BIOBASED 2.0: DUURZAME BIJDRAGE VAN 25% AAN DE NATIONALE (EN EUROPESE) MITIGATIEDOELSTELLING VOOR 2050

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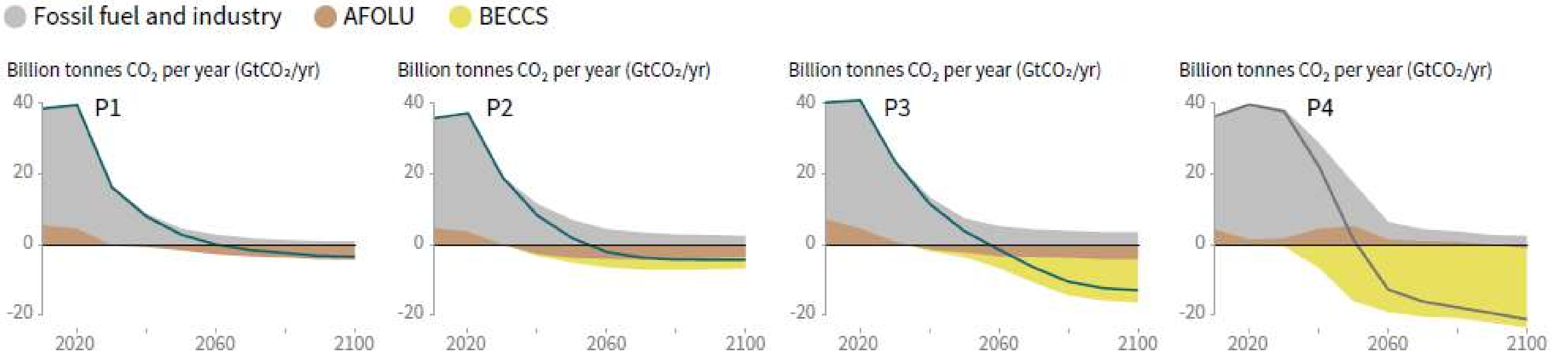
THE IPCC 1,5 OC REPORT: EMISSION PATHWAYS

KEY PILLAR OF THE EU'S GREEN DEAL.

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

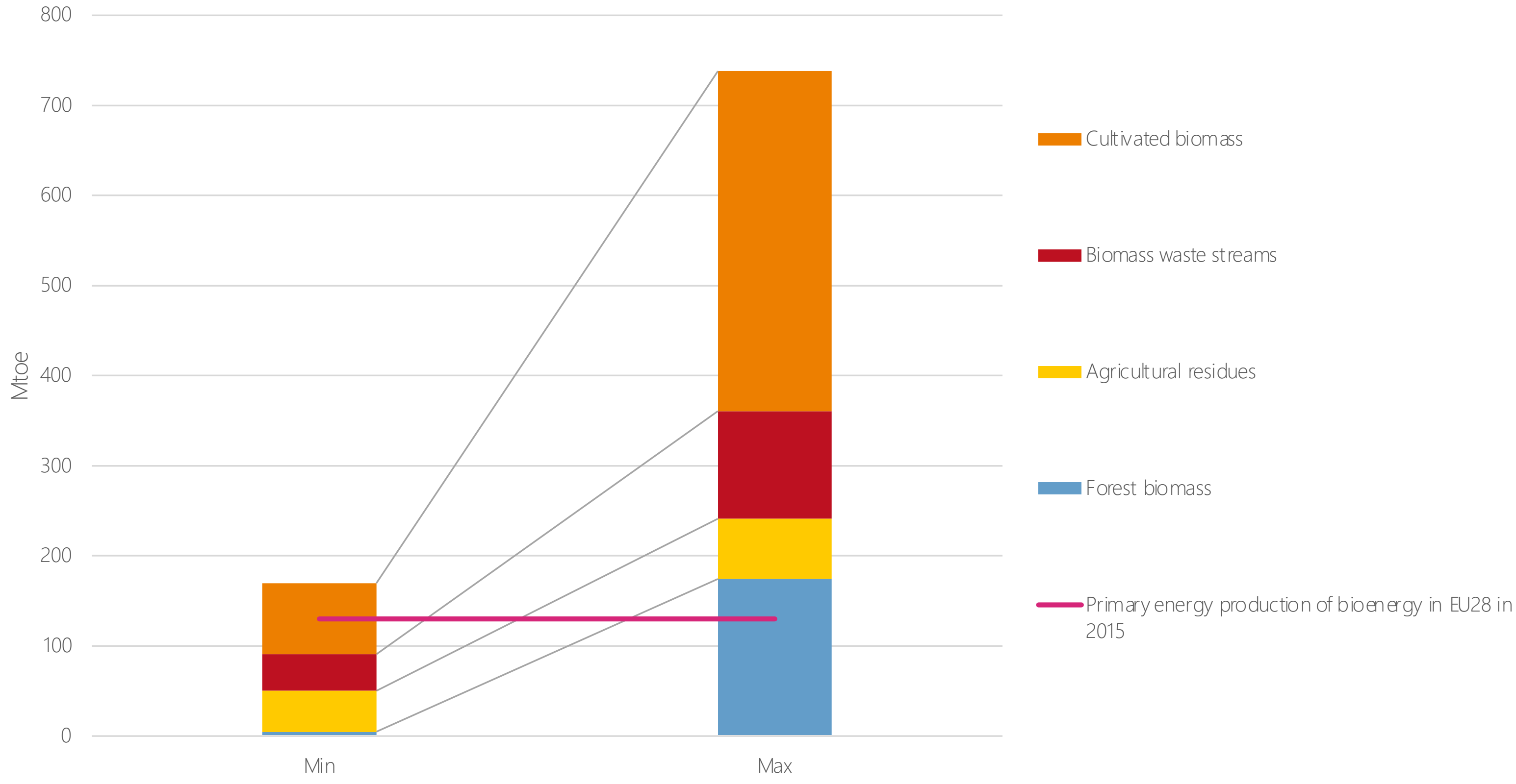
THE CONTRIBUTION THAT THE USE OF BIOMASS FOR ENERGY AND MATERIALS TO AVOIDING GHG EMISSIONS IN EUROPE DEPENDS ON:

- Potential future **sustainable** biomass **availability** in Europe for energy and materials
- Potential **future use** of biomass for energy and materials **as part of** the 2050 GHG mitigation strategy of the EU, leading to 80 – 95% GHG emission reduction compared to 1990 levels.
- The **share of BECCS** that may be deployed in biomass conversion processes.
- Changes **in carbon stocks**, the operation and management of value chains and the way in which biomaterials are used (e.g. cascaded use and energy recovery).
- The **GHG balances** of different biomass value chains and biomass – product/energy carrier combinations.

POTENTIAL SUSTAINABLE (= MEETS KEY CRITERIA) BIOMASS AVAILABILITY DEPENDS ON:

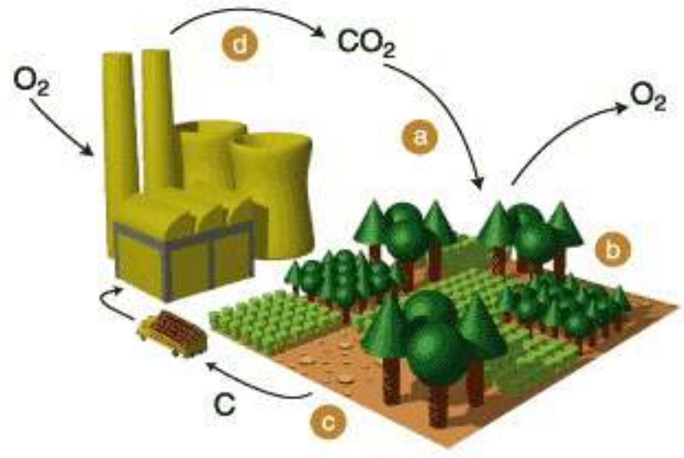
- Balance between improving agricultural (and livestock) management practices to reduce land use per unit of food and use of land for biomass crops.
- Food demand; base scenario;s usually included; reduction of food losses across value chains and alternative protein sources often not included in biomass potential studies.
- Land type – crop combinations, land zoning and land use patterns highly determine ecological impacts (can to a large extent be steered towards co-benefits).
- Utilisation of idle, marginal or degraded lands (that can result in substantial ecological benefits; soil restoration, water retention, carbon storage, increased biodiversity.
- Agricultural management practices also influence net sustainable availability of biomass residues (better farming = higher availablility)
- Better farming can strongly coincide with more sustainable and less GHG intensive farming
- Avoidance of competition with high value applications (e.g. fodder, materials)
- Good forest management (see later)
- Possible surprises from aquatic biomass (progress micro-algue and macro-algue/seaweed).
- **MANY, ALSO RECENT, STUDIES IGNORE PARTS OR MANY OF THESE KEY FACTORS!**

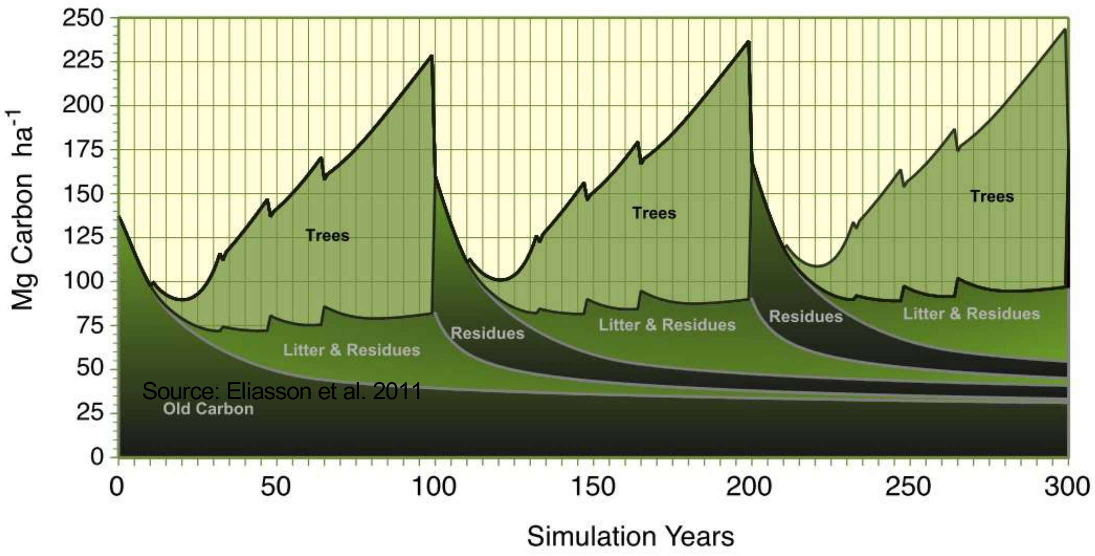
BIOMASS POTENTIALS EU28 IN 2050; 7-30 EJ COMPARED TO 68 EJ TOTAL PRIMARY ENERGY USED TODAY

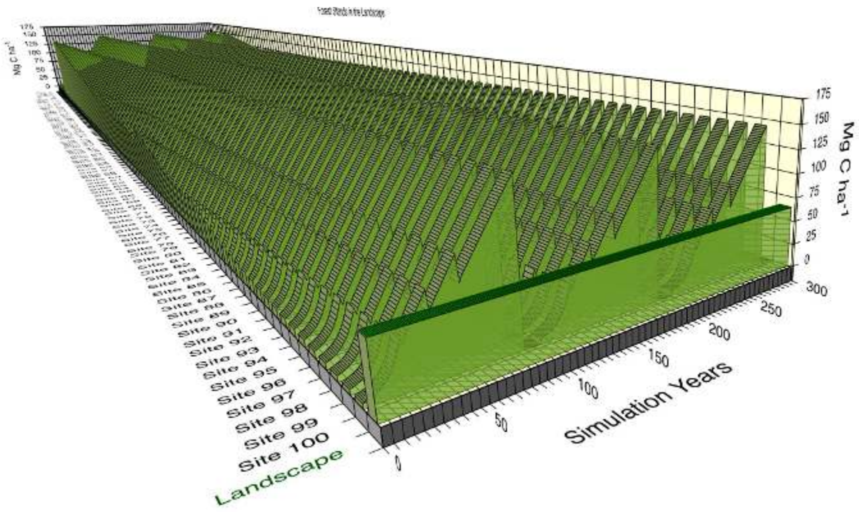


[Faaij, Bioenergy Europe, 2018]

NORMAL PRODUCTION FOREST STAND LEVEL CARBON STOCK DYNAMICS (FREQUENCY DEPENDS ON MANAGEMENT AND CLIMATE)







Landscape-level carbon stock dynamics of production forest

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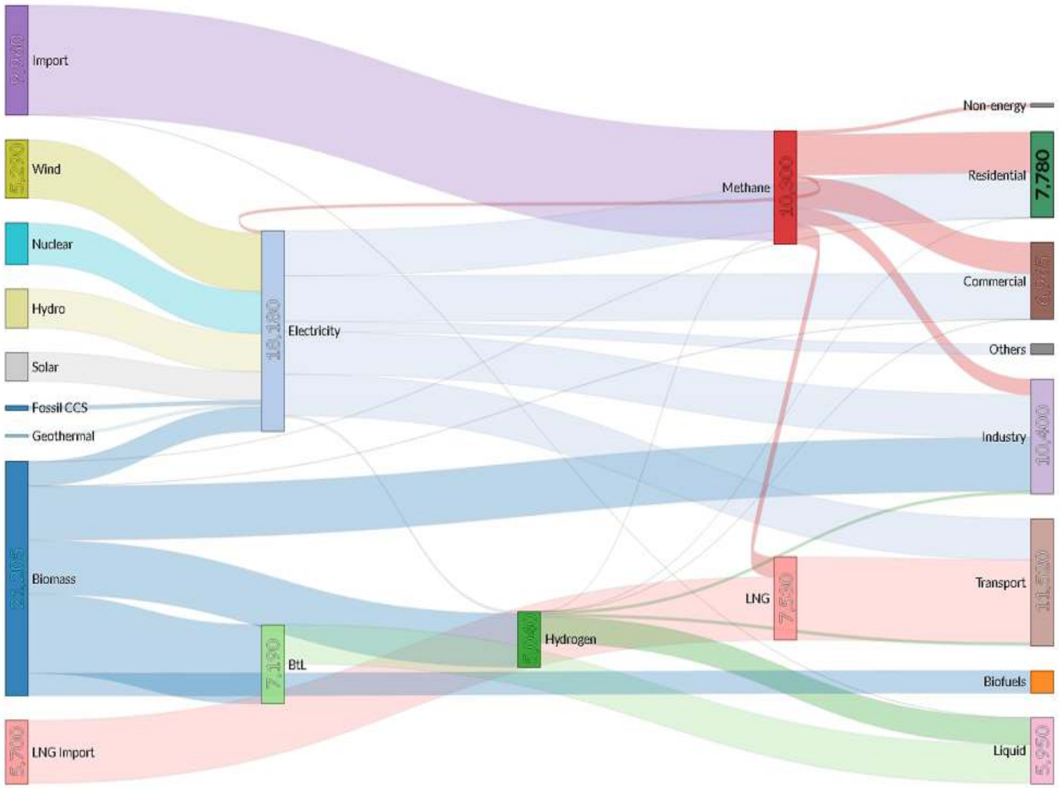
KEY NOTIONS ON FOREST BIOMASS

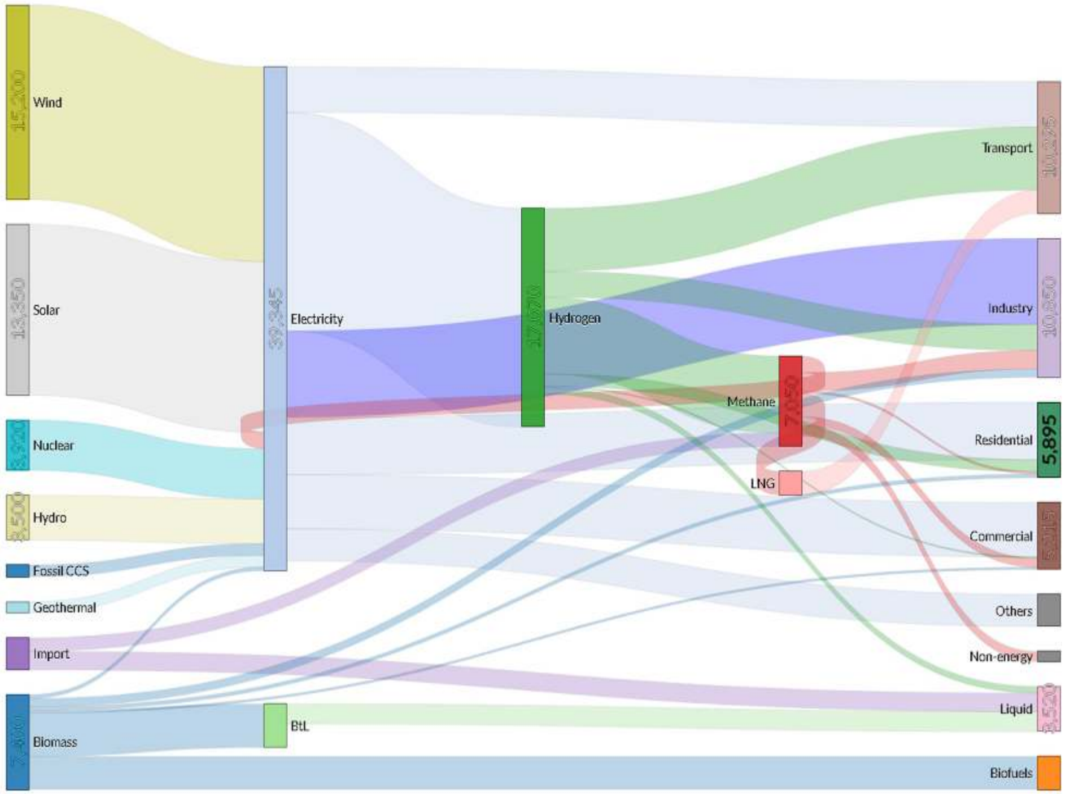
- First know what you are talking about; natural forest vs. production forest, stand vs. landscape, whole stem vs. residue, etc.
- Bulk of utilized solid biomass in the EU = residue (!!) = short payback.
- Reported payback times vary widely; many are hypothetical scenarios; assuming that forest will remain unaffected over 100 years is highly unlikely (fires, disease, competing claims…; worsened by climate change)
- Best method / reference scenario & management strongly case–dependent – no ‘one-size fits all solution’. Key elements are:
  - Well managed forest becomes more productive per hectare which increases CO2 uptake.
  - New plantations on degraded/C-poor land
  - Managed/commercial forests: fertilizer and weed control (within SFM limits) – increases productivity strongly
  - Increased early stand density & use of pre-commercial thinnings

Scandinavian experience over 4 decades shows: strongly increased bioenergy use, increased forest stands, increased carbon stocks combined (!)

TWO UP TO DATE DEEP GHG REDUCTION SCENARIO'S FOR THE EU IN 2050 (DEVELOPED WITH THE JRC-TIMES MODEL)



high biomass and CCS scenario



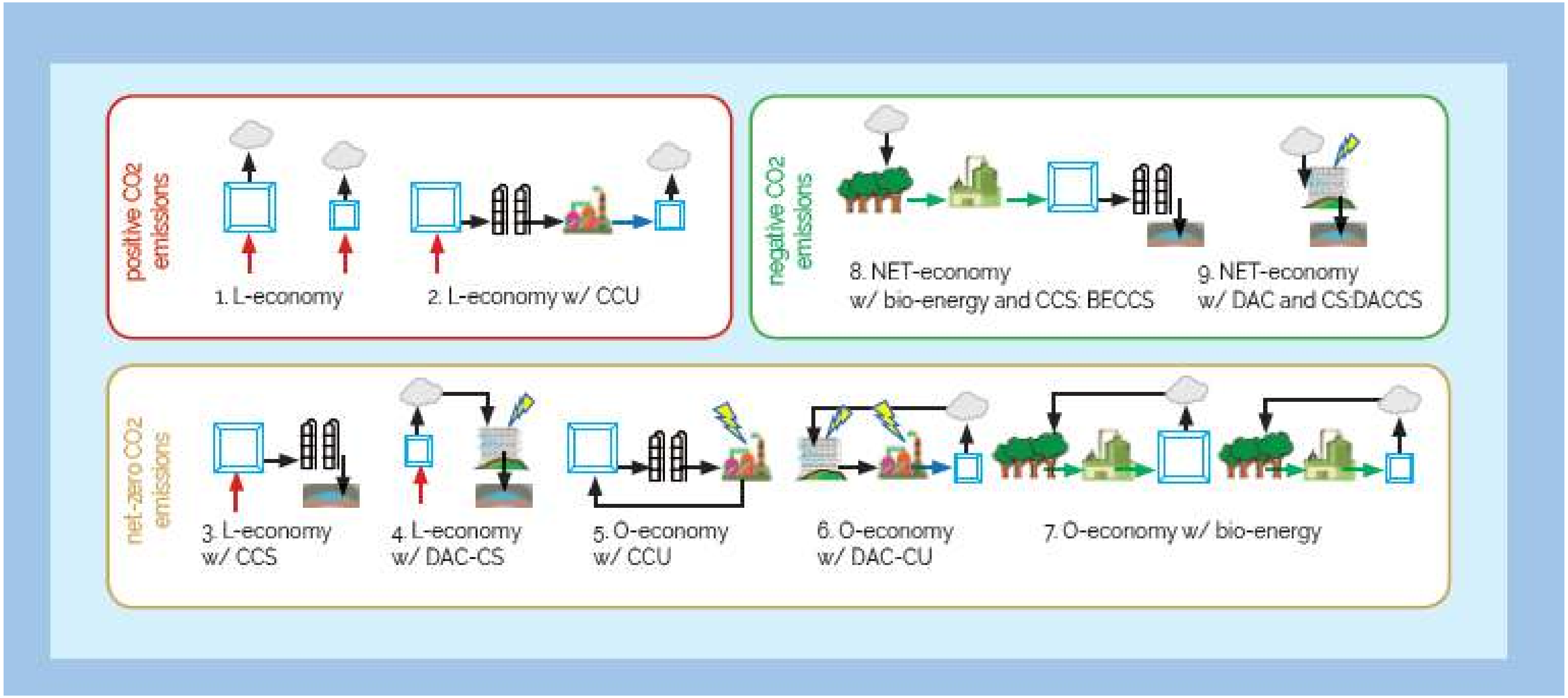
Max solar & wind scenario (+ no CCS, minimal Bio)

[Blanco et al., applied Energy 2018]

STATE OF THE ART INSIGHTS OF THE ROLE OF BBE OPTIONS IN DEEP GHG MITIGATION AND ENERGY SYSTEM TRANSITIONS

- When biomass is deemed sustainably available, it is a highly attractive mitigation option.
- Over time, optimal biomass use shifts from heat and power to advanced fuels and feedstock for industry.
- BECCS options are of major importance in SOTA scenario's to achieve negative emissions, compensate very difficult remaining GHG emissions and lower overall mitigation costs; essential for the overshoot pathways.
- Biomass use get's intermixed with green Hydrogen and CCUS options; not so much competition but synergy between these key mitigation options.
- **EXCLUDING biomass from integral mitigation strategies increases mitigation costs substantially and in many cases makes achieving a 1,5oC pathway impossible.**
- Scenario;s that include LUC and carbon stock impacts show the additional benefit of increased C-storage combined with good land use practices.
- This is shown using IAM's, for the EU and for an increasing number of national ESM models that have the right granularity

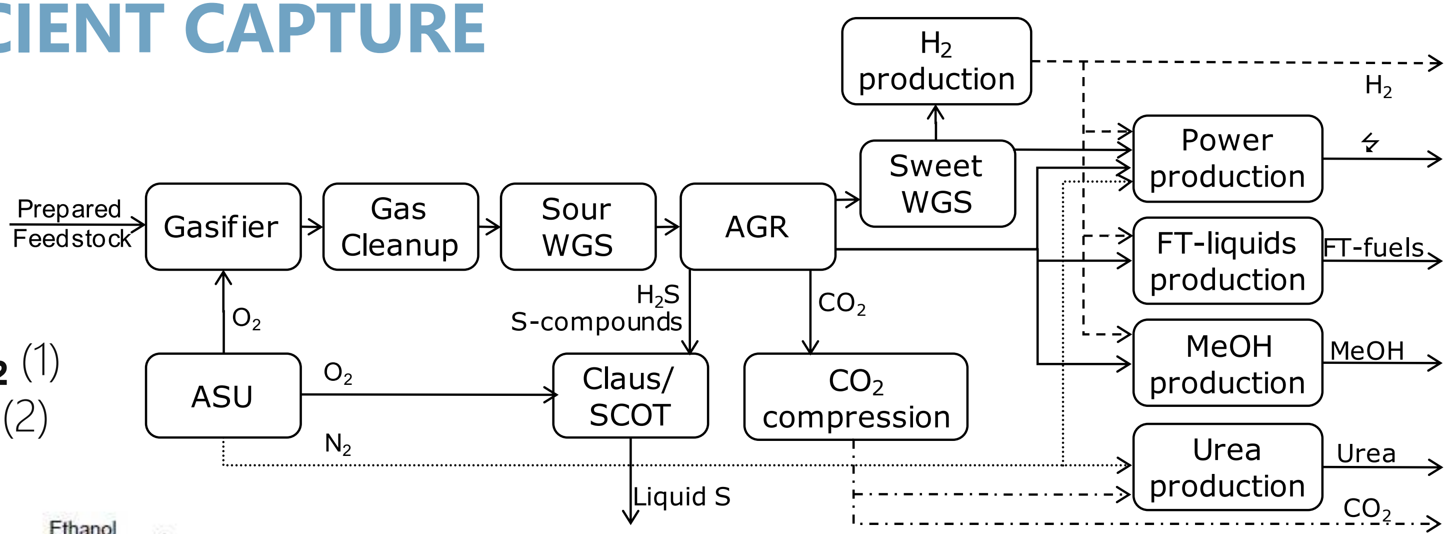
BASIC CARBON BALANCES OF CCU WITH DIRECT AIR CAPTURE (DAC), BECCS AND COMBINATIONS OF BOTH.



Major opportunities for future low carbon chemical industry [SAPEA, 2018]

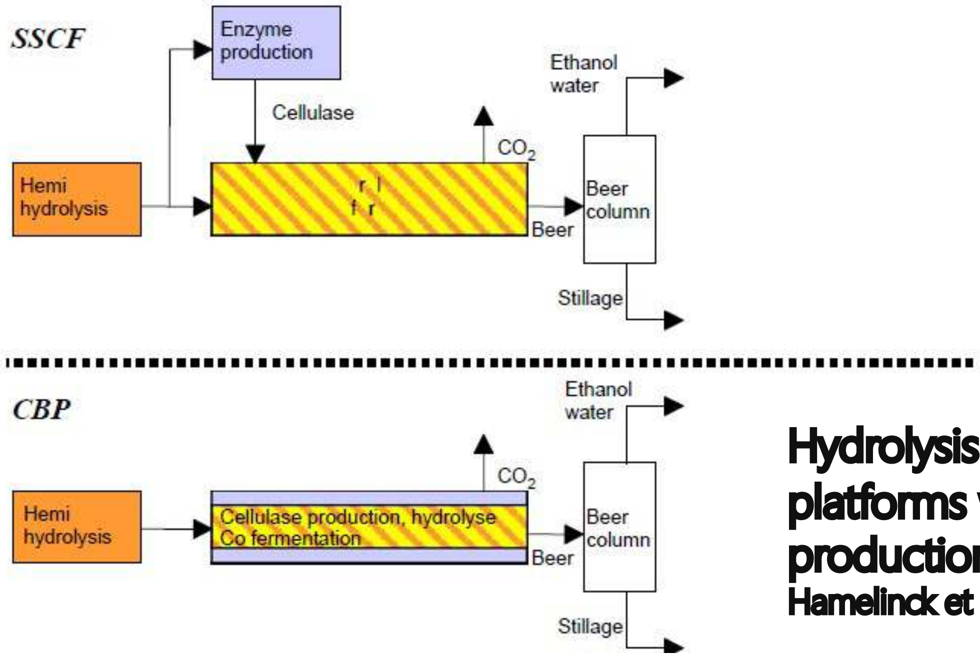
ADVANCED BIOMASS CONVERSION ALLOWS FOR EFFICIENT CAPTURE OF BIOGENIC CO2

$3C_5H_{10}O_5 \rightarrow 5C_2H_5OH + 5\mathbf{CO_2}$ (1)
$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2\mathbf{CO_2}$ (2)



Gasification platforms with CO2 removal as part of syngas production

Meerman et al., RSER, 2012]



Hydrolysis & fermentation platforms with inherent production of pure CO2.
Hamelinck et al., Biomass & bioenergy, 2005

EU$_{2018}$ GHG EMISSIONS 4.4 GTON $CO2_{EQ}$ VS BBE

Main product	GHG emissions biomass value chains (Mton CO2eq)		Avoided emissions fossil reference products (Mton CO2eq)		Net avoided emissions (Mton CO2eq) (low impact defined as higher emissions biomass value chain + low deployment; high impact defined as lower emissions biomass value chains + high deployment	
	Low	high	Low	High	low	High
Biofuels (2nd generation ethanol, DME, Fischer-Tropsch)	51	71	205	1014	154	943
Electricity (larger scale)	25	0	84	96	59	96
Heat (larger scale & Industrial)	24	0	145	0	121	0
Biogas	-1	-42	10	34	10	76
Bulk biochemicals	3	0	24	332	22	332
Totals	102	29	468	1476	366	1447

In addition: - BECCS options may contribute up to 700 Mton/yr.

- Carbon stock increases due to additionally planted perennial crops, increased productivity of marginal and degraded lands and increased carbon stocks due to improved agricultural productivity may contribute another 10-50 Mton/yr up to 2050.

[Faaij, 2019]()

CONCLUDING REMARKS

- Sustainable biomass resources are not fiction and can be made available while achieving major **synergies** with sustainable agriculture, forest management and restoration of degraded lands.
- Sustainable European biomass potentials can cover **1/3 of the future primary energy** supply; comparable to the role of mineral oil today.
- Improved trade balance of the EU + sustained additional income for especially rural regions are a major Green Deal opportunity, fitting the CAP and reducing the need for agricultural subsidies.
- Advanced technologies and BECCS offer major pathways for supplying high quality fuels and sustainable heavy industry with **negative emissions**.
- Biobased economy in the EU with European biomass resources can tackle **> 1/3 of the required GHG mitigation effort in 2050.**

RATIONALE VOOR BIOBASED ECONOMY 2.0: ONDERZOEK EN INNOVATIEPROGRAMMA VOOR EEN DUURZAME BIJDRAGE VAN BIOMASSA VAN 25% AAN DE NEDERLANDSE ENERGIE EN MATERIAALVOORZIENING IN 2050

- - Biobased economy is (erkend) van strategisch belang (mitigatie, circulaire economie), maar wordt nauwelijks geaddresseerd in de Missiegedreven aanpak.
- Integrale aanpak nodig voor betrokken sectoren; biomassa-inzet dynamisch in de tijd qua beschikbaarheid en gebruik (van warmte en kracht naar (advanced) fuel en grondstof). Negatieve emissies extra drijfveer.
- Een missiegedreven aanpak analoog aan de inzet van ''Groenvermogen" voor waterstof,; mikkend op bv groeifonds en EU Recovery fonds. Doel: 25% bijdrage aan de mitigatiedoelstelling. **Vanaf nu.**
- Nationaal consortium van bedrijven, kennisinfrastructuur en beleid met sterke Europese links (en afstemming).
- Majeure rol voor "show how" en ''duurzaam": zichtbaar en communiceerbaar (draagvlak).

INHOUDELIJKE HOOFDELEMENTEN

- Duurzaamheid biomassa resources; subthema's: integratie in duurzame, robuusten (adaptatie! en hoog efficiente landbouw, bosbouw, aquatisch
- Logistiek, markt en ketens (cascadering, circulair)
- Geavanceerde conversieroutes:
  - Toepassingen in nieuwe industriële processen (inclusief BECCS)
  - BIoraffinage voor optimalisatie biomassavalorisatie en impacts
  - Combinaties biomassaconversie en PtoX/CCUS
  - dynamiek in toepassingen (en resources): flexibiliteit in conversiecapaciteit
- Draagvlak, perceptie en beleid; borging duurzaamheid en opschaling.
- Integrale systeemanalyse

HOOFDELEMENTEN ORGANISATIE

- Selectie van een aantal strategische demo's voor BECCS/CCUS & bioraffinage
- Selectie van een aantal demonstratieregio's voor integrale duurzaamheid landgebruik, landbouw en biomassaproductie, inclusief organisatie logistiek.
- Organisatie van missiegedreven aanpak, bv. middels een open eind PPS met bedrijfsleven, overheid en kennisinfrastructuur.
- Kenniscoalitie voor uitvoering integrale systeem en impactanalyses, monitoring en optimalisatie van BBE inzet en toepassingen in de tijd. Majeure rol voor borging duurzaamheid en communicatie.

› Groeifonds (-achtig), EU recovery fund, uitstekende koppeling en afstemming met EU activiteiten (IPCEI model?).

DISCUSSIE OVER:

- BBE (zoals gedefinieerd) kan en moet een essentiele bijdrage leveren?
- BBE niet goed belegd in Nederlandse aanpak?

- Draagvlak voor een nationale missiegedreven aanapak (bedrijfsleven en kennisinfrastructuur OK; betrokken departementen?)
- Perspectief voor realisatie? Staan bestaande kaders in de weg of zijn ze behulpzaam?
- Overleg op korte termijn en inzetten initiërende fase?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AGRICULTURAL YIELD PROJECTIONS EUROPE; FOCUSING ON YIELD GAPS AND ACHIEVABLE AGRICULTURAL YIELDS AND LIVESTOCK EFFICIENCY

Observed yield

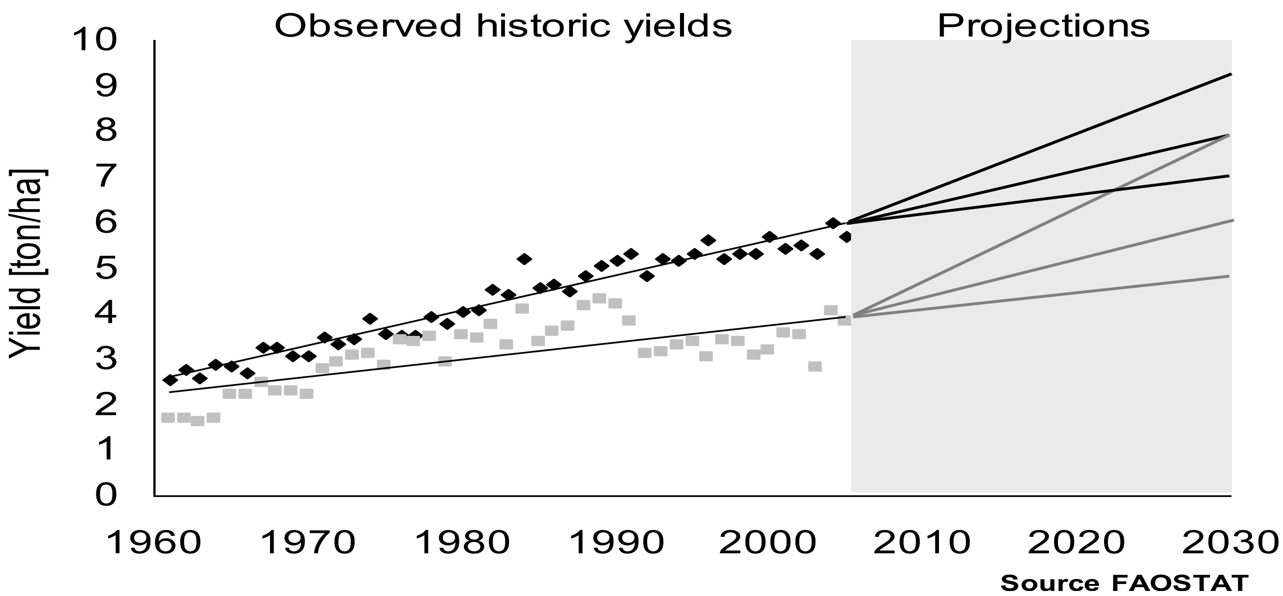
- CEEC and WEC

Linear extrapolation of historic trends

- Widening yield gap

Applied scenarios

- Low, baseline and high

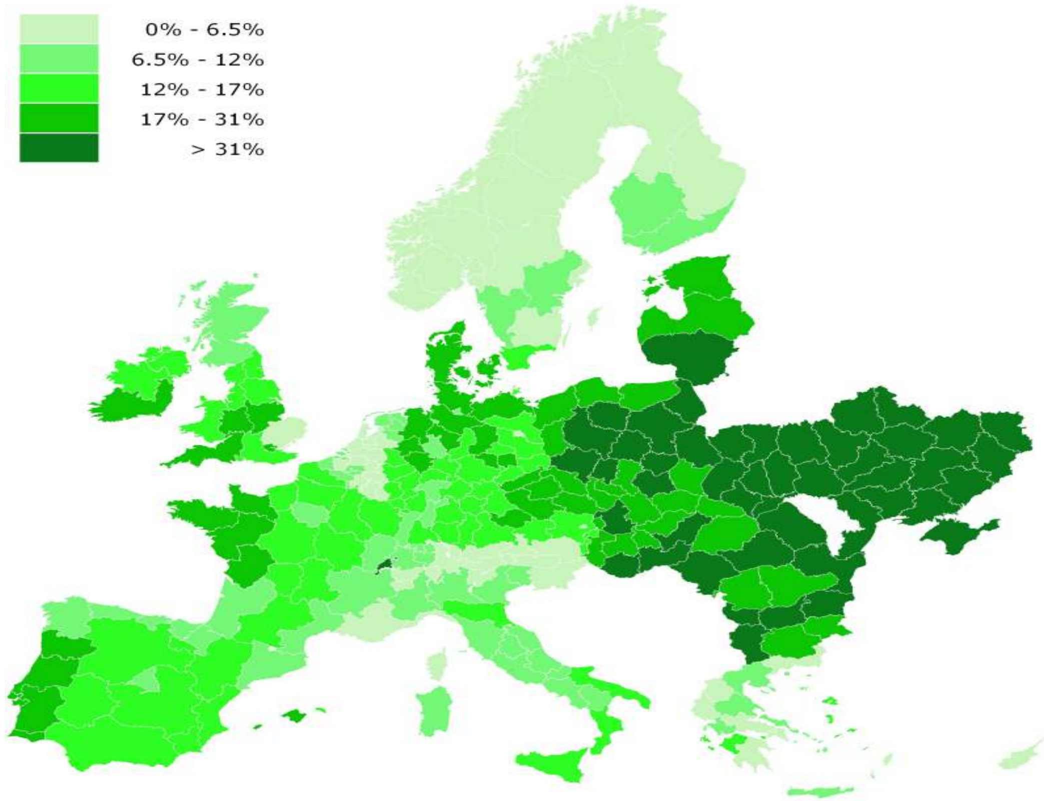


[Wit & Faaij, Biomass & Bioenergy, 2010]

SPATIAL PRODUCTION POTENTIAL FOR BIOMASS IN EUROPE FOR SOTA IMPROVEMENT LEVELS OF THE AGRICULTURAL SECTOR

Arable land available for dedicated bio-energy crops divided by the total land

Potential		Countries
Low potential	< 6,5%	NL, BE, LU, AT, CH, NO, SE and FI
Moderate potential	6,5% - 17%	FR, ES, PT, GE, UK, DK, IE, IT and GR
High potential	> 17%	PL, LT, LV, HU, SL, SK, CZ, EST, RO, BU and UKR

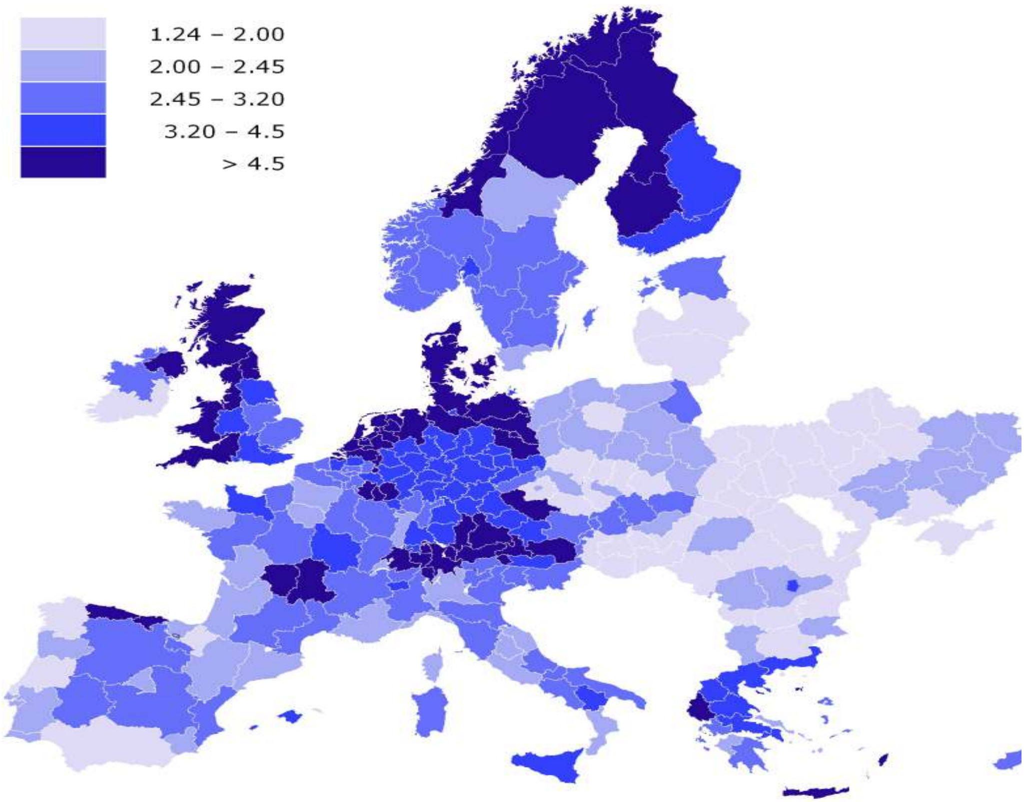


[Wit & Faaij, Biomass & Bioenergy, 2010]

SPATIAL COST DISTRIBUTION FOR PERENNIAL CROPS ON VIRTUAL SURPLUS AGRICULTURAL LAND AND PASTURES

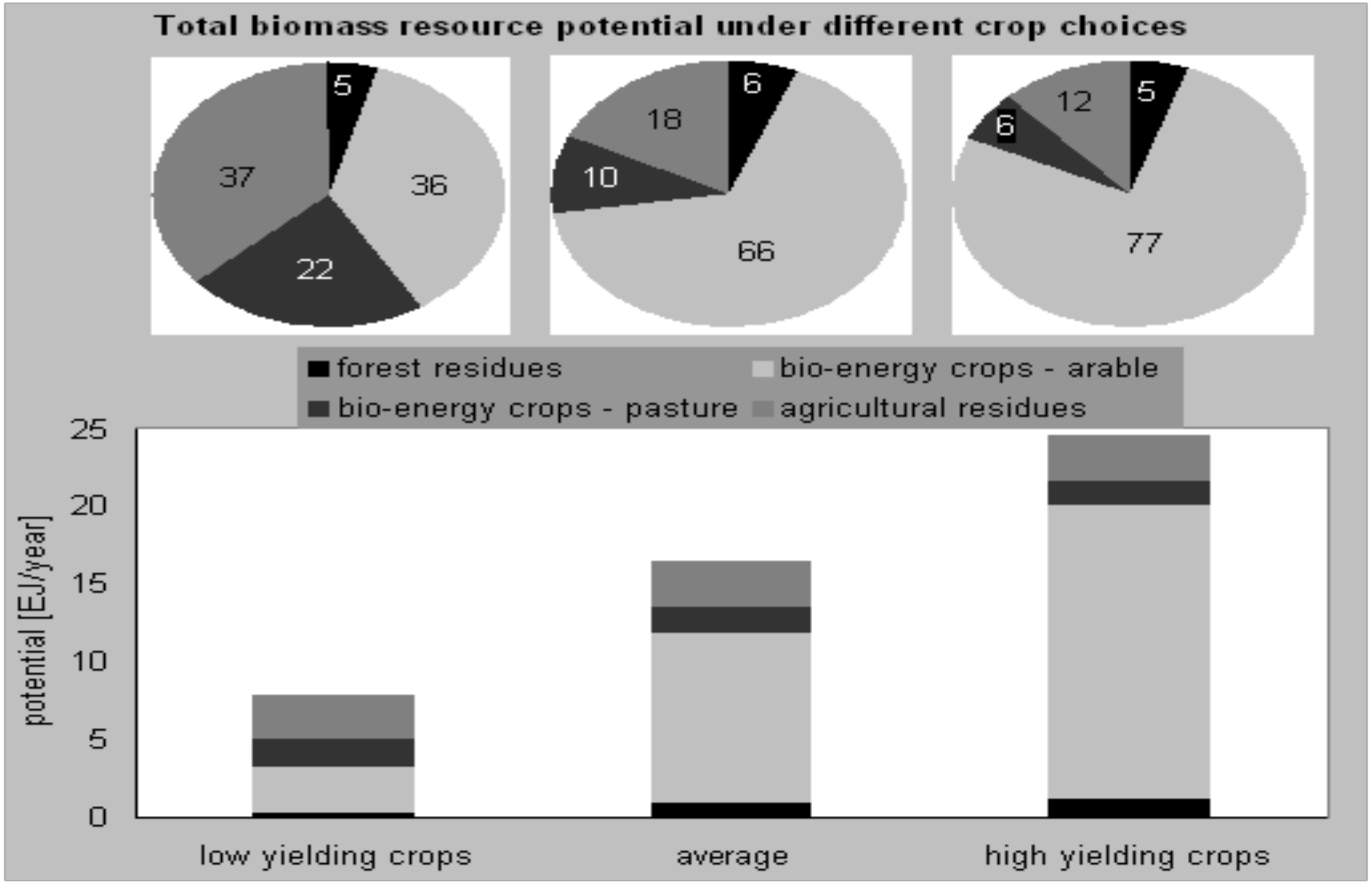
Production cost (€ GJ^{-1}) for Grassy crops

Potential		Countries
Low Cost	< 2,00	PL, PT, CZ, LT, LV, UK, RO, BU, HU, SL, SK, EST, UKR
Moderate Cost	2,00 – 3,20	FR, ES, GE, IT, SE, FI, NO, IE
High Cost	> 3,20	NL, BE, LU, UK, GR, DK, CH, AT



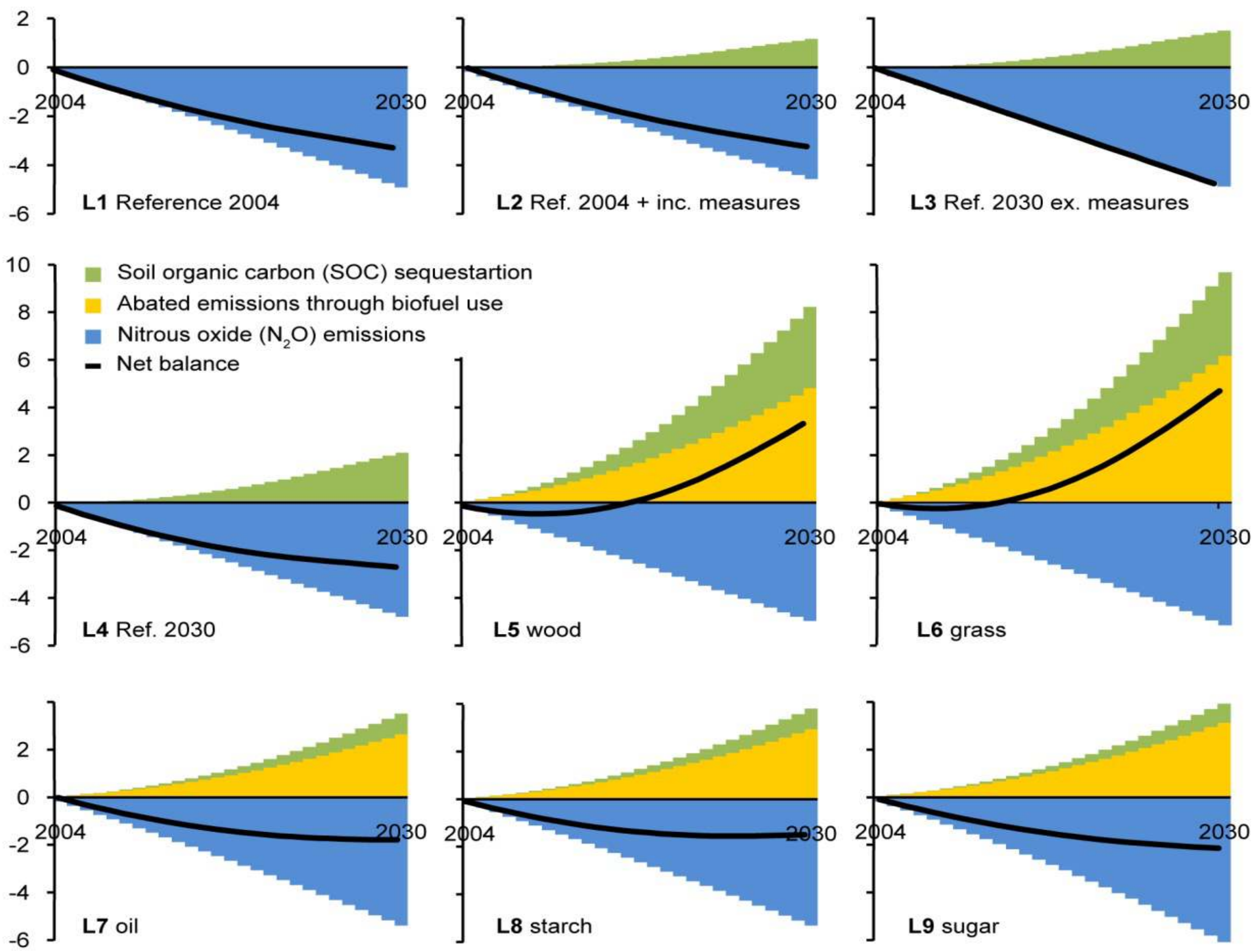
[Wit & Faaij, Biomass & Bioenergy, 2010]

TOTAL PRIMARY BIOMASS ENERGY POTENTIAL FOR DIFFERENT LEVELS OF IMPROVEMENT OF AGRICULTURE .



[Wit & Faaij, Biomass & Bioenergy, 2010]

Cumulative mitigation balance 2004-2030, Gt CO_2-eq.

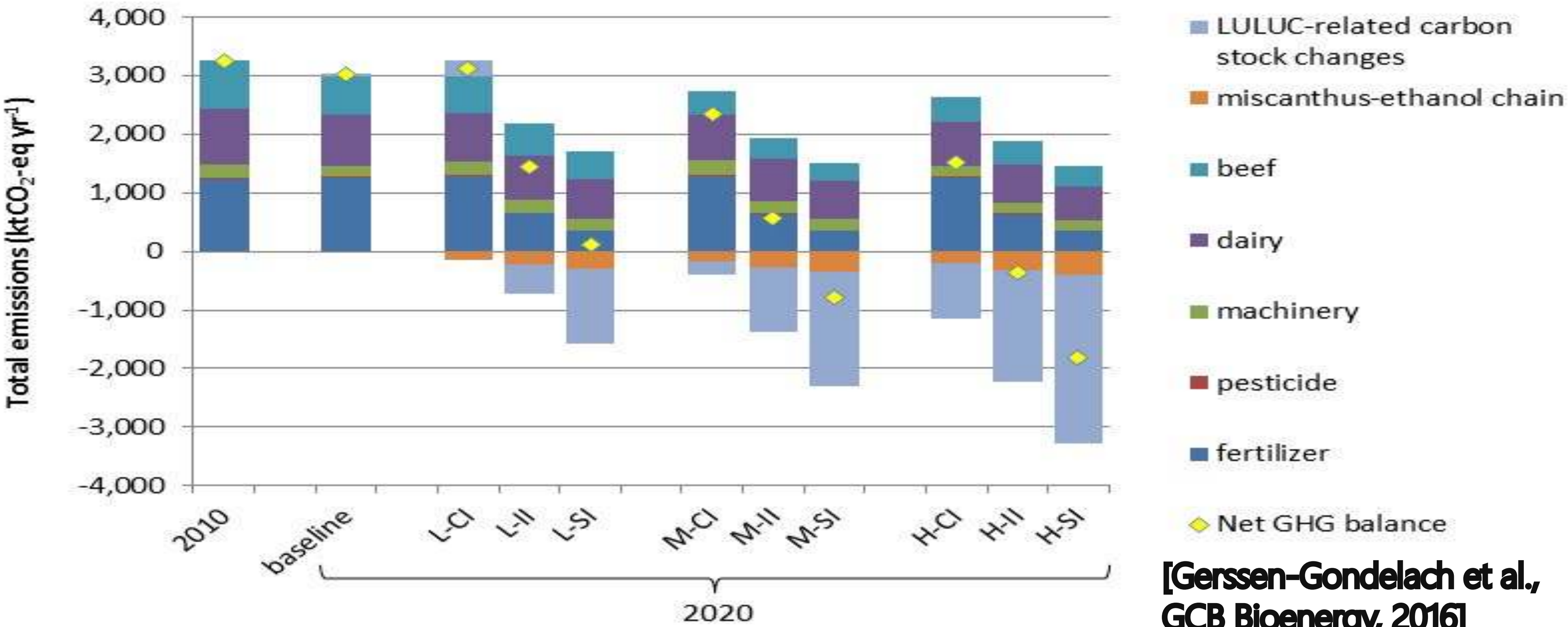


<u>Cumulative</u> GHG balance of combined agricultural intensification + bioenergy production in Europe + Ukraine over 3 decades

[Wit et al., BioFPR, 2014]

Full impact analysis

TOTAL AND NET ANNUAL GHG EMISSIONS FOR 2010 AND THE BASELINE AND ILUC MITIGATION SCENARIOS IN 2020. EMISSIONS FROM THE MISCANTHUS-ETHANOL VALUE CHAIN. THE EQUILIBRIUM TIME FOR SOIL CARBON STOCK CHANGES IS 20 YEARS.
ILUC PREVENTION SCENARIOS: L, LOW; M, MEDIUM; H, HIGH. INTENSIFICATION PATHWAYS: CI, CONVENTIONAL INTENSIFICATION; II, INTERMEDIATE SUSTAINABLE INTENSIFICATION; SI, SUSTAINABLE INTENSIFICATION.



[Gerssen-Gondelach et al., GCB Bioenergy, 2016]

Biomass option	Chain GHG emissions (CO2 eq-MJ)	Fossil reference emissions (CO2eq/MJ)	Remarks
Biomass to electricity	0-47 (per MJe)	100 (per MJe)	Assumes larger scale conversion using gasification or advanced combustion; reference value represents the current European electricity generation mix.
Biogas	-70 - -3	56	Used for wet biomass streams as wet organic waste, manure, sludges; avoidance of methane emissions in reference situation results in negative emissions
Heat lower temperature	4-15	92	Typically for domestic heating
Heat higher temperature	4-15	92	Industrial heat, large scale.
1st generation ethanol	4-86	100	Assumes crops as beet and corn
1st generation biodiesel	10-35	100	Assumes rapeseed as main feedstock
2nd generation Biofuels (ethanol, Fischer Tropsch, methanol, DME)	0-10	100	Assumes lignocellulose from residues or perennial crops as feedstock. Reference emission value mixture of gasoline, diesel and kerosene.
	Chain GHG emissions (CO2 eq-ton)	Fossil reference emissions (CO2eq/ton)	
Bulk Chemicals (ethylene, propylene, BTX, PLA, PTT, PHA)	0-0,5	4,5	A wide range of emission values is reported. The chosen values here represent a ''weighted average'' based on expert judgement.

TYPICAL LIFE CYCLE GHG BALANCES FOR WELL MANAGED BIOMASS VALUE CHAINS; WELL OVER 90% REDUCTION VS FOSSIL IS FEASIBLE.

[e.g. based on Gerssen-Gondelach, RSER, 2014]

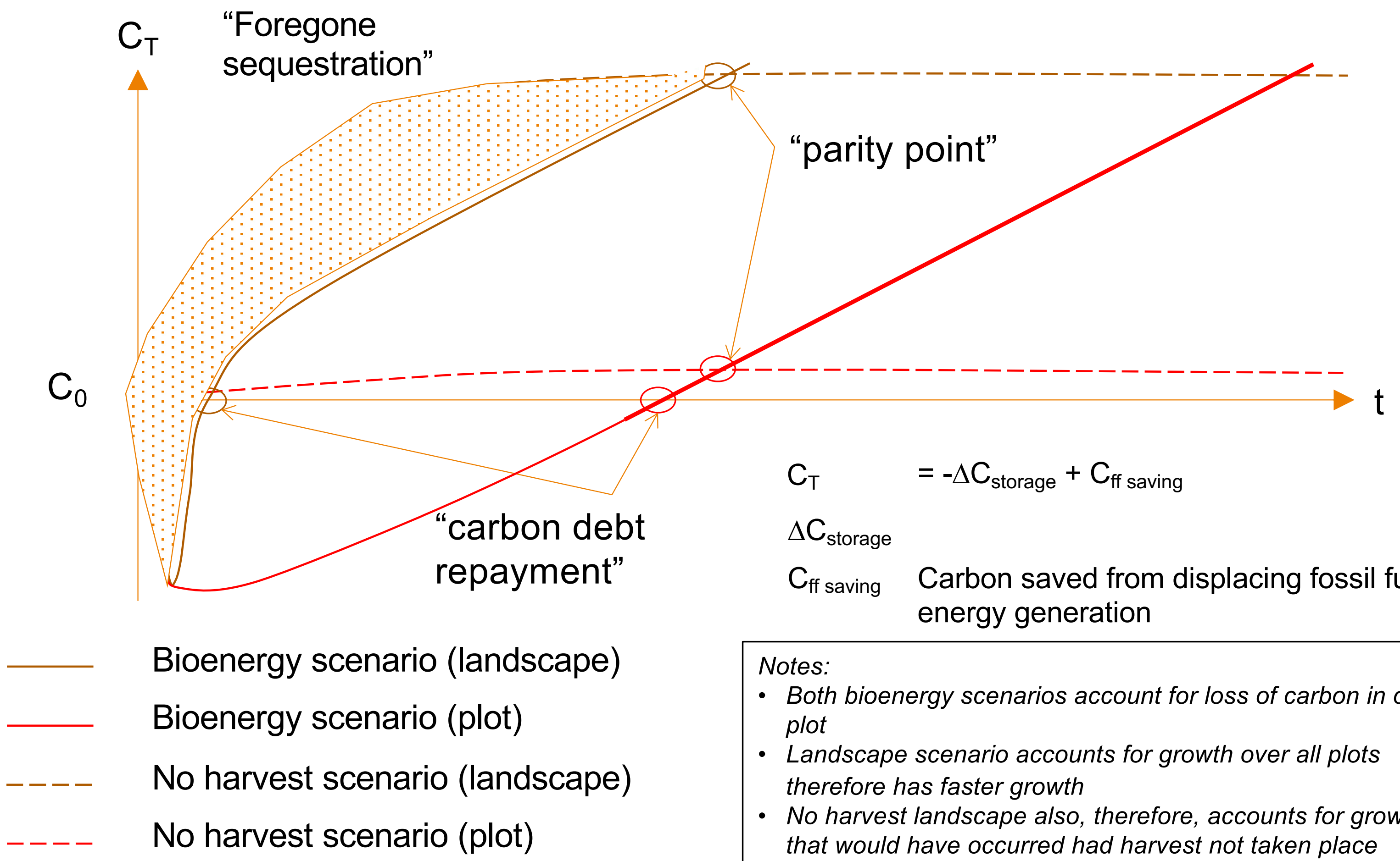
RANGES FOR BIOMASS DEPLOYMENT FOR DIFFERENT MAIN USES IN EUROPE IN 2050.

THE HIGH BIOMASS POTENTIAL WILL RESULT IN A HIGH IMPACT OF BIOMASS USE IN GHG MITIGATION AND THE LOW BIOMASS POTENTIAL IN LOW IMPACT.

Main product	Primary biomass allocated (EJ)		Net energy Conversion efficiency (%)	Final energy (or product) (EJ)		
	low	high		low	high	
Biofuels (2nd generation ethanol, DME, Fischer-Tropsch)	3,15	15,6	65	2,0	10	
Electricity (larger scale)	1,05	1,2	50	0,5	0,6	
Heat (larger scale & Industrial)	1,75	0	90	1,6	0	
Digestion	0,7	2,4	25	0,2	0,6	
Large scale biorefinery complexes	0,35 (18 Mton)	4,8 (246 Mton)	50	0,2 (5,4 Mton)	2,4 (74 Mton)	(*)

(*): a crude average 0,3 conversion factor from primary biomass to chemicals is assumed, based on a range of actual conversion factors for different process and expert opinion.

CARBON DEBT & PARITY POINTS – STAND & LANDSCAPE LEVEL



C_T $= -\Delta C_{storage} + C_{ff\ saving}$

$\Delta C_{storage}$

$C_{ff\ saving}$ Carbon saved from displacing fossil fuel energy generation

Notes:

- *Both bioenergy scenarios account for loss of carbon in one plot*
- *Landscape scenario accounts for growth over all plots therefore has faster growth*
- *No harvest landscape also, therefore, accounts for growth that would have occurred had harvest not taken place*
- *Concept based on Mitchell (2012) with extension to stand/landscape level by Robin Grenfell / MWH*

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