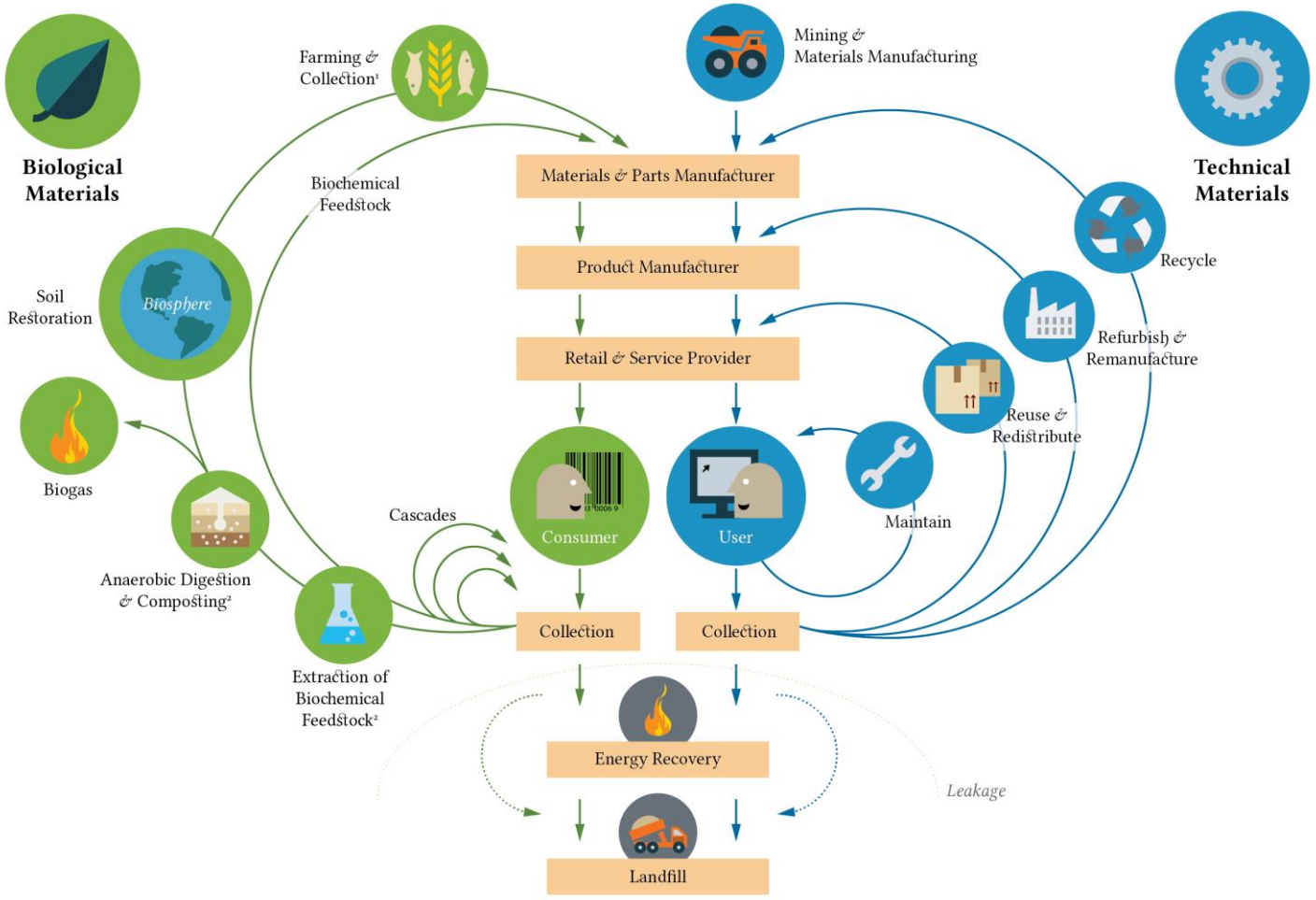
What ar ethe most circular uses of these residues?



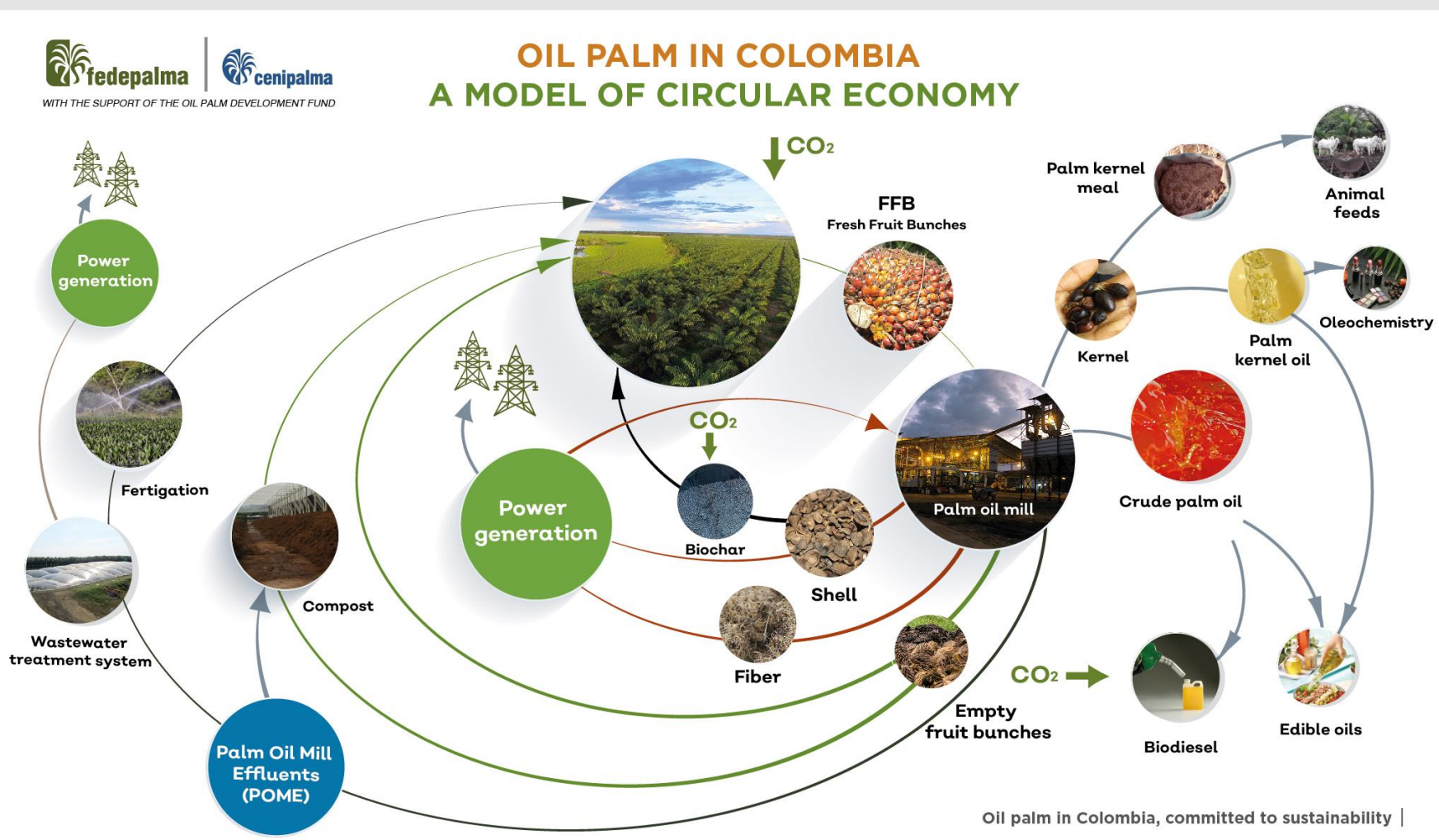
Ref: MPOB

What is circular?

Principles Ellen MacArthur Foundation: only post consumer?



How will it look in 10 or 20 years?

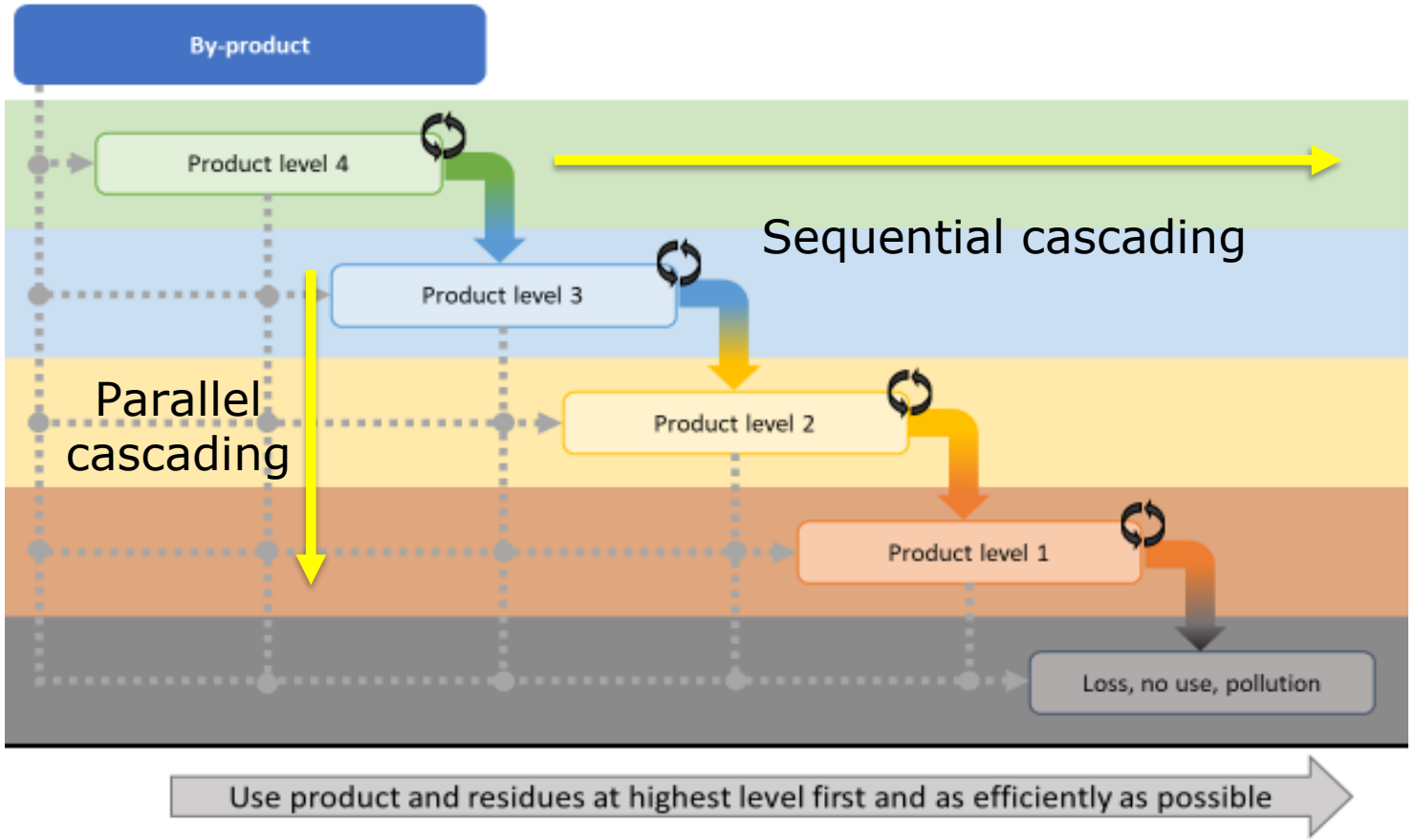


Principles Ellen MacArthur Foundation:

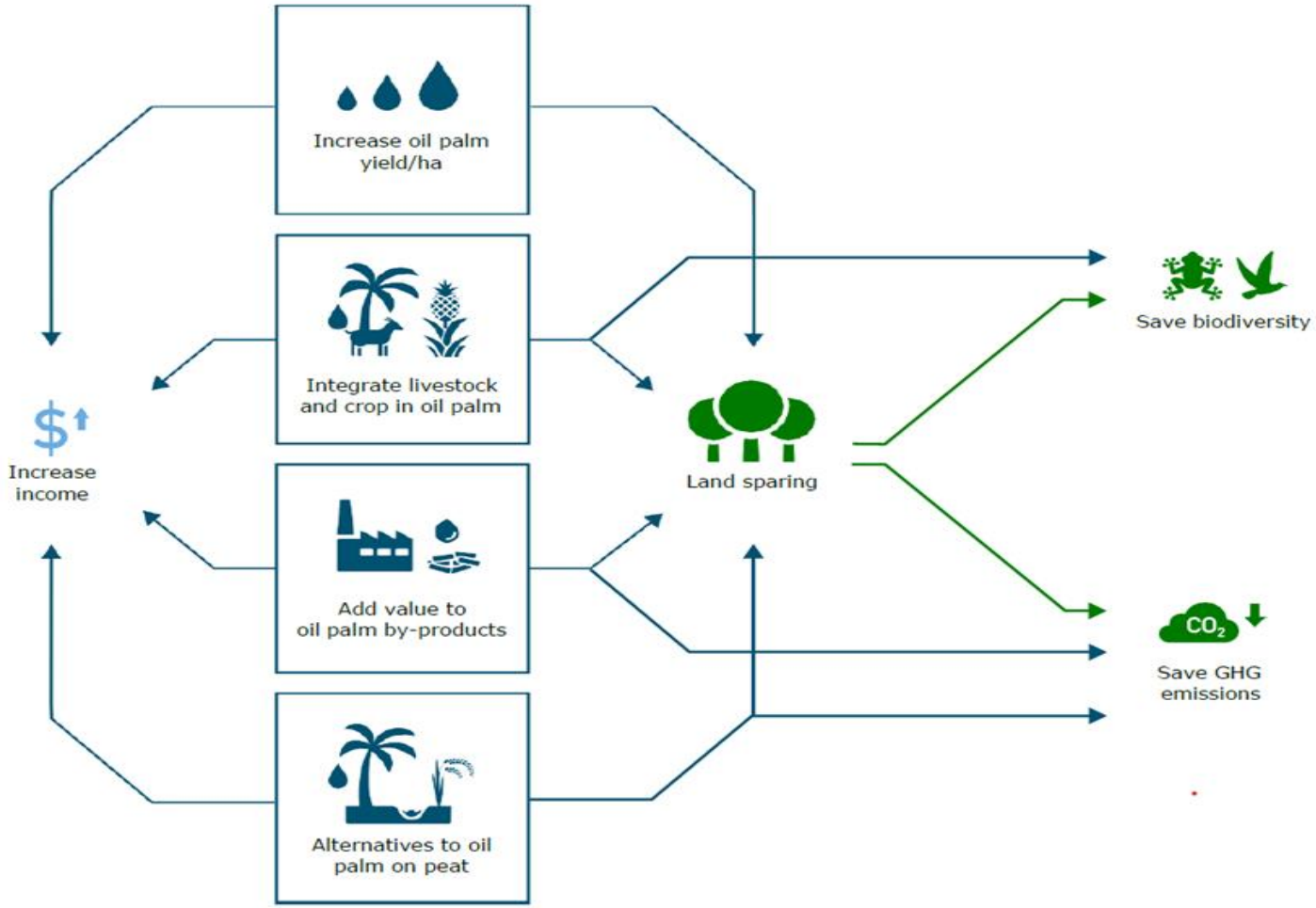
- Design out waste and pollution
- Keep products and materials in use
- Regenerate natural systems

→ Cascading biomass use + maintain functionality

→ Save / regenerate soil quality and biodiversity



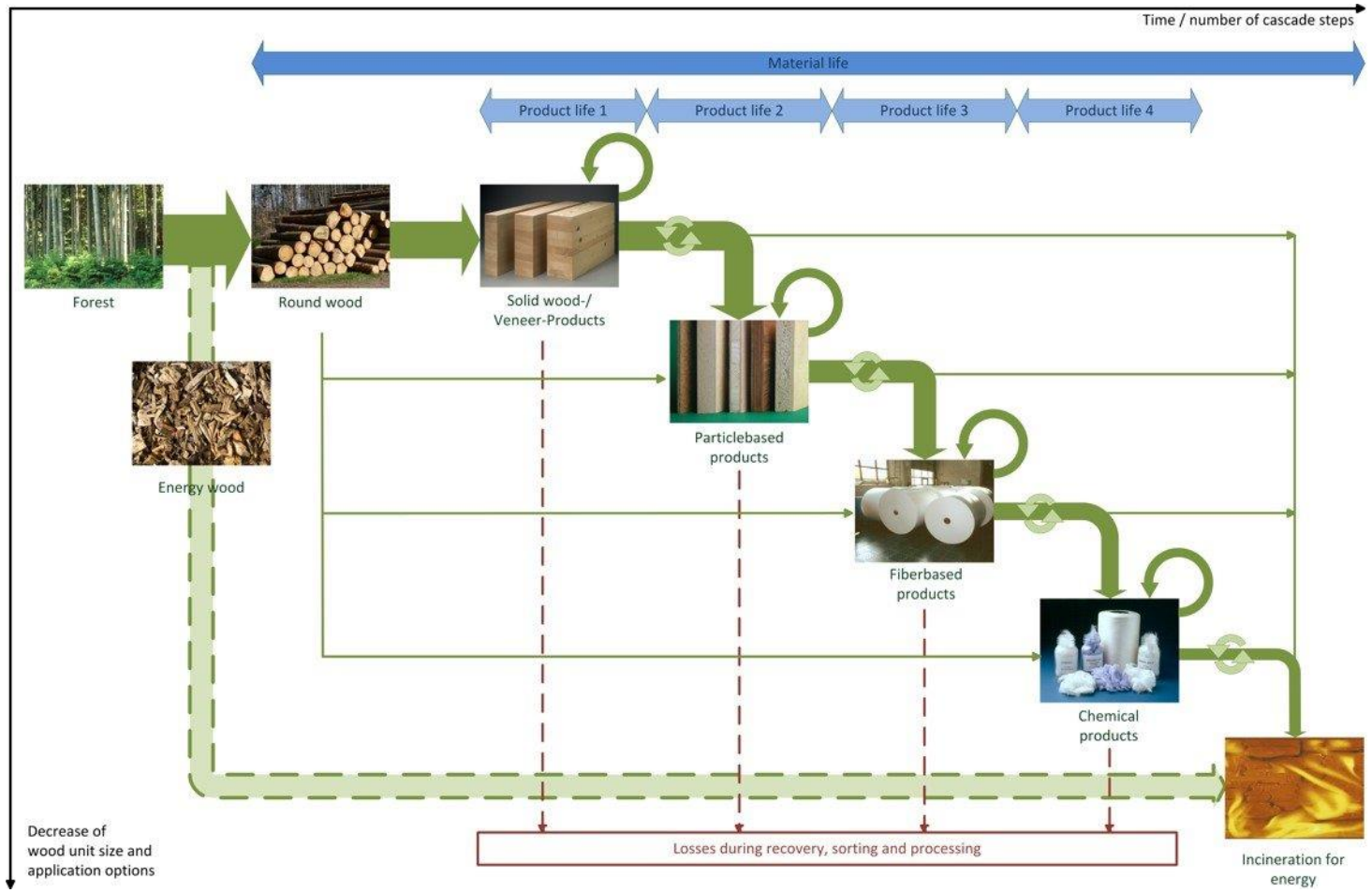
THE TRANSFORMATIVE POWER OF OIL PALM



- Cascading led to savings of up to 14% of the annual primary wood supply needed
- More cascading scenarios had 7% lower GHG emissions

Circular biomass use saves biomass and spares land (and energy, labor, fertilizer, etc)

Or biomass is released for other uses replace fossil fuel and/or land sparing



What is a logic hierarchy for wood?

4. Wood applications with little reduction in functionality (furniture, building material, wooden shoos)
3. Fibre applications (paper/pulp, MDF, bedding)
2. Monomers / molecules (chemicals, fuels, electricity)
1. Energy (heat)
0. Discard or burn without using any functionality (landfilling, burning)

Functionality x efficiency

+ Reuse potential

+ Landsparing

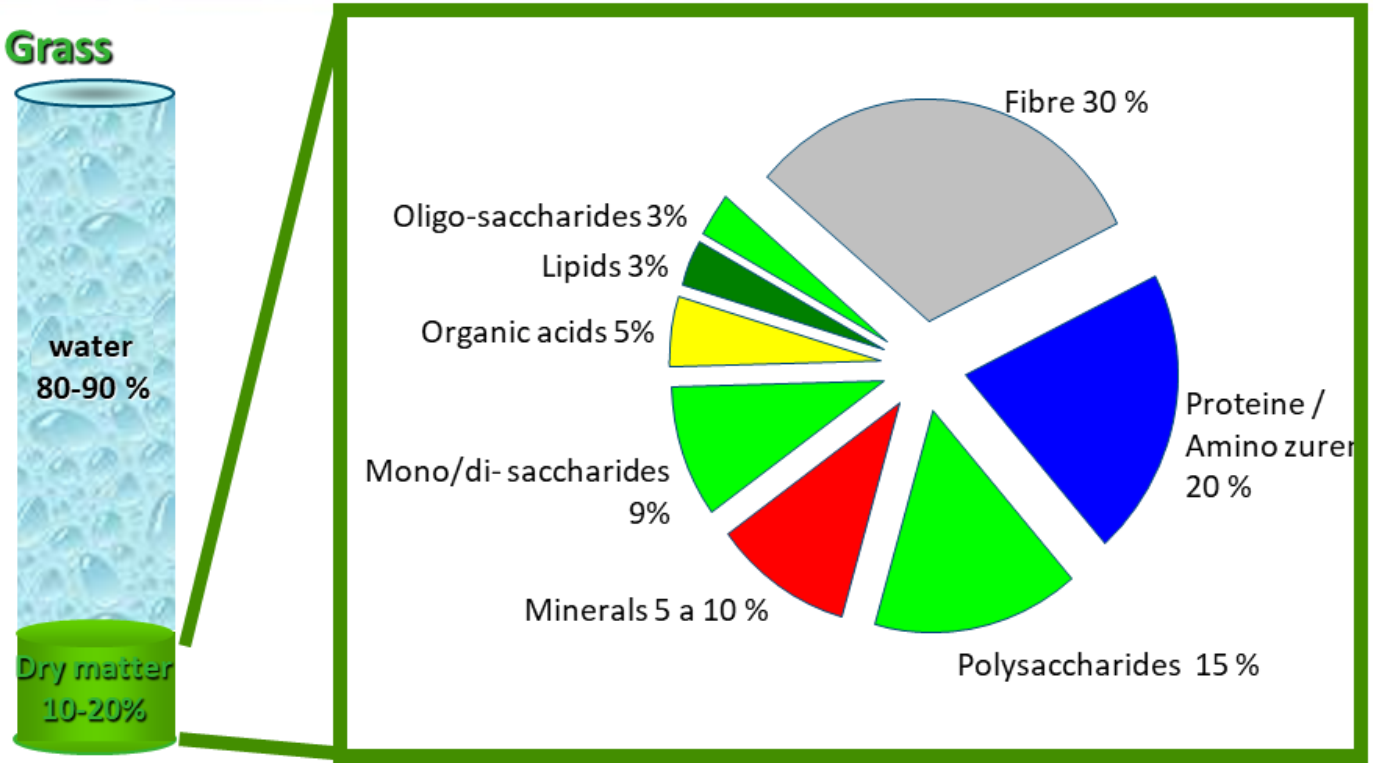




Measuring circularity of biomass applications; extending the cascade – maintaining functionality

Most biomass residues are mixed:

- Some components are scarcer or have more circular value
- Each component has a different hierarchy



Concept	Protein (N * 6.25)	Fat / oil	Fibre	Starch / sugar	P	K
Circular value	4	2.2	1	1	9	3

Hierarchy/functionality for biomass component?

- Try to keep component integrity
- Food over feed
- Final uses are postponed

Functionality /priority level	Fibre	Protein (Nitrogen)	Fat and oil	Carbohydrates (starch and sugars)	Phosphate, Potassium, etc.	Other
4	Materials	Food	Food	Food	Food	Food
3	Pulp, Feed, etc.	Feed / Materials	Feed / Materials (paint, chemicals) /	Feed / Materials	Feed	Feed
2	Monomers (chemicals and fuels[1])	Fertilizer	Transport fuels[1]	Monomers (chemicals and transport fuels[1])	Fertilizer and high value chemicals	Material
1	Energy[2], Soil	Energy[2]	Energy[2]	Energy[2], Soil	Materials	Fuels[1], Soil
0	Loss, Pollution	Loss, Pollution	Loss, Pollution	Loss, Pollution	Loss, Pollution	Loss, Pollution

$$Circularity_{Appl.\ j} = \sum_{Comp.\ i} \begin{matrix} Content_i \\ \times Efficiency_{i,j} \\ \times Appreciation_{i,j} \\ \times Funtionality_{i,j} \end{matrix} \Big/ Ref.value$$

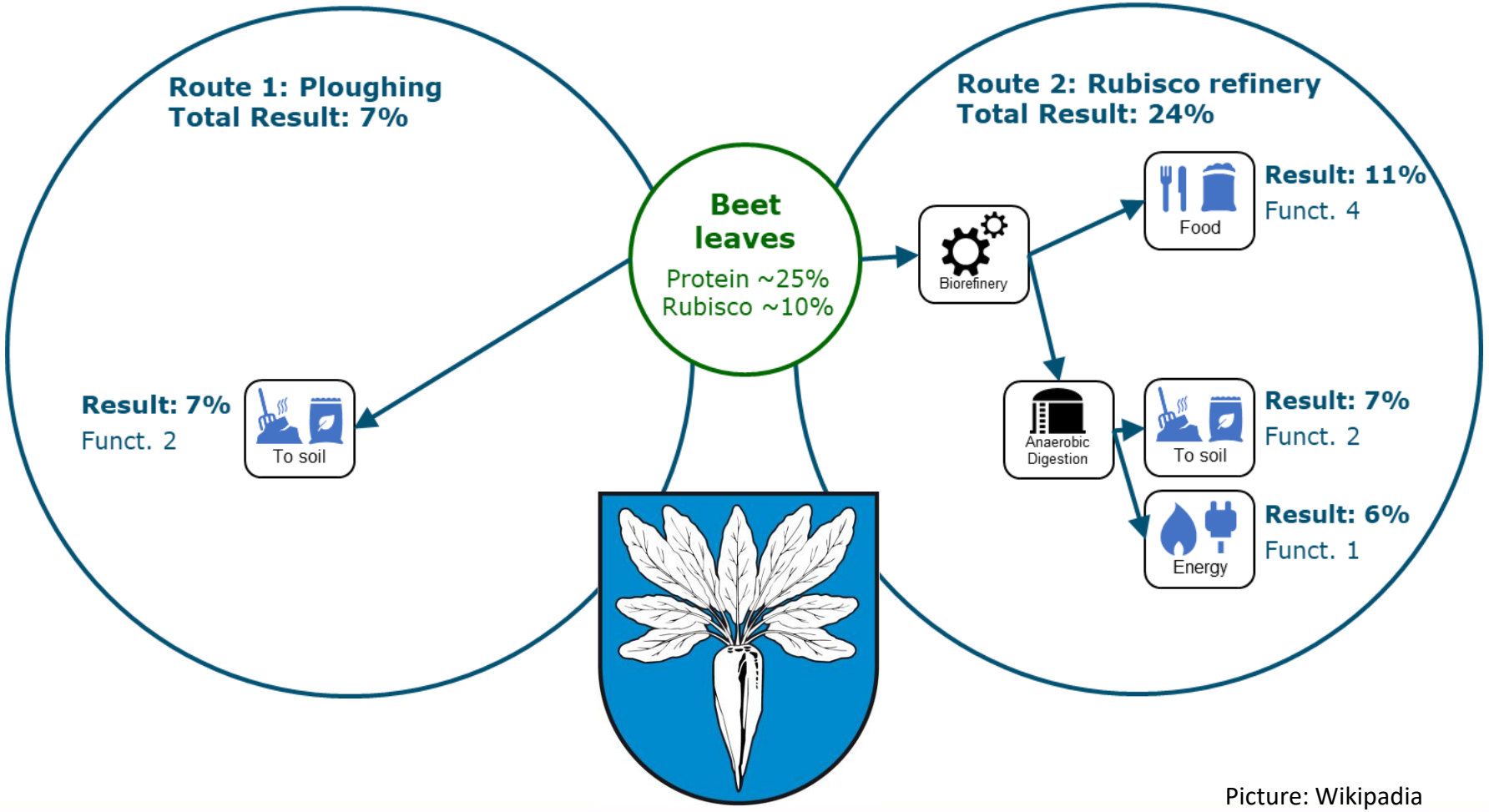
Concept	Protein (N * 6.25)	Fat / oil	Fibre	Starch / sugar	P	K
Appreciation	4	2.2	1	1	9	3

Scoring circularity

Case: Sugar Beet Leaves:

Leaving in the field 7% score **vs** Biorefinery into food protein and biogas production for energy and digestate for soil application 24% of max score

(Concept!)

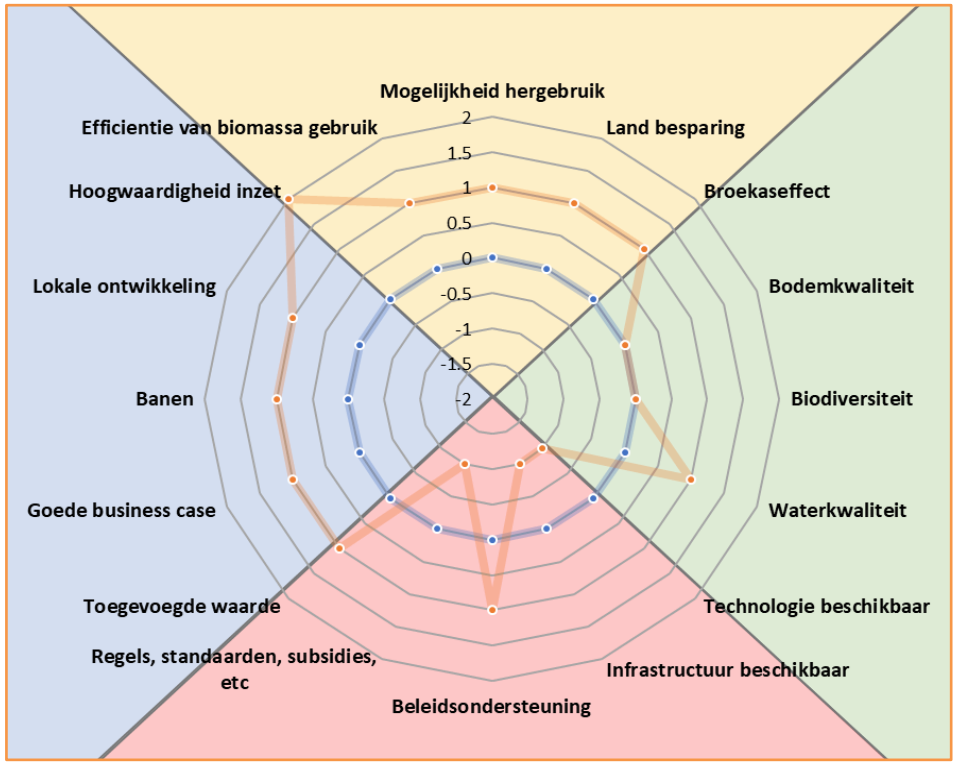


Picture: Wikipadia

Circualarity is only one of the impact categories!

Also consider:

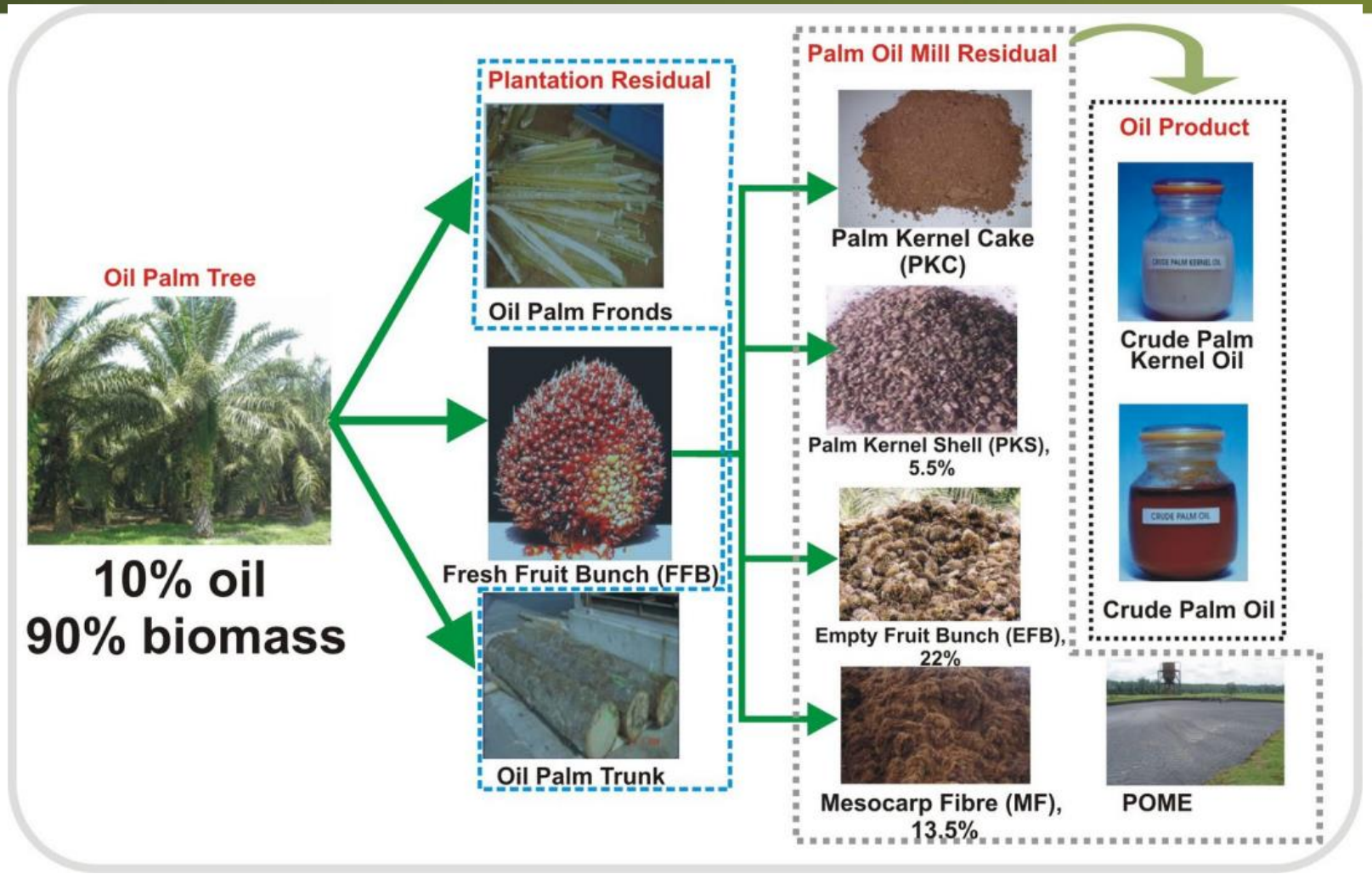
- Socio-economic impacts
- Environmental impacts
- “Implementability”



The circular palm oil mil:

Running the mill biogas produced from POME and EFB (and some MF)

Making Shell and MF available for other uses



Ref: MPOB

The circular palm oil mil:
Running the mill on energy from biogas produced from POME and EFB (and some MF)

Making Shell and MF available for other uses!

Base case – Open POME ponds	Anaerobic digestion of POME	Anaerobic digestion of POME, EFB, and MF
• Biomass boiler (MF and 13% of Shell) • CH4 emission from POME ponds • EFB mulching - costly	• Biomass boiler (MF and Shell) • EFB mulching • POME electricity to grid	• Boiler on biogas • Anaerobic digestion of EFB and POME • Surplus electricity to grid

Current set-up

- Biomass boiler (MF & Shell)
- Low thermal efficiency (60%)
- Cyclone and electrostatic filter required
- CAPEX and OPEX (electricity: 4.5 kWh/ton FFB)
- Nitrogen is lost (emission)
- Availability of minerals (P & K) in boiler ash is limited

Circular palm oil mill

- Biogas from POME & EFB (+MF)
- Thermal efficiency (87%)
- No flue gas treatment necessary
- Biogas production for steam and electricity generation
- Sludge (C + N, P & K) available for soil
- Extra process steps
  - Covered lagoon and /or reactor, H_2S washer, biogas boiler, biogas generator

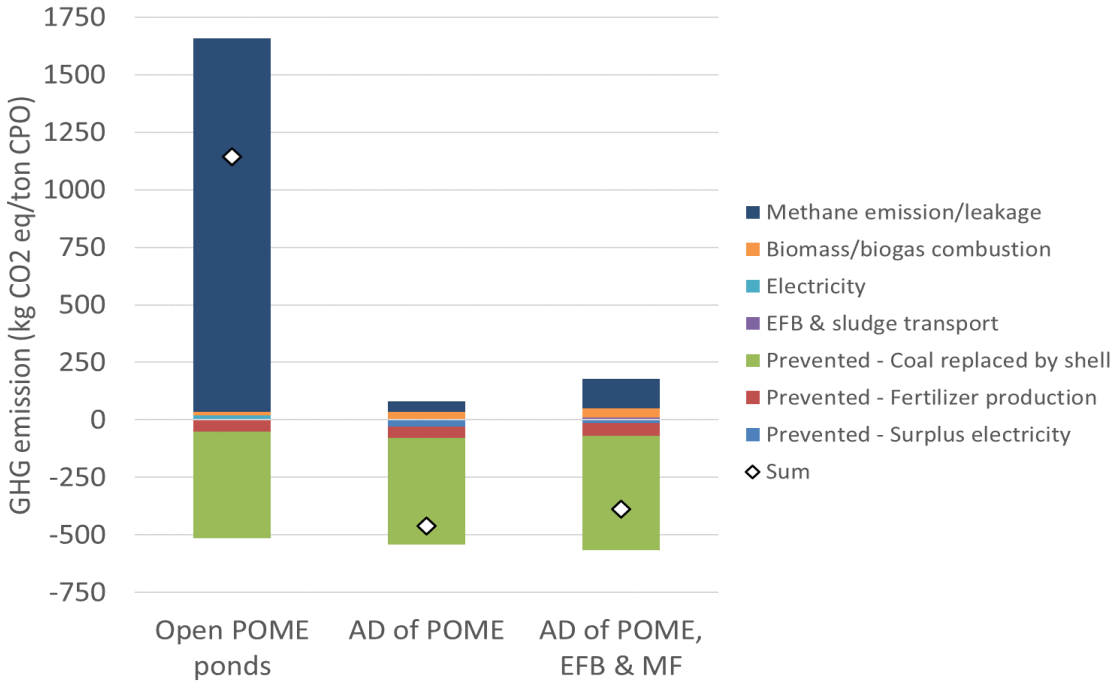
Biogas yield from EFB and MF with and without steam treatment

	Untreated		Steam treated	
	EFB	MF	EFB	MF
DW	44%	65%	44%	65%
Moisture	56%	35%	56%	35%
OM removal	56%	35%	66%	46%
Biogas production (m3/ton OM in)	**350**	**260**	**475**	**360**
Increased production			**36%**	**38%**
CH4 content	54%	59%	54%	59%

		Open POME ponds	AD of POME	AD of POME, EFB & MF
CAPEX	M$	21.4	22.1	21.4
Average cash flow	M$/y	4.0	4.7	4.7
Simple pay-back period	y	5.4	4.7	4.6
Net present value	M$	14.3	20.4	20.6
Internal rate of return		13%	17%	18%

Needs updating!

TXT



Effect	Current mill†	AD of POME‡	Circular mill. AD of POME, MF, EFB	Explanation
GHG performance	- -	+	++	No methane emission from open pond; GHG neutral electricity production from surplus biogas.
IRR	0	+	+	Income from sales of electricity + shell and GHG emission savings benefit
Pay-back period	0	+	+	Saving on fluegas cleaning – expensive filter not necessary when biogas used for making steam – Investment needed for lagoon covering and biogas cleaning (H_2S removal)
Air Quality	- -	++	++	Biomass burning emits more CO, NOx and PM. Steam production from biogas very clean
Soil quality	0	+	++	More nutrients returned to soil, more carbon returned to soil than base case
Circularity	-	+	++	Nitrogen not burned but used for soil, stable carbon (lignin) used for soil and not burned. Easily converted biomass (sugars, hemicellulose) are used for biogas and not lost in the soil

Pulling down oil palm

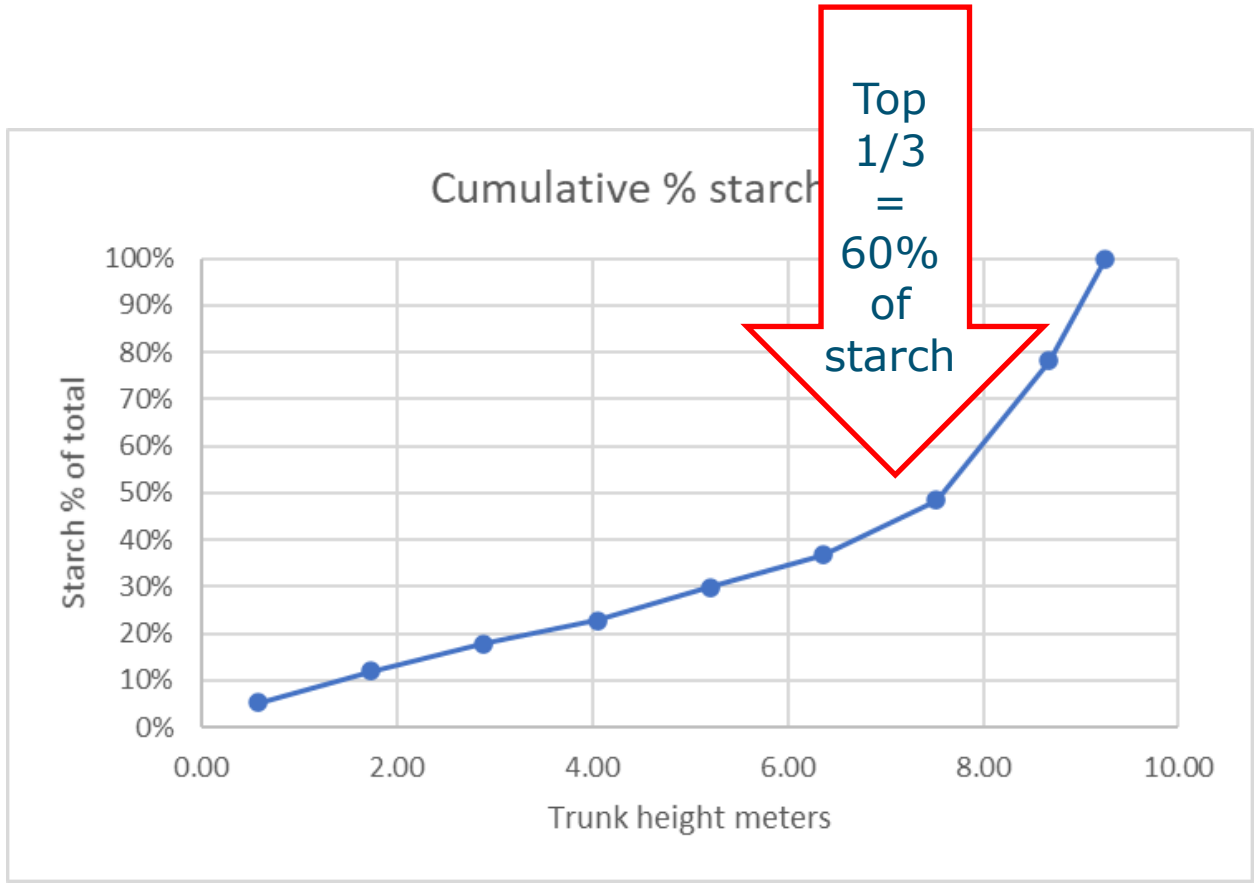

SMITHS

Pressing OPT samples

Pressed liquid after sedimentation

How much land can be spared by using starch from oil palm trunk replacing cassava starch?

	Palm oil area harvested	Average ha replanted	Total starch in trunks	Oil palm starch per ha when replanted	Cassava starch per ha	land sparing factor	Long term land sparing
	Ha x million	Ha per year	Million tons	Ton /ha	Ton / ha	Ha / ha	Ha
Colombia	0.50	20,165	0.107	5.3	3.27	1.62	**32,703**
Indonesia	14.68	587,102	3.112	5.3	6.83	0.77	**455,458**
Malaysia	5.22	208,673	1.106	5.3	5.18	1.02	**213,342**
Thailand	0.90	35,853	0.190	5.3	6.72	0.79	**28,260**

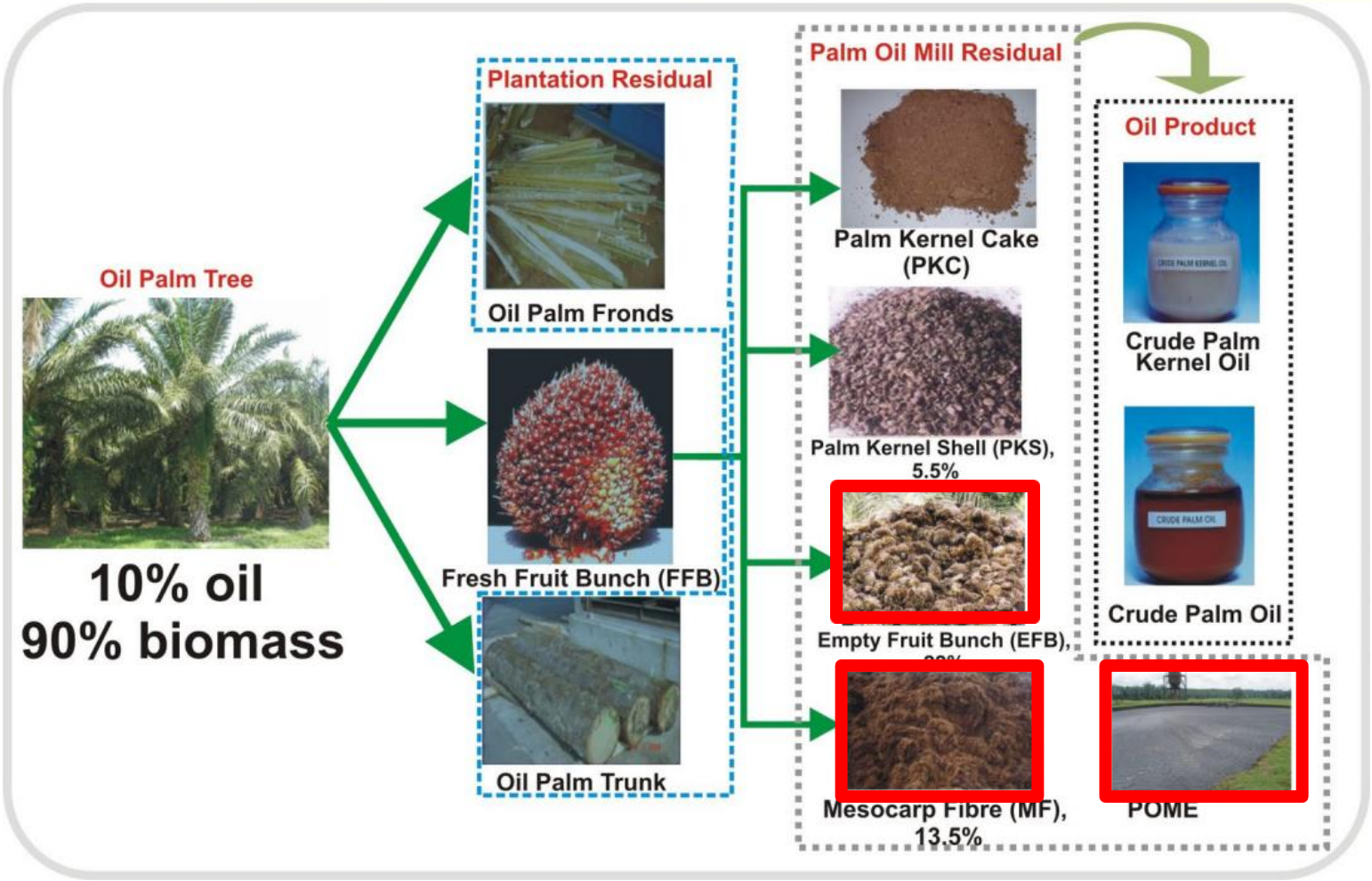

Cumulative % starch
Top 1/3 = 60% of starch
Starch % of total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.00
2.00
4.00
6.00
8.00
10.00
Trunk height meters

Afb. 1 Een 3D-ontwerp van de Mobile Drying Unit (MDU)

- Mobile factory processing starch plus wood
- Mobile factories near plantation renovation
- Concentrated starch fraction for glue + (food, plastics, other)
- Wood for veneer for other biobased applications
- Pulp for soil after fermentation (ethanol, biogas, etc)

Ref. Dadtco / Ebbens Cassava

- Virgin oil for biofuels being phased out in EU but.....
- Residue oils have a premium value for biodiesel and SAF in the EU
- POME fatty acids are already being collected for fuels
- 200.000 tons POME biodiesel in NL in 2021
- Why not extract residual oils from EFB and MF??????



Residual oils have a value for biofuel production in EU

- Potential is 5.6 million ton residual palm oil per year worldwide
- What part can be brought to market?
- POME and EFB is on the Annex IX list of the EU
- Mesocarp residual oil should be on that list too

Worldwide potential?	Production fresh	Residue oil
	----------Million tons per year----------	
POME	253	1.8
MF	50	1.9
EFB	71	1.9
Palm oil	75.5	

References:

Voogt, Barrera Hernandez, Van Groenestijn, Elbersen, Garcia-Nunez. **Improving Sustainability and Circularity of Palm Oil by Anaerobic Digestion of Empty Fruit Bunch, Mesocarp Fibre, and Palm Oil Mill Effluent, Enabling Self-Sufficient Energy Production from Biogas.** Proceedings of the 29th European Biomass Conference and Exhibition. 2021
https://research.wur.nl/en/publications/improving-sustainability-and-circularity-of-palm-oil-by-anaerobic

Wolter Elbersen, Anton Schultze-Jena, Siemen van Berkum, Just Dengerink, Anton Schultze-Jena, Maria Naranjo-Barrantes, Elisabeth Obeng. 2022. **Identifying and implementing circular applications of agri-residues. A circular evaluation framework for assessing impacts and circularity of different agri-residue applications.** WFBR report 2247, DOI 10.18174/563389. Wageningen, The Netherlands.

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Thanks

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