Mobilizing residues for biofuel production

Masterclass Platform Duurzame Biobrandstoffen

Wolter Elbersen Wageningen Food & Biobased Research

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Agenda

- The Dutch biomass balance
- Classification of biomass residues: primary, secondary and tertiary
- How much is out there?
- First vs second generation feedstocks
- Circular valorisation of agri-residues
- Example of wood
- Opportunities in the Netherlands
- Opportunities abroad

How much biomass do we produce in the Netherlands

- 41.543 km² (18% water)
- 4.154.300 hectares

- How much biomass is importend?

- How much biomass is exported?

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How much biomass do we have in The Nederlands?

	Mton Dry Matter	PJ
Harvestable production	??	??
Plus: Import		
Flux		
Minus: Export		
Balance		

Primary energy use is 3000 PJ

What part can we use for the Biobased Economy?

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Rabou et al 2006 en Meesters et al 2010.

How much biomass do we have in The Nederlands?

	Mton Dry Matter	PJ
Harvestable production	29	500
Plus: Import	??	??
Flux	??	??
Minus: Export	??	??
Balance	??	??

Primary energy use is 3300 PJ

What part can we use for the Biobased Economy

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Rabou et al 2006 en Meesters et al 2010.

How much biomass do we have in The Nederlands?

	Mton Dry Matter	PJ
Harvestable production	29	500
Plus: Import	36	685
Flux	65	1185
Minus: Export	-25	-466
Balance	41	719

Primary energy use is 3300 PJ

What part can we use for the Biobased Economy

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Rabou et al 2006 en Meesters et al 2010.

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.
- Imports such as crops, primary and secondary (by)-products

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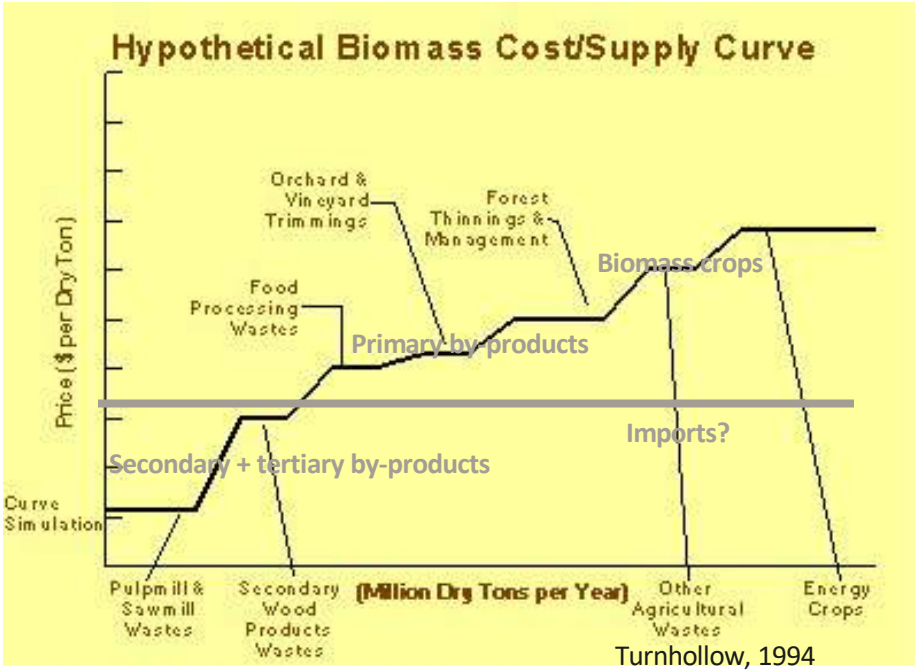
Byproducts and/or dedicated crops?



Turnhollow, 1994

- Tertiary by-products
- Secondary by-products
- Primary by-products
- Dedicated crops
- (Imports)

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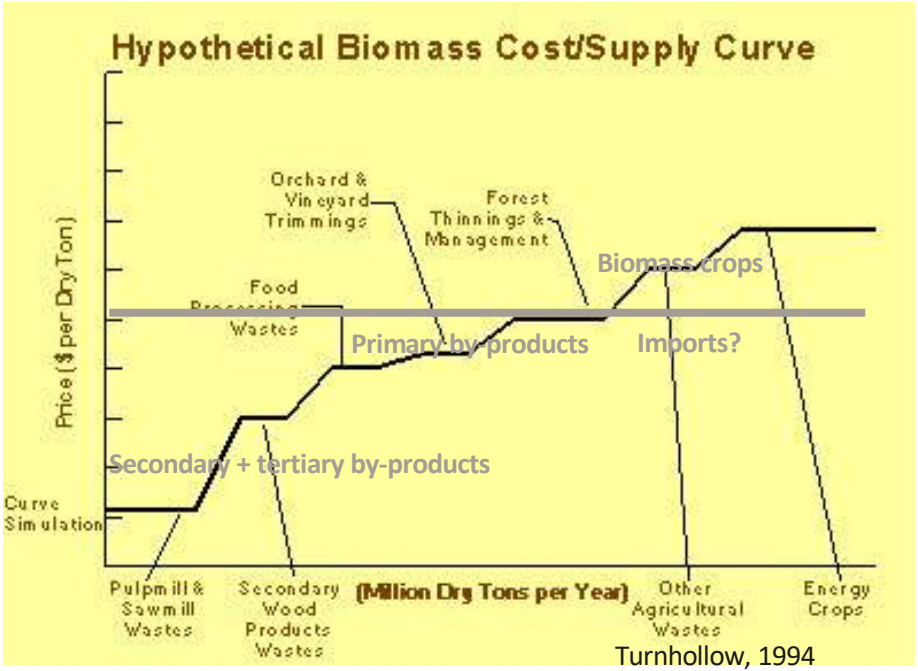
Byproducts and/or dedicated crops?



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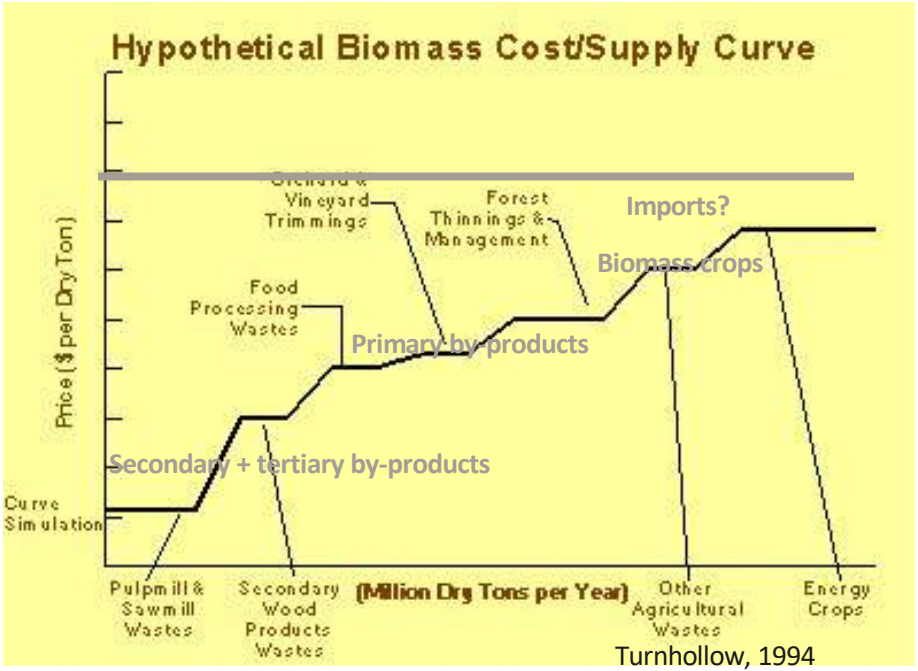
Byproducts and/or dedicated crops?



Turnhollow, 1994

- Tertiary by-products
- Secondary by-products
- Primary by-products
- Dedicated crops
- (Imports)

Biomass production per hectare

Crop	Yield Main product	Field residues	Processing residues	Total
	----------Ton DM per hectare ----------			
Tropical grasses	20 tot 60	nvt		20/60
Sugar cane	10	10	10	30
Oil Palm	**4**	21	5	30
Sugarbeet (NL):	20	5	?	25
Wheat (NL)	9	5	?	14
Grass (NL)	8 to 15	Nvt		12
Verge grass (NL)	2 to 7	Nvt		2 to 7
Forest wood production per year (NL)	4.5	?	*50%*	4.5

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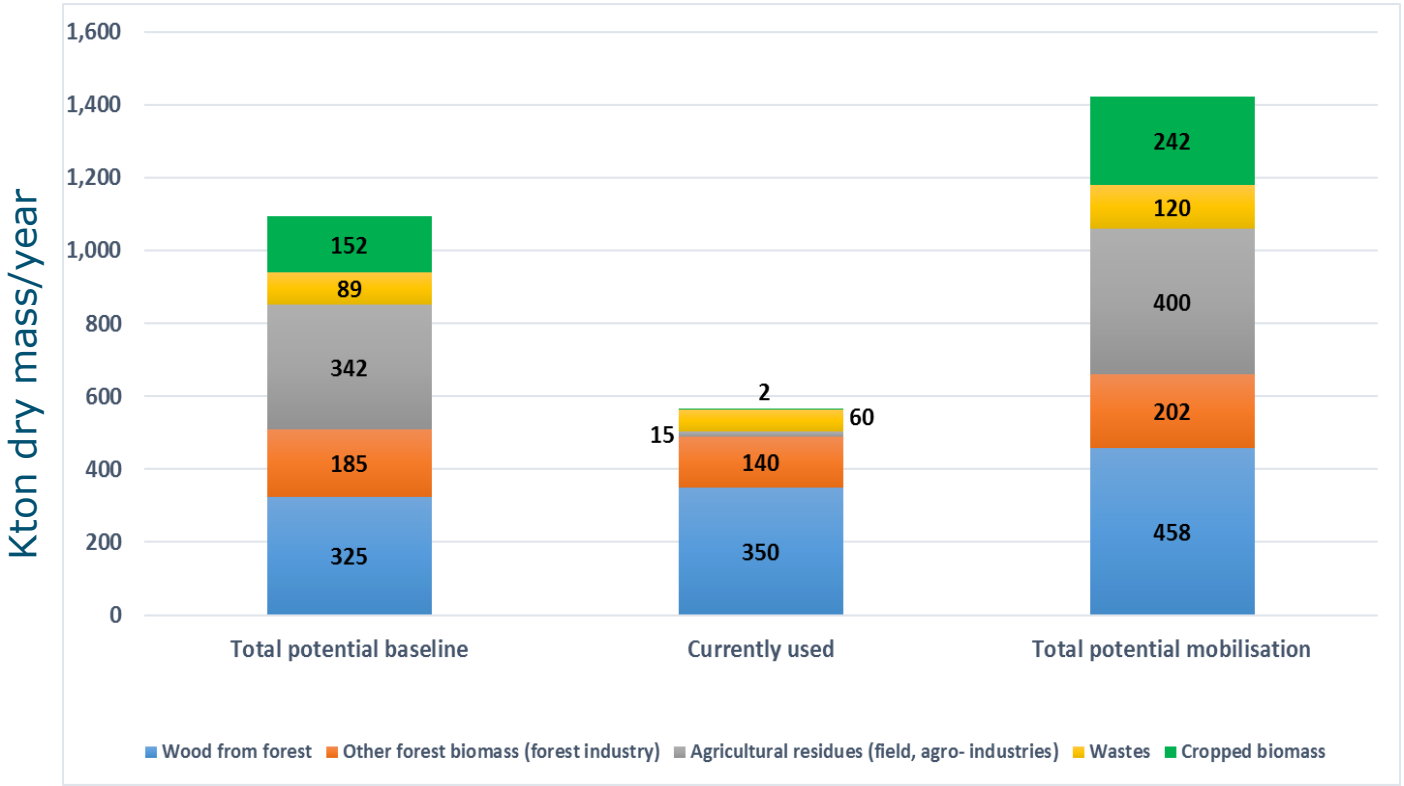
Vision for 1 Billion tonnes supply by 2030 in the EU



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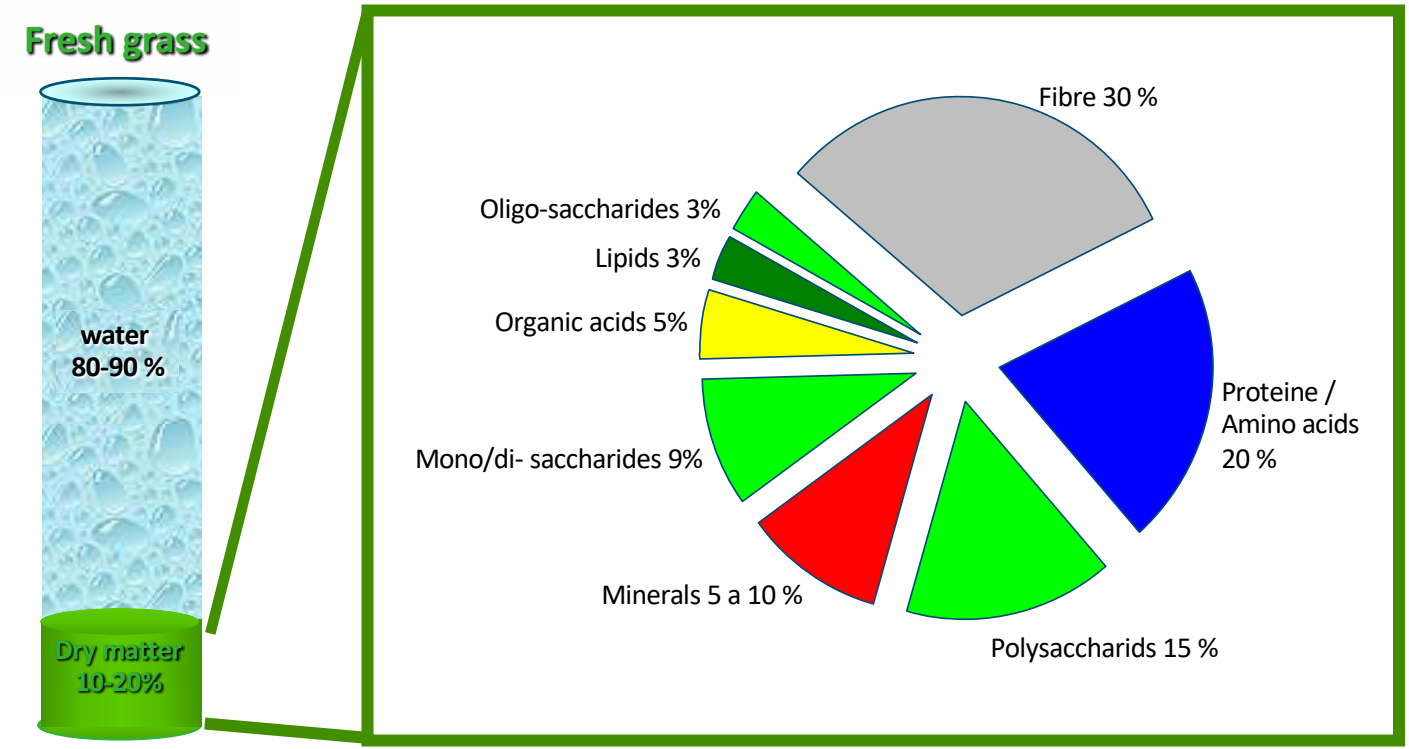
EU S2Biom project. Vision for 1 billion tonnes biomass 2030

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? What part is needed for the soil?

Almost all biomass is a mix of different components



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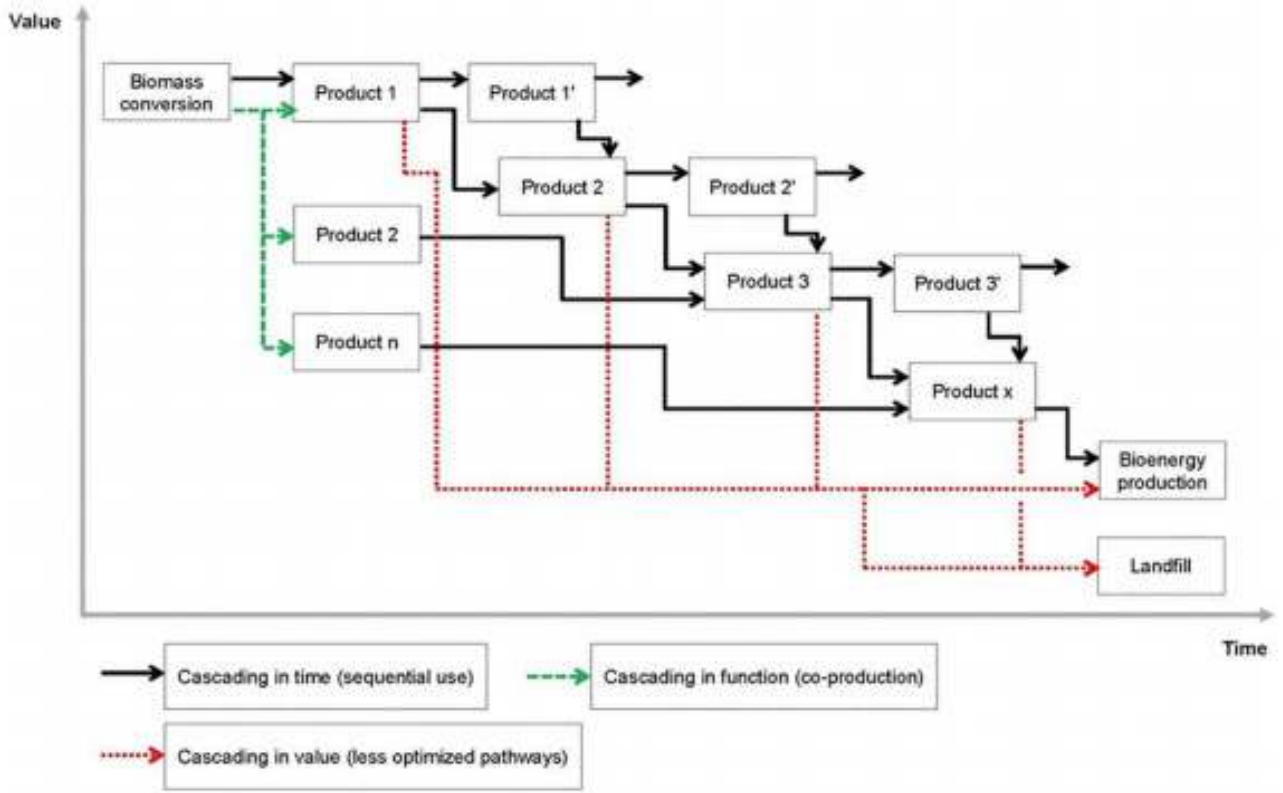
Ref. Sanders

Push for Circular economy: Opportunity or threat?

Circularity principles as formulated by The Ellen MacArthur Foundation:

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

→ Cascade use of materials

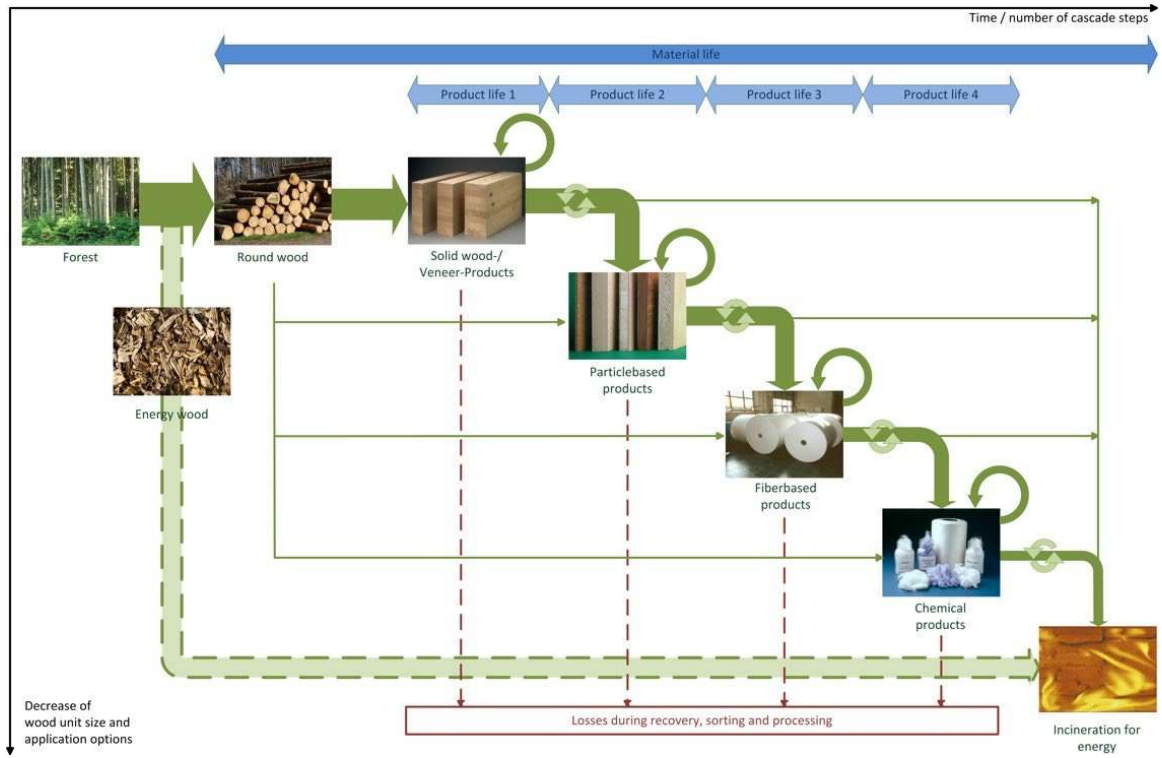


Ref: Jarre et al. 2020.

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 or biomass is released for other uses



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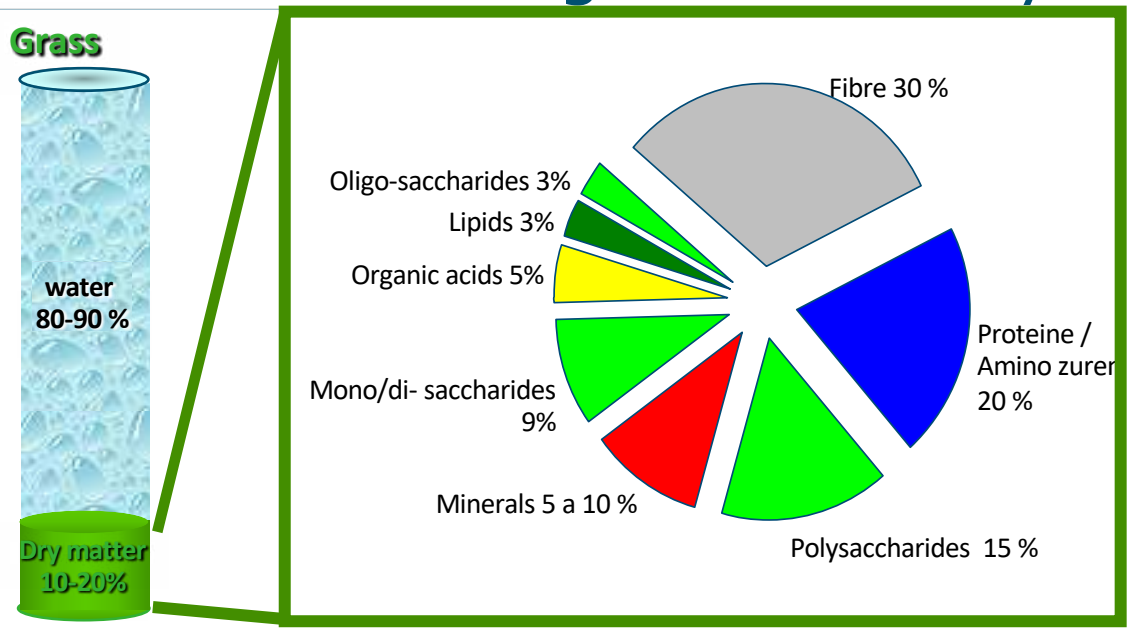
Measuring circularity of biomass applications; extending the cascade – maintaining functionality

Most biomass residues are mixed:

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



	Protein (N * 6.25)	Fat	Fibre	Starch / Sugar	P	K
Importance ??	+++	++	+	+	+++ ++	+++

Circularity = Σ	Contents	(per component: protein, starch, ...)
	× Weight	(importance of protein, starch, fat, ...)
	× Functionality	(preservation and use of functionality in application)
	× Efficiency	(how much ends in the application)

We need to know composition and current application of biomass residues

A database of Agri-residues is being developed

	Kenmerk	Eenheid	Opmerking
1	Droge stof (DS)	gr/kg reststroom	
2	As	gr/kg DS	Bij as zijn er 3 opties: a) asgehalte na verbranding op 550°C b) asgehalte na verbranding op 850°C en c) asgehalte na verbranding, maar T is niet gegeven
3	Eiwit	gr/kg DS	
4	Vet	gr/kg DS	
5	Ruwe celstof	gr/kg DS	ruwe celstof bestaat uit de in water onoplosbare voedingsvezels: cellulose, hemicellulose en lignine[1]
	- cellulose	gr/kg DS	
	- hemicellulose	gr/kg DS	
	- lignine	gr/kg DS	
6	Zetmeel	gr/kg DS	
7	Suiker	gr/kg DS	
8	Overig	gr/kg DS	1 kg verminderd met de waarde van rij 9 in deze tabel
9	Totaal DS - overig	gr/kg DS	De optelsom van rij 2 t/m 7 in deze tabel
10	N	gr/kg DS	
11	P	gr/kg DS	
12	K	gr/kg DS	
13	NDF	gr/kg DS	Hemicellulose+cellulose+lignine+cutine
14	ADF	gr/kg DS	Cellulose+lignine
15	ADL	gr/kg DS	Lignine

	Kenmerk	Eenheid	Opmerking
1	Gewicht nat	kton	Gewicht van de reststroom in Nederland in een bepaald jaar
2	Gewicht DS	kton	Gewicht van DS van reststroom in een bepaald jaar
3	Omvang indicator	%	Deze waarde geeft de relatieve omvang in een bepaalde context aan, op ba waarvan besloten is of de tabel wordt ingevuld voor die reststroom. Nameli indien een stroom klein is en het moeilijk is om de samenstelling te achterhalen, wordt het invullen van de tabel verder niet gedaan.
4	Gewicht per huidige bestemming	kton	Een reststroom krijgt één of meer bestemmingen. De verdeling van de reststroom in gewicht wordt per bestemming aangegeven.
	- veevoer	kton	Als niet duidelijk is of het voor varken of rund is, wordt het in de kolom veevoer gezet. Dat geldt ook als het voor andere dieren is, zoals kippen, schapen e.d.
	- veevoer varken	kton	
	- veevoer rund	kton	
	- vergisten	kton	
	- composteren	kton	
	- verbranden	kton	
	- storten	kton	

Circularity opportunities and threats

Threat: End of pipe uses such as energy have a lower priority

Opportunity: Current inefficient or wasteful uses of residues also have a low priority

Focus more on residues

Conserve nutrients (N, P, K)

Conserve soil quality

Field residues

Opportunity: residues left in the field contain protein and starch and sugars.

Protein functionality is mostly lost

N, P and K may run-off

Labile materials (starch, sugars, hemicellulose) decay fast with little value for the soil

Persistent materials have more value for the soil: fibre (lignin, cellulose)

→ Biorefine residue for high an low protein product for chicken and pig feed and for fuel. Return recalcitrant material + nutrient to soil

Obstacles: fertilizer application is capped for Na and P. If residues are removed a nett nutrient loss occurs for the farmer.

Is it cost effective to remove?

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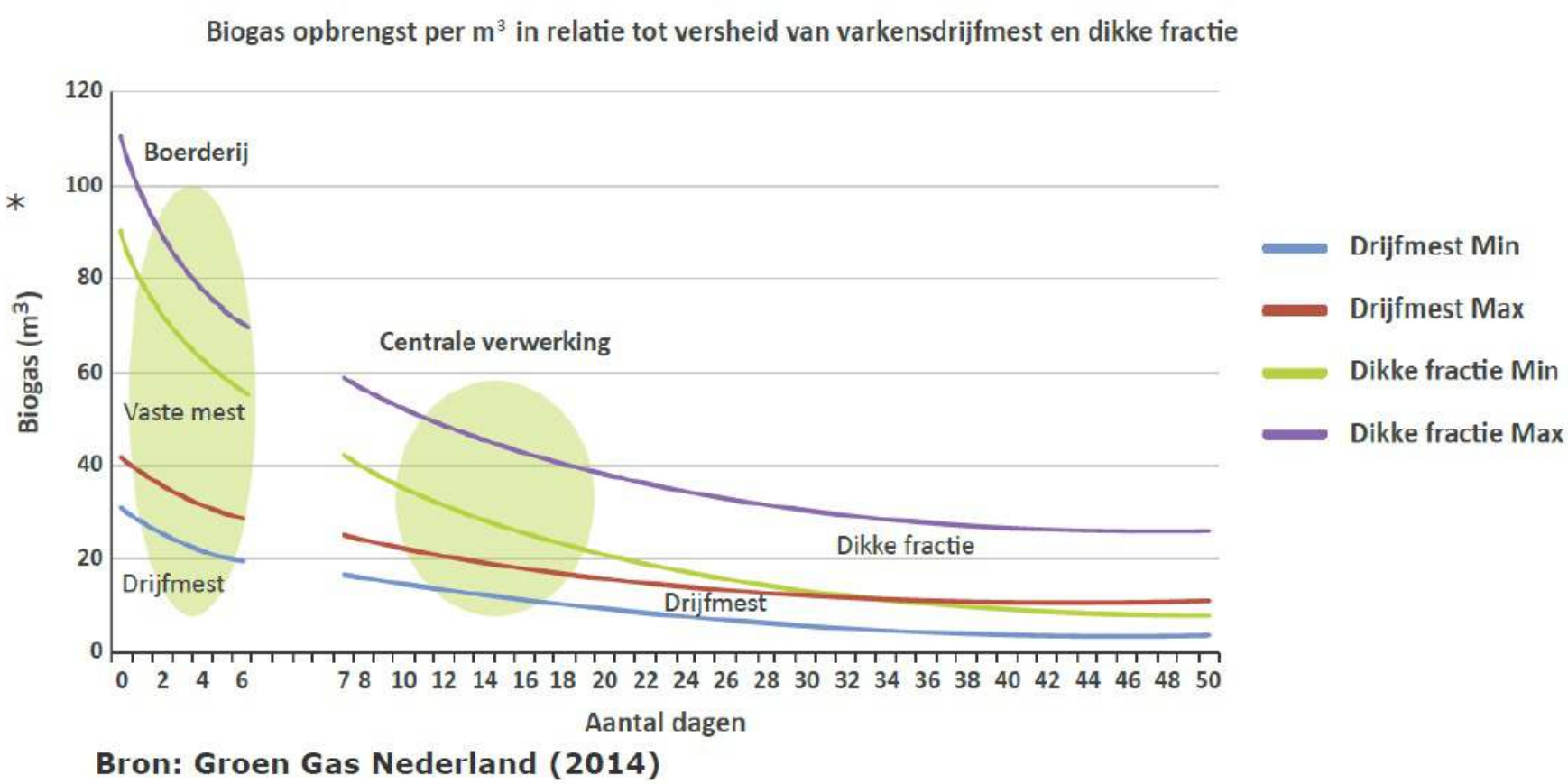
Ref: Zwart et al. 2004

Gewas	Type oogstrest	Hoeveelheid	2017 Totaal mogelijk oogstrest	
		(kg ha-1)	Ha Mln Kg	
Akkerbouw gewassen				
Aardappel, consumptie	loof	5600	76300	427.28
Aardappel, consumptie	oogstrest	1667	76300	127.19
Aardappel, consumptie	kriel	2775	76300	211.73
Aardappel, poot-	loof	35354	42330	1496.53
Aardappel, poot-	oogstrest	1667	42330	70.56
Groene erwt droog	stro	1961	3040	5.96
Stamslaboon	loof/stro	17600	2420	42.59
Suikerbieten	blad+kop[1]	32300	85350	2756.81
Winterrogge	stro	4300	1500	6.45
Wintertarwe	stro	4400	108020	475.29
Zomergerst	stro	3200	20910	66.91
Zomertarwe	stro	3600	8410	30.28
Graszaad	hooi	6000	10080	60.48
Blauwmaanzaad	stro	1730	330	0.57
Bruine bonen	stro	2988	1350	4.03
Cichorei		4321	3240	14.00
Kapucijners	stro	1961	600	1.18
Karwij	stro	3450	10	0.03
Lijnzaad		2662	50	0.13
Vlas		148	2560	0.38
Veldboon	stro	1961	570	1.12
Vollegrondsgroentegewassen				
Andijvie		20000	220	4.40
Bloemkool		50000	2100	105.00
Broccoli		36000	1880	67.68
Chinese kool		35000	130	4.55
IJssla		40000		
Kropsla		11000	2060	22.66
Prei		22000	2280	50.16
Rode kool		45000	670	30.15
Spinazie		9000	2060	18.54
Spruitkool		30000	2630	78.90
Witte kool		55000	1670	91.85

Which opportunities?

- Verge grass: Currently left or composted → Verge grass is contaminated with sand and waste
- Sludges: Now burnt – Can we use it for soil? Stable carbon+ nutrients → pollution is a problem

Use fresh manure → avoid methane emissions!



Bron: Groen Gas Nederland (2014)

Biogas opportunities Manure and field residues

	kton nat	kton ds	PJ HHV	PJ LHV	Nm3 Groen Gas / ton ds	Miljoen Nm3 Groen Gas	
Grass	66,667	10,000	181,1	30,5	220	2,200	kosten / Feed/fuel alleen resten?
Manure	**61,145**	**4,892**	**81,5**	**-**	**150**	**734**	**Goed GHG effect Excellent GHG effect**
Wet crops residues	6,567	985	17,8	3,0	200	197	In conbination with protein recovery?
Dry ploultry manureand other manure	**5,404**	**2,972**	**47,7**	**35,9**	**150**	**446**	**Goed GHG effect - kosten -**
Biomass from nature management	**2,700**	**1,080**	**19,6**	**14,3**	**175**	**189**	**Schoon aanvoeren nodig, voorbehandelen nodig**
Wet residues horticulture	**2,543**	**356**	**6,4**	**0,7**	**175**	**62**	**voorbehandeling nodig / plastic**
Verge grass (road + waterways)	**1,600**	**640**	**11,6**	**8,5**	**150**	**96**	**Schoon aanvoeren, voorbehandelen, andere toepassingen**
Wet waste collected in rural areas	700	490	8,9	7,4	100	49	Niet schoon GFT vergister
Groenbemester	467	70	1,3	0,2	200	14	Kosten aanvoer, voorbehandelen, nutriënten
					Totaal	**6,265**	
					Niet teelt	**1,787**	

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Ref: Koppejan, Elbersen et al. 2009

Examples: oil palm starch in trunks at replanting

- Old trunk contain 2 to 10 ton starch per ha
- Oil palm trunks are burnt or mulched – starch has no value for the soil
- Starch can be extracted for:
    - Fuels
    - Bioplastics
    - Feed / Food

Thank you!

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Projects

- Joop Spijker, Wolter Elbersen, Iris Vural Gursel, Bas Lerink. 2020. **Marktverkenning biomassareststromen hout uit landschap.** Wageningen Environmental Research. Rapport 2991. 42 blz.

- Elbersen, B., R. Bugter, K. Meesters, I. Vural Gursel, W. Elbersen, M. van Leeuwen, P. Mostert, M. de Vries, R. Jongschaap, G. Piet, I. van der Fels Klerx (2020) **Monitoring and impact evaluation system. Circularity at different scales.** KB-1-1B-1 project 2019 progress report.

- Elbersen en Groen. 2020. **Biomassa Circulair verwaarden in Zuid Holland**. Euro 22.000.

- Elbersen Wolter, Siemen van Berkum, Just Dengerink, Anton Schultze-Jena (2020). **Circular valorisation of agri-residues. How to make better use of agricultural residues.** Interim Report by Wageningen Food & Biobased Research and Wageningen Economic Research. Commissioned by the Dutch Ministry of Agriculture, Nature and Food Quality. Wageningen, In progress.

- **Circulariteit van reststroombenutting** (BO-43-002.01-011). Project for Min LNV. In progress

- **Monitoring Circulariteit Agro-reststromen.** Project for Min LNV. In progress

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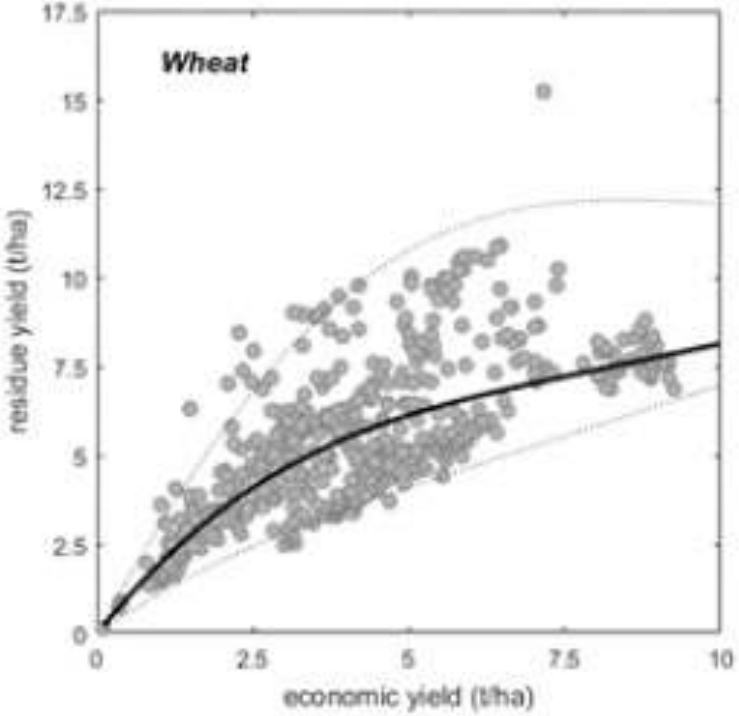
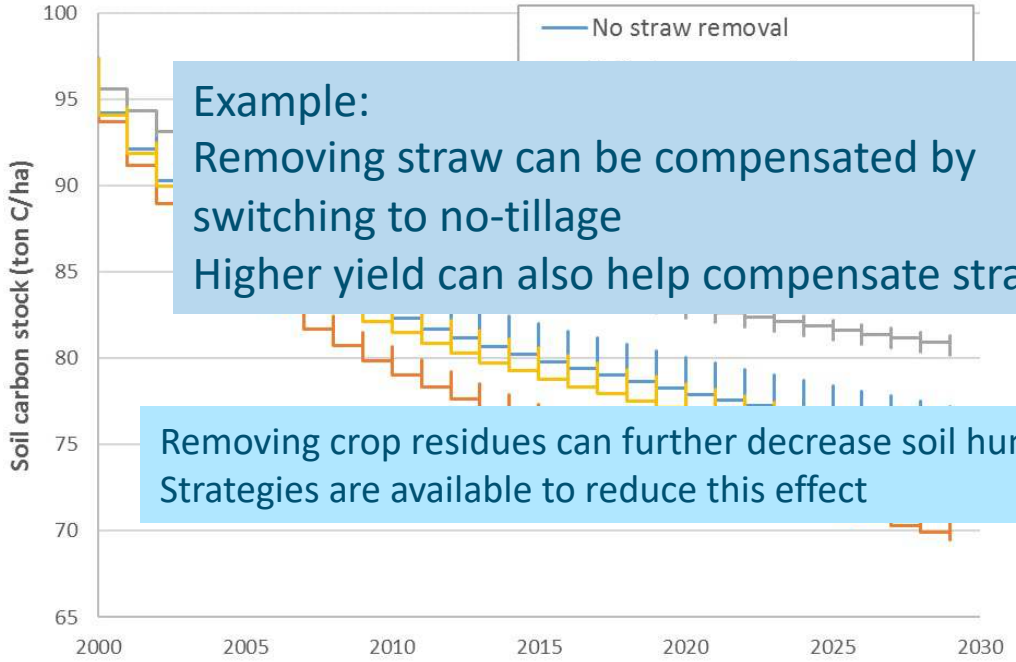
Removing crop residues can reduce soil productivity, especially if yields are low



Straw removal scenarios and effect on soil C



Example:
Removing straw can be compensated by switching to no-tillage
Higher yield can also help compensate straw removal

Removing crop residues can further decrease soil humus
Strategies are available to reduce this effect

- Vinnytsia
- Continuous
- ield increase based on yield gap atlas (60% increase)

Mest methaanpotentie: jonge mest!

	Oude mest	Nieuwe mest
Stalmest per jaar m^3	68 Miljoen ton	68 Miljoen ton
m^3 biogas (per m^3 mest)	9	Tot 40
CH_4 fractie in biogas	*0.65*	*0.56*
kg CH_4 per m^3 Biogas	0.67	0.67
Methaanproductie (Mton CH_4)	0.27	1.02
kg CO_2eq /kg CH_4	21	21
Methaanproductie in Nederland (Mton CO_2eq) ”te vermijden”	5.6	21.4
Potentie aardgas eq uit mest? (Miljoen m3)	379	1451

Pers comm Prof. Sanders