Biomass Supply for Bio-based Products and Fuels in a Circular Economy

Webinar on Markets and Strategies for Renewable Chemicals and Materials

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Adding value to biomass: Biomass innovation plant

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Agenda

- Types of biomass: Crops, primary secondary, tertiary residues
- First generation feedstocks vs second generation feedstocks
- Sourcing first generation feedstock
  - Solutions variable demand → filling the yield gap
- Sourcing second generation feedstocks
  - Commodities
  - Marginal land
- Circular use of feedstocks: what does it mean for feedstock supply?
  - Examples

Which biomass categories?

- Primary by-products: At the source = sugar beet tops, straw, verge grass, prunings, greenhouse residues, etc.

- Secondary by-products, later in the production chain = potato peels, sugar beet pulp, sawdust, etc.

- Tertiary by-products, has had a use = used frying oil, slaughterhouse waste, *manure*, household organic wastes, used paper, demolition wood.

- Specific crops, rape, energy grain, Miscanthus, switchgrass, SRC, sugar beet for ethanol, etc.

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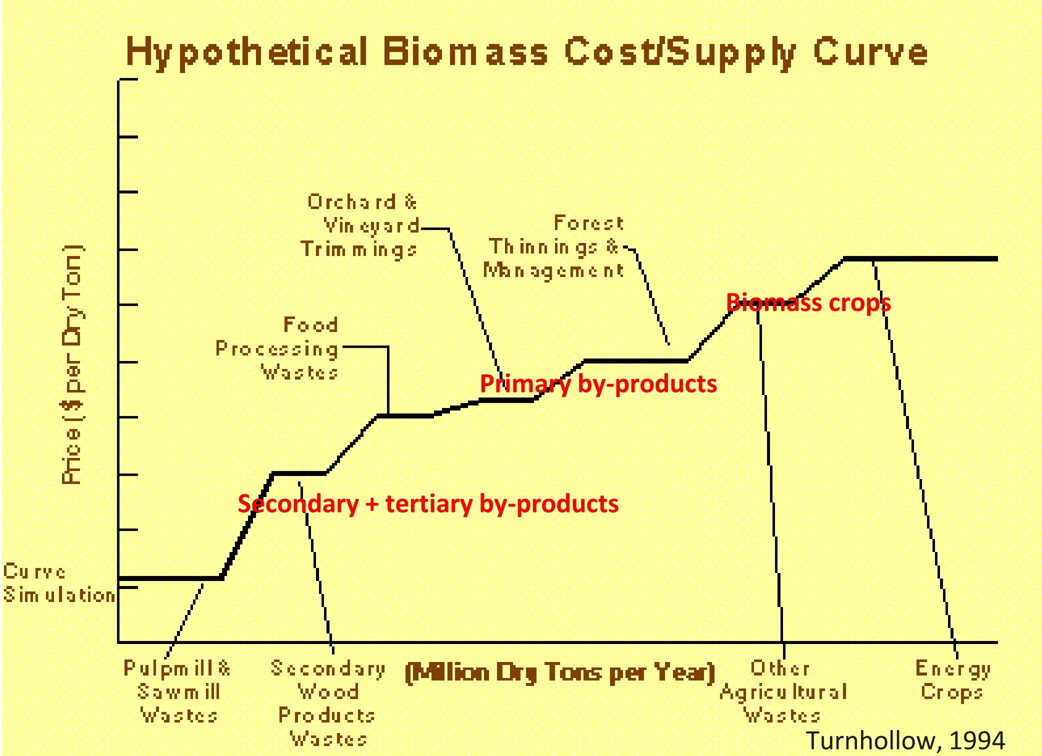
Byproducts and dedicated crops?



- Tertiary by-products
- Secondary by-products
- Primary by-products
- Dedicated crops

First generation technologies need sugar, starch, oils

Advantages:

- Relatively easy to convert
- Readily available feedstock
- GHG balance positive (in the chain) > 50% better than fossil equivalent (for fuels and chemicals)

Issues

- Variable availability and price
- Competition with food
- Indirect land use change risk

→ deforestation

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Effect of first generation feedstock demand for fuels and chemicals

1. Higher prices → food/fuel issues, food insecurity for low income people

and/or

2. More land is converted into crops → (indirect) land use change, GHG emissions and reduced biodiversity

and/or

3. Increased production per hectare / intensification → this is what we want! → land productivity of is not exploited fully

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Vary the demand for first-generation biofuels (ethanol/biodiesel). Prioritize food and chemicals

Vary the production of first generation biofuels (ethanol / biodiesel) according to feedstock availability / price. This will:

- Increase food security – "**feedstock for biofuels is a virtual reserve**"
- Add to investments in agriculture – keep soil productivity stable
- Help reduce (indirect Land Use Change) risk → stable prices contribute to increasing yield.
- Can also secure availability of 1e generation feedstocks for biobased economy at reasonable price (**chemicals / bioplastics**)

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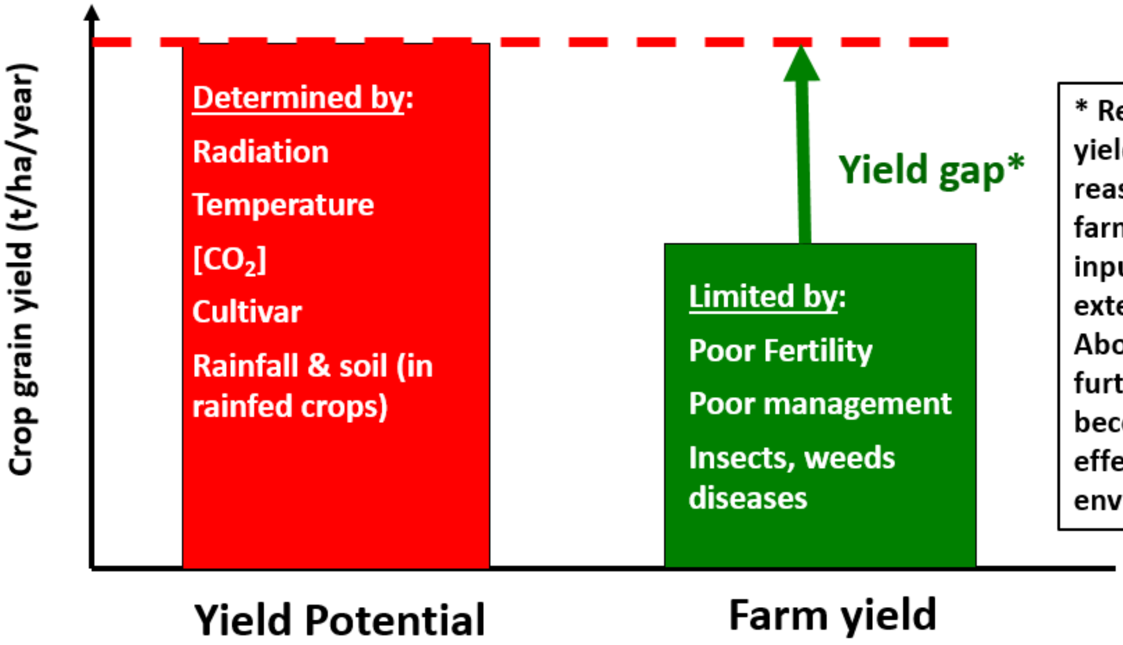
Yield Gap



* Reaching 75-85% of yield potential is a reasonable target for farmers with access to inputs, markets, and extension services. Above this threshold, further yield increase becomes not cost-effective and/or environmental sound.

Modified from: van Ittersum and Rabbinge, *Field Crops Research* (1997)

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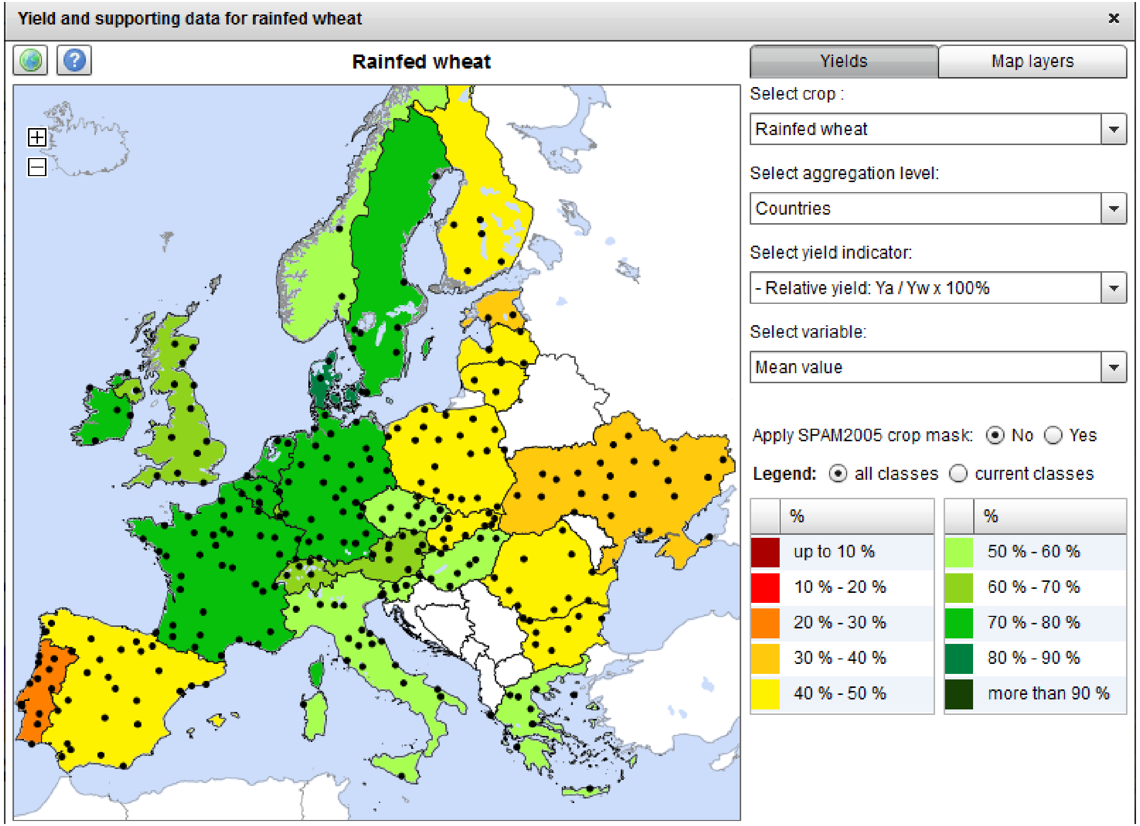
Yield of rainfed wheat as % of potential yield

- Yield of rainfed wheat as % of potential yield
- Yield of 75/85 % of potential is attainable by farmers

→ High opportunity to increase yields on currently used land (Eastern Europe and many other regions)



Ref. www.yieldgap.org/

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Is varying the biofuel demand new?

No!?

- Brazil: Ethanol blending is varied in gasoline (22% / 29%) – factories produce both ethanol and sugar and can vary output
- Colombia: low sugar cane yields led to suspension of mandatory ethanol blending in gasoline → prevented higher sugar prices
- FAO-DG José Graziano da Silva advocated "Flexible Biofuel Policies for Better Food Security"

Securing lignocellulosic (second generation) biomass supply

Second generation technologies need = lignocellulose wood, crop and processing residues

Advantages:

- Huge potential (many residues underutilised)
- Can be grown on marginal / abandoned land
- Low cost
- No food fuel issue

Issues

- Costly to convert into fuels / chemicals
- More energy needed to convert than for first generation feedstocks
- Biomass mobilisation takes time
- Purification for chemical conversion difficult

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Not only wood. Herbaceous biomass is underutilized – Often causing pollution problems – how much can be used for biobased applications?

Top 10 crops in the world		Total field	Total mill
	Million hectares	Million ton DM crop residue per year	
Maize	185	1,038	
Rice, paddy	163	816	
Wheat	220	729	
Sugar cane	27	264	264
Oil Palm	19	192	52
Barley	49	173	
Sorghum	45	103	
Sunflower seed	25	66	8
Millet	31	43	
Seed cotton	35	35	
Sum:	**800**	**3,459**	**316**
All crops worldwide:	1,414		

What part can we mobilize?

Can we recycle the nutrients?

How do we maintain soil quality?

Agricultural residue potential in EU hardly used

	Current potential	Used potential
	Million tons dry matter per year	
Wood from forests	325	350
Other forest biomass (forest industries)	185	140
Agricultural residues (field and agro-industries)	**342**	**15**
Waste	89	60
Cropped biomass	152	2

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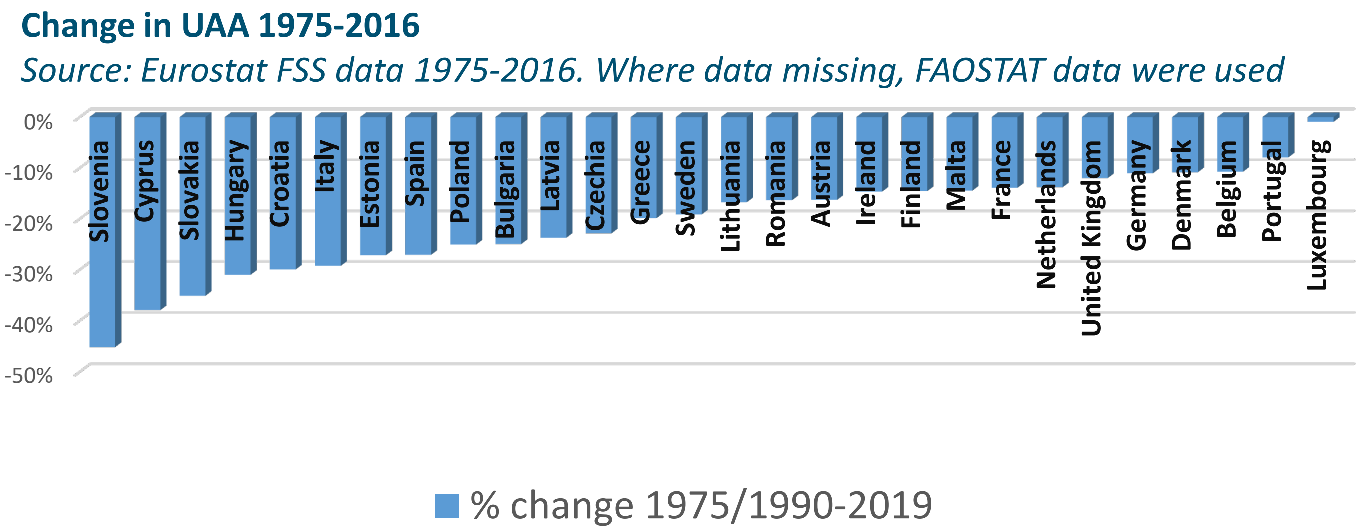
Panoutsou et al., 2016

Estimated land abandonment. Change in Utilised Agricultural Area (UAA)



Total decline in UAA for all EU-28 is 36 million hectares

This is 18% of the UAA in 1975

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Where should a lignocellulose conversion plant / biorefinery be located?

Location: Factor	Near the biomass	At a large logistical hub (harbour)
Cost of biomass	+	-
More security of supply	-	+
Availability of Infrastructure	-	+
Maximum scale	-	+
Availability of personnel / expertise	-	+
Value or residues	-	+
Sum	1+	5+

We need real commodities!

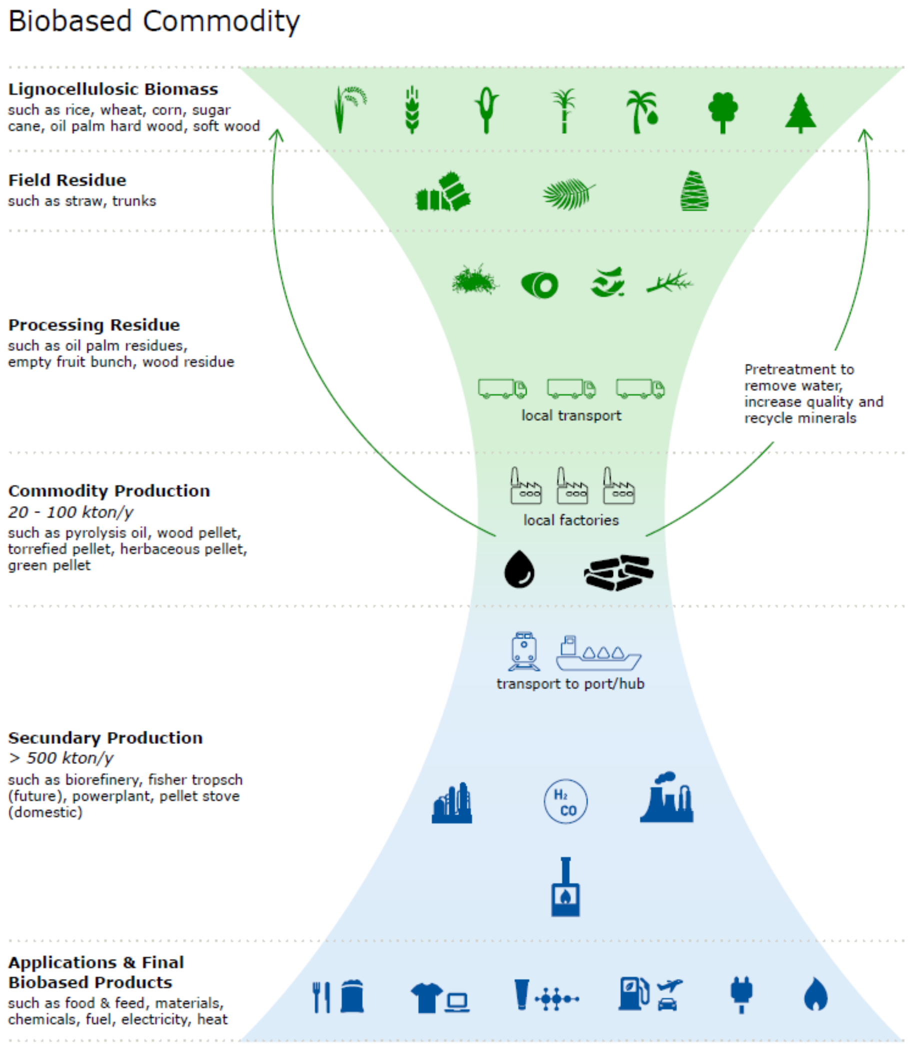
Easy to store and transport - high energy density, dry, low volume, low ash, nutrient depleted

Fungible "exchangeable" = standard quality

Standardization of transport, contracting, insurance, conversion systems

Functioning markets: Trade systems, Financial instruments (futures, etc.) High tradability

Sustainability: Standard sustainability certification systems



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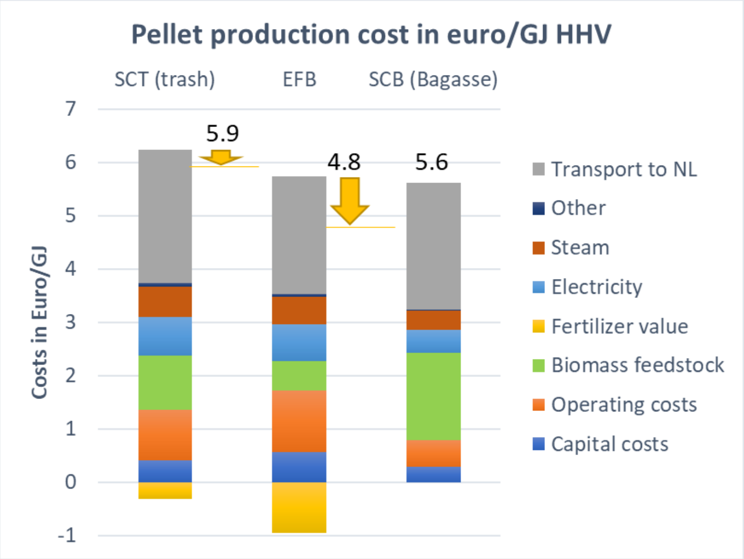
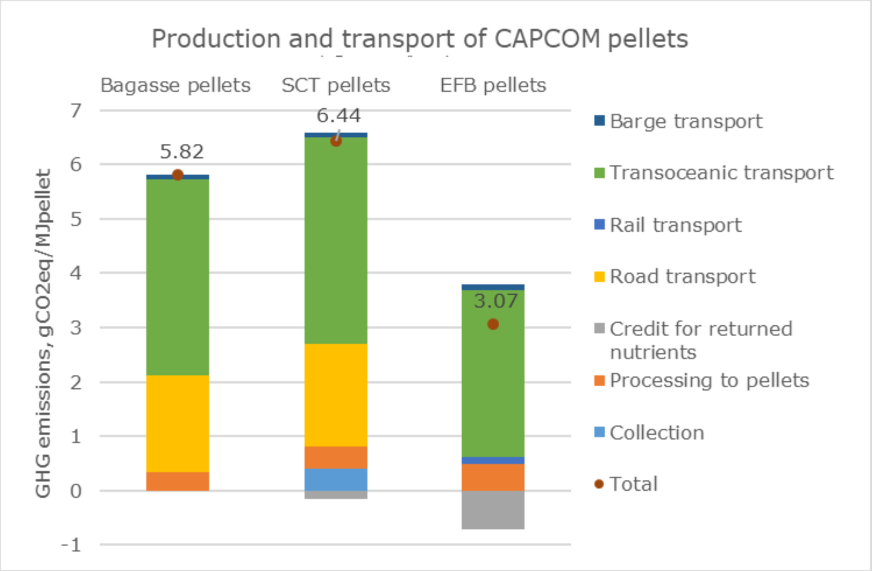
Pretreated standardized pellets shipped to remote markets





Cost for delivery sugar cane trash, palm empty fruit bunch, sugar cane bagasse

GHG emissions of pellet production and transport 90 to 70% lower than fossil equivalent

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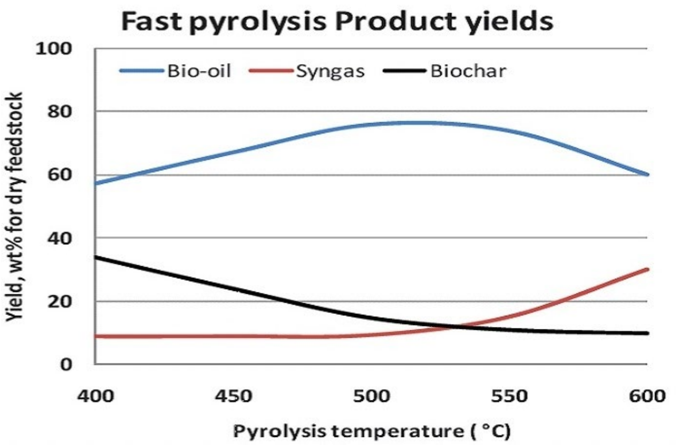
Ref: Meesters et al. 2021

Pyrolysis oil?

- **Lignocellulose to pyrolysis oil**:
  - Input is (dry) lignocellulose
  - Low oxygen + 500 °C
  - Rel. small scale: 20.000 tons per year
  - Pyrolysis oil (70%) + char (20%?)
  - Pyrolysis oil can be used for heat, electricity, refinery to fuels and chemicals
  - Not a commodity yet

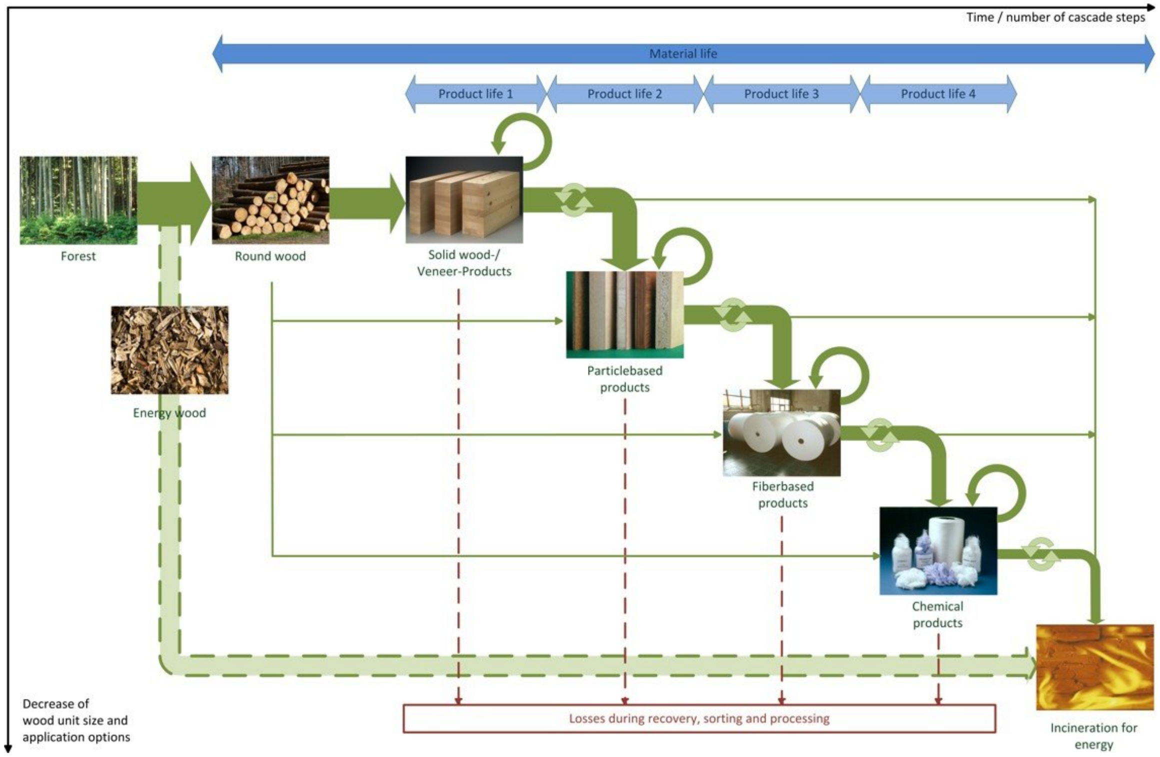


Bio-oil (~22 GJ m^{-3}) + Bio-char (~21 MJ kg^{-1}) + Syngas (~6 MJ kg^{-1})

The rationale of cascading

- Cascading led to savings of up to 14% of the annual primary wood supply of the study area.
- A difference of 7% in GHG effect between more and less cascading scenarios

Circular biomass use saves biomass and thereby land <u>or</u> biomass is released for other uses!



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Ref: Höglmeier 2015

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)

How to quantify?

Functionality x efficiency

+ Reuse potential

+ Landsparing





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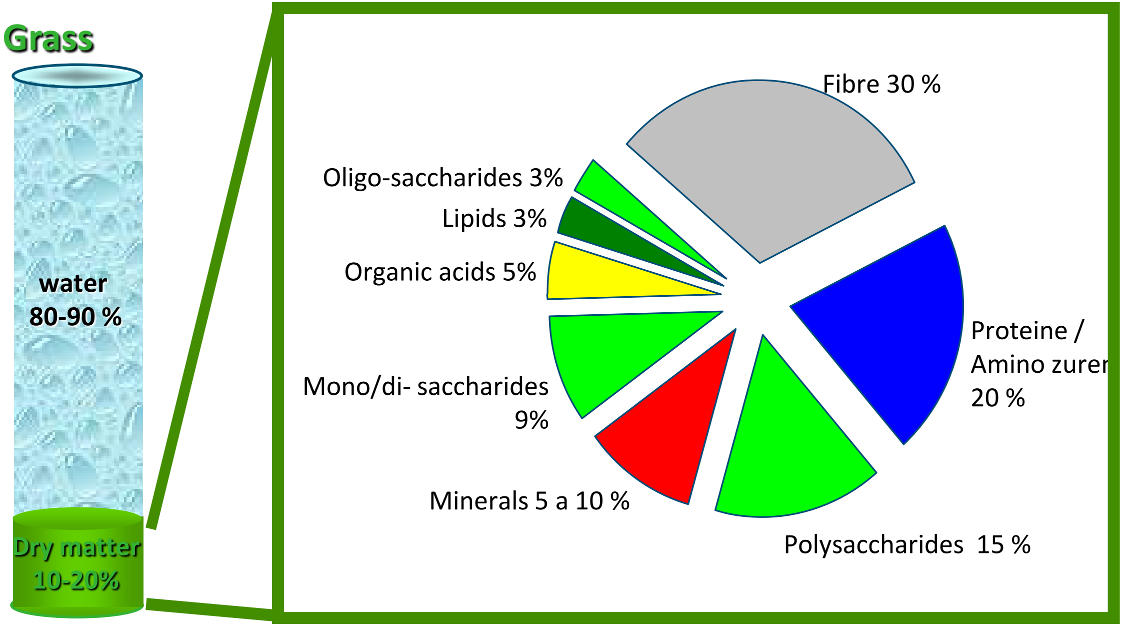
Measuring circularity of biomass applications; extending the cascade – maintaining functionality

Most biomass residues are mixed:

- Fibre (lignin, cellulose, hemicellulose)
- Protein
- Sugars
- Starch
- Fat
- Minerals (N, P, K)
- Specific molecules (pectin, antioxidants, acids, etc.)



Examples: better use of residues: starch in trunks

- Old trunk contain 2 to 6 ton starch per ha
- Oil palm trunks are burnt or mulched – starch has no value for the soil
- Biorefine out starch for:
  - Bioplastics
  - Fuels
  - Feed / Food?

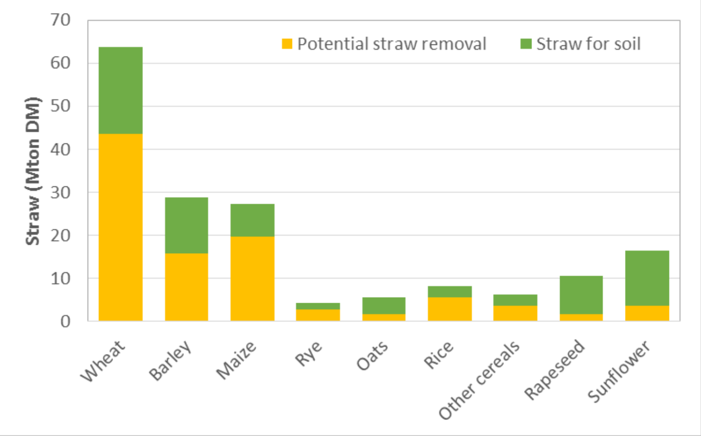
How much land could be spared by using starch from oil palm trunk replacing cassava starch?

	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**

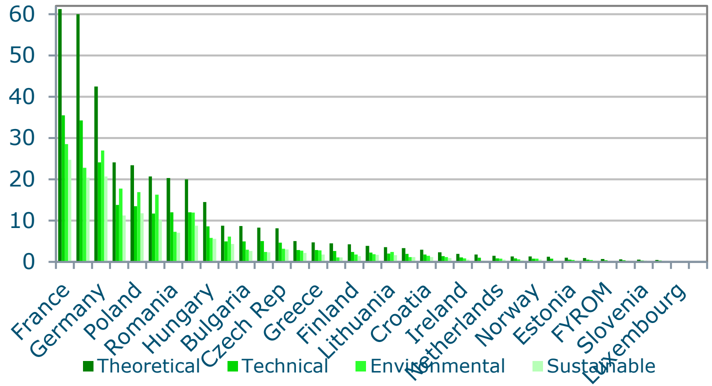
- How much GHG emissions saved?
- How much biodiversity saved?

EU sustainable straw potential

- JRC (Scarlatt): Sustainability of residues removal in terms of SOC preservation
- Maybe better to remove all straw and bring in nutrients and organic matter (that has had a function)?



	Theoretical	Technical	Environmental	Sustainable
EU	291	168	162	124
Europe	368	212	190	149



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Strategies to maintain soil quality and use the straw

1. *Harvesting straw only once every 2-3 years*
2. *Use stems, leaves for the soil (2/3 nutrients left in the field + 1/3 of organic matter)*
3. *No-till planting – no ploughing*
4. *Increase crop yields*
5. Planting a green manure crop after harvest
6. Apply other organic fertilizers (that have had a function): digestate, manure, sludge, etc.
7. Returning ash to the field/forest

Circularity

- Use biomass at the highest functionality level (food/feed/product) there is a hierarchy
- Maintain functionality of the biomass components
- Use the biomass efficiently!
- Final use is postponed (soil and energy)
- We are going to refine out oils, starch, sugars, etc. from residues that are now not used optimally

→Get more out of the biomass → save land and other inputs (labour, energy, scarce materials)

Thank you!

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Perspective

Biofpr Biofuels Bioproducts & Biorefining

Variable demand as a means to more sustainable biofuels and biobased materials

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