Biobased economy in Europe; challenges and opportunities

***Bio4Fuels:* The Final Conference Organized by the FME Centre Bio4Fuels**
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André Faaij

Director of Science TNO Energy & Materials Transition

Distinguished Professor Energy System Analysis – Utrecht University
University of Groningen

Universiteit Utrecht

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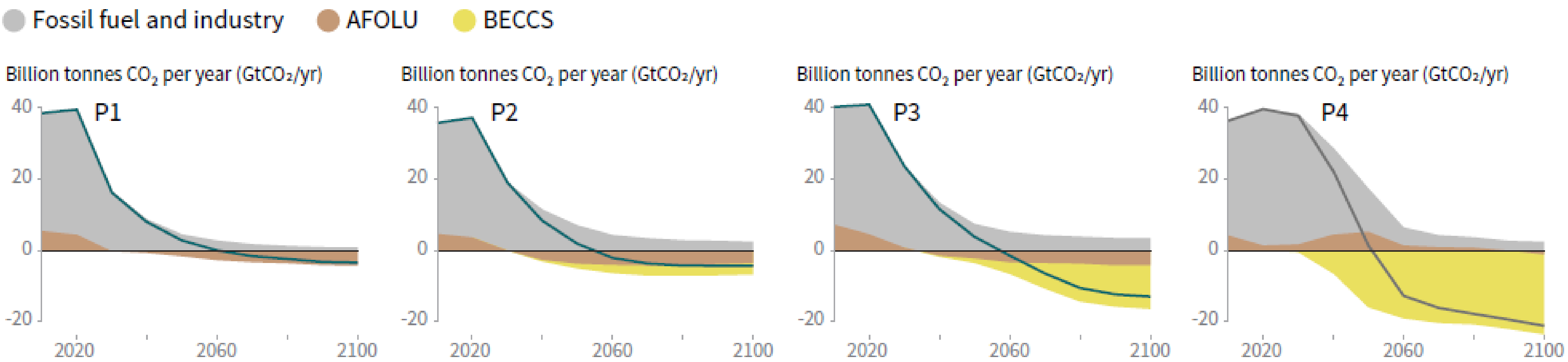
The IPCC 1,5 oC report: emission pathways

KEY PILLAR OF THE EU’S GREEN DEAL.

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



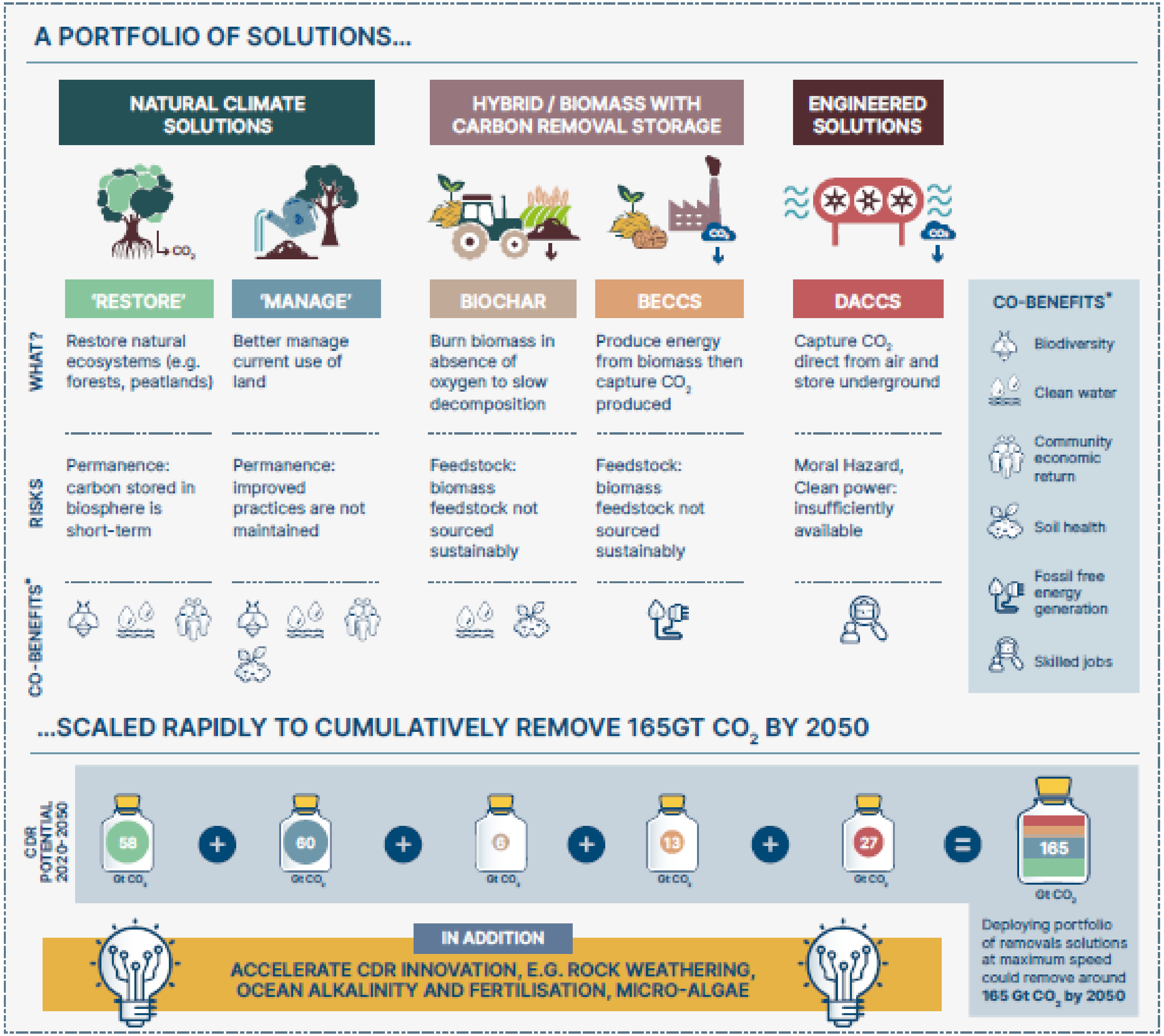
P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither 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.

What will it take to scale CDR to keep 1.5°C alive?



MIND THE GAP REPORT, ENERGY TRANSITIONS COMMISSION, MARCH 2022 & IPCC AR6:

SEVERAL 100 GTON CO2 REMOVALS NEEDED THIS CENTURY

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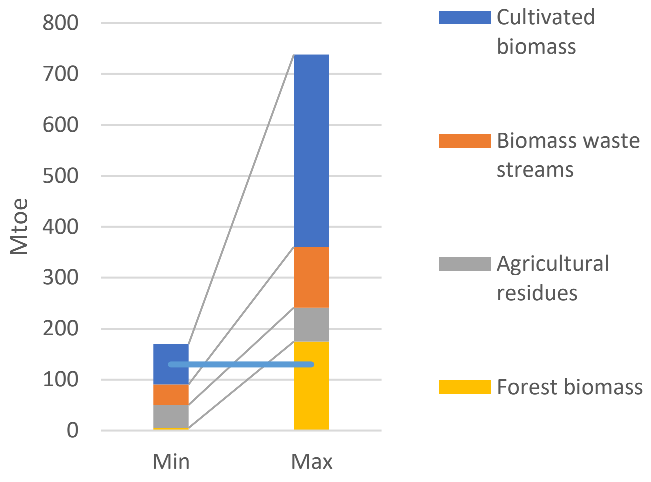
The contribution of biomass for energy and materials to avoid GHG emissions depends on:

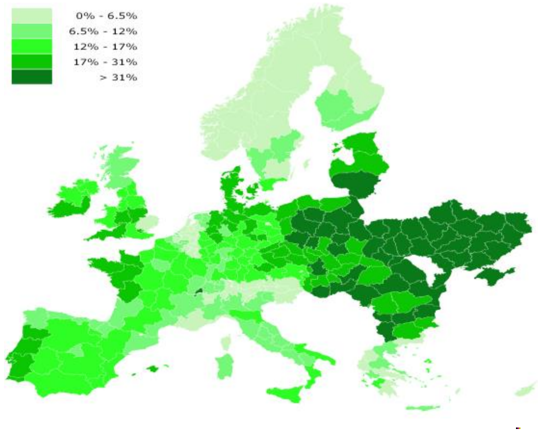
- Potential future **sustainable** biomass **availability** in Europe for energy and materials
- Potential **future use** of biomass for energy and materials **as part of** the 2050 GHG mitigation strategy of the EU, leading to 80 – 95% GHG emission reduction compared to 1990 levels.
- The **share of 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.

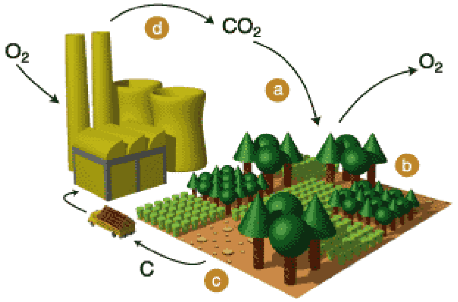
Sustainable biomass supplies can increase considerably in synergy with:

- Adaptation to climate change (vegetation covers are key!)
- Improving agricultural (and livestock) management reduces land use, environmental impacts and increases resilience.
- Reduction of food losses across value chains and alternative protein sources
- Land type – crop combinations, land zoning and land use patterns can to a large extent be steered towards co-benefits.
- Regeneration of idle, marginal or degraded lands gives ecological benefits; soil restoration, water retention, carbon storage, increased biodiversity.
- Good forest management improves resilience and productivity.
- Possible surprises from aquatic biomass (progress micro-algue and macro-algue/seaweed).

MANY, ALSO RECENT, STUDIES IGNORE PARTS OR A MULTITUDE OF THESE FACTORS!







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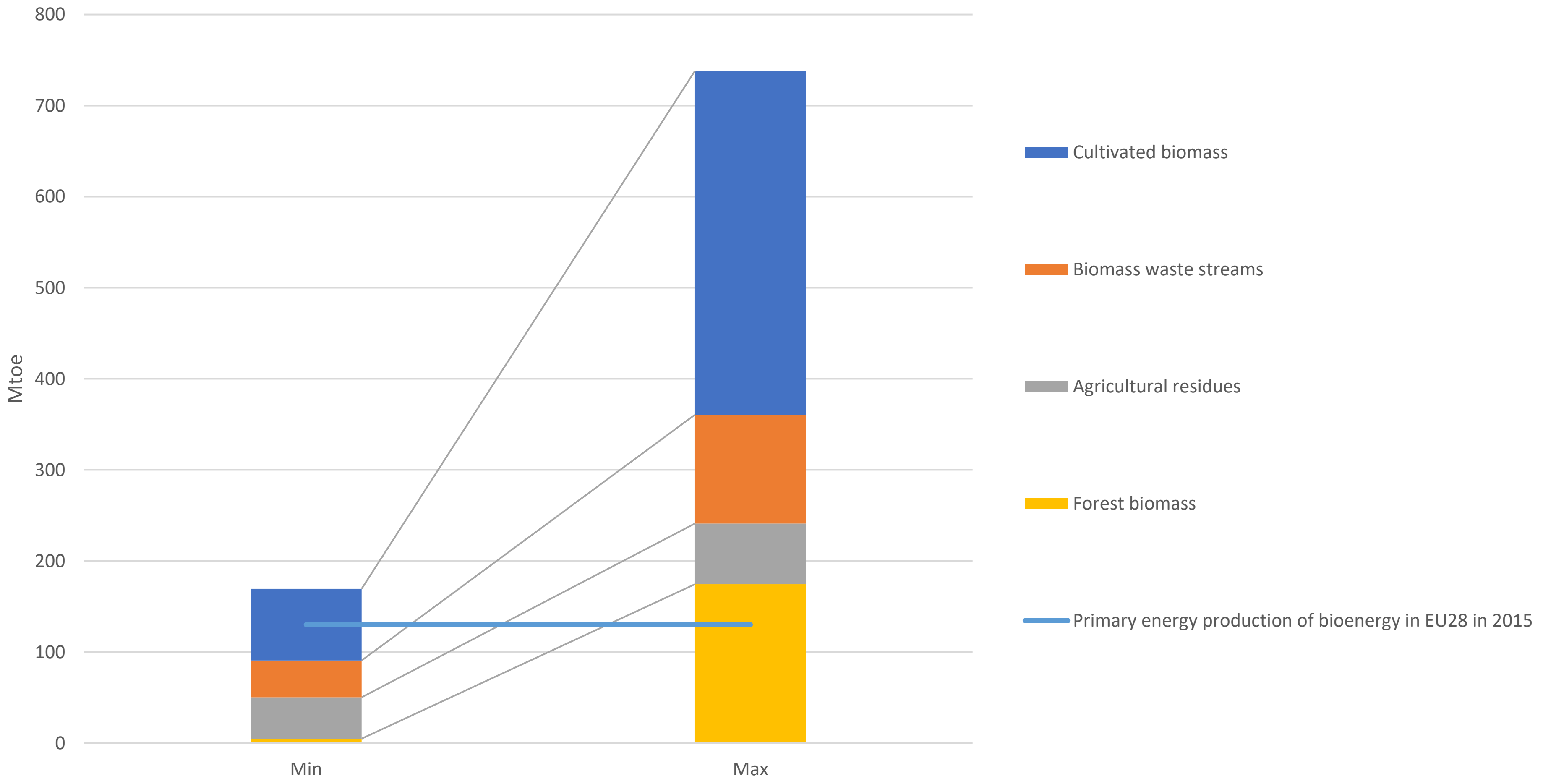
Biomass potentials EU28 in 2050; 7-30 EJ compared to 68 EJ total primary energy used today



[Faaij, Bioenergy Europe, 2018 Energies, 2022]

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GLOBAL CHANGE BIOLOGY
BIOENERGY

GCB Bioenergy (2014), doi: 10.1111/gcbb.12205

REVIEW

Bioenergy and climate change mitigation: an assessment

FELIX CREUTZIG[1], N. H. RAVINDRANATH[2], GÖRAN BERNDES[3], SIMON BOLWIG[4], RYAN BRIGHT[5], FRANCESCO CHERUBINI[5], HELENA CHUM[6], ESTEVE CORBERA[7], MARK DELUCCHI[8], ANDRE FAAIJ[9], JOSEPH FARGIONE[10], HELMUT HABERL[11,12], GARVIN HEATH[6], OSWALDO LUCON[13], RICHARD PLEVIN[14], ALEXANDER POPP[15], CARMENZA ROBLEDO-ABAD[16], STEVEN ROSE[17], PETE SMITH[18], ANDERS STROMMAN[5], SANGWON SUH[19] and OMAR MASERA[20]

[1]Mercator Research Institute on Global Commons and Climate Change, Technical University Berlin, Berlin, Germany, [2]Centre for Sustainable Technologies, Indian Institute of Science, Bangalore, India, [3]Department of Energy and Environment, Chalmers University of Technol… Roskilde, Denmark, [5]T… Trondheim, Norway, … Environmental Scienc… Barcelona, Spain, [8]Tra… Research Institute Gr… USA, [11]Institute of S… Research Institute on … [13]Sao Paulo State En… Davis, CA, USA, [15]P… Institute for Environ… Zurich, Switzerland, … USA, [18]Institute of Bi… [19]Bren School of Envi… Ecosystems Research, …

Table 1 (continued)

	Scale	
May promote concentration of income and/or increase poverty if sustainability criteria and strong governance is not in place (2, 16, 26)	–	Local to regional
Using waste and residues may create socio-economic benefits with little environmental risks (2, 41, 36)	+	Local to regional
Uncertainty about mid- and long term revenues (6, 30)	–	National
Employment creation (3, 14, 15)	+	Local to regional
Technological		
Can promote technology development and/or facilitate technology transfer (2, 27, 31)	+	Local to global
Increasing infrastructure coverage (+). However if access to infrastructure and/or technology is reduced to few social groups it can increase marginalization (–) (27, 28, 29)	+/–	Local
Bioenergy options for generating local power or to use residues may increase labor demand, creating new job opportunities. Participatory technology development also increases acceptance and appropriation (6, 8, 10, 37, 40)	+	Local
Technology might reduce labor demand (–). High dependent of tech. transfer and/or acceptance	–	Local

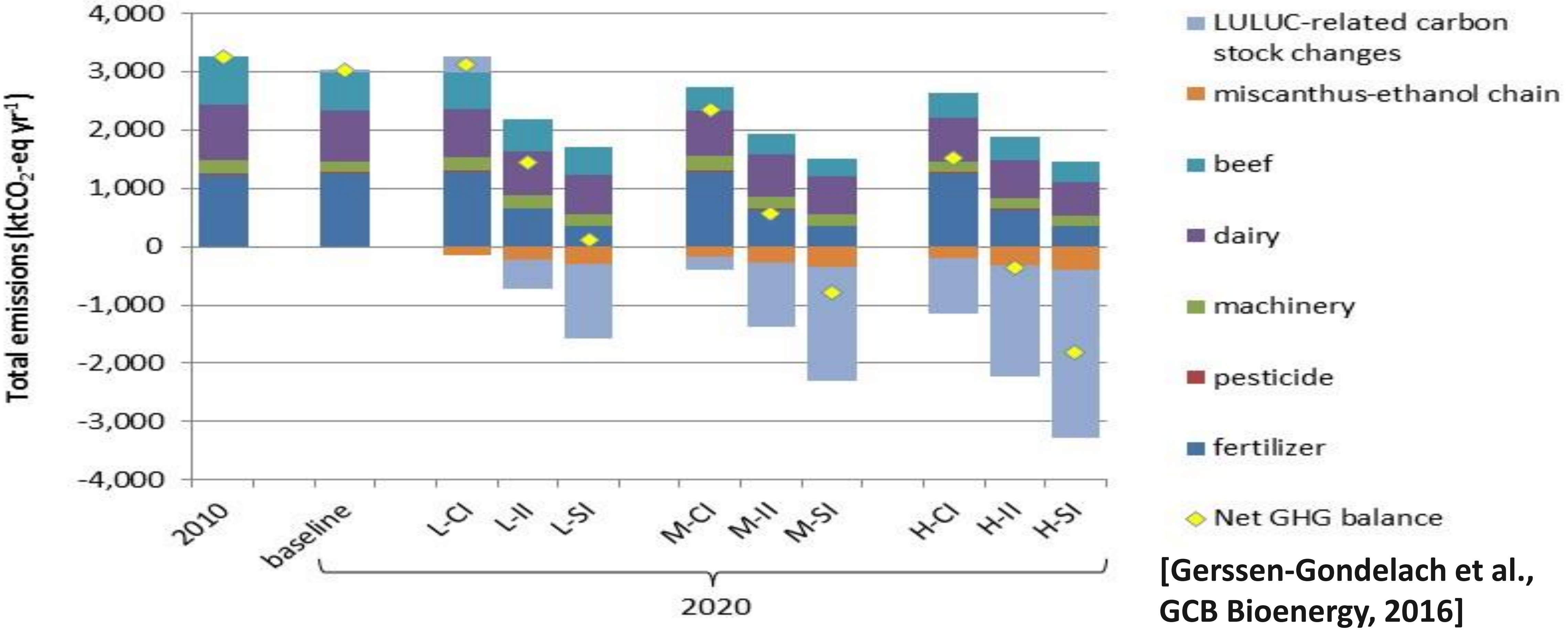
(1) (Finco & Doppler, 2010); (2) (Amigun et al., 2011); (3) (Arndt et al., 2012); (4) (Arndt et al., 2011a); (5) (Arndt et al., 2011a,b); (6) (Awudu & Zhang, 2012); (7) (Beringer et al., 2011); (8) (Borzoni, 2011); (9) (Bringezu et al., 2012); (10) (Cacciatore et al., 2012); (11) (Cançado et al., 2006); (12) (Danielsen et al., 2009); (13) (Diaz-Chavez, 2011); (14) (Duvenage et al., 2013); (15) (Ewing & Msangi, 2009); (16) (Gasparatos et al., 2011); (17) (German & Schoneveld, 2012); (18) (Haberl et al., 2011); (19) (Hall et al., 2009); (20) (Hanff et al., 2011); (21) (Huang et al., 2012); (22) (Koh & Wilcove, 2008); (23) (Koizumi, 2013); (24) (Kyu et al., 2010); (25) (Madlener et al., 2006); (26) (Martinelli & Filoso, 2008); (27) (Mwakaje, 2012); (28) (Oberling et al., 2012); (29) (Schut et al., 2010); (30) (Selfa et al., 2011); (31) (Steenblik, 2007); (32) (Stromberg & Gasparatos, 2012); (33) (Searchinger et al., 2009); (34) (Searchinger et al., 2008); (35) (Smith & Searchinger, 2012); (36) (Tilman et al., 2009); (37) (Van de Velde et al., 2009); (38) (Von Maltitz & Setzkorn, 2013); (39) (Wu & Lin, 2009); (40) (Zhang et al., 2011); (41) (Fargione et al., 2008); (42) (Jerneck & Olsson, 2013); (43) (Gurung & Oh, 2013); (44) (O'Shaughnessy et al., 2013); (45) (German et al., 2013); (46) (Cotula, 2012); (47) (Mwakaje, 2012); (48) (Scheidel & Sorman, 2012); (49) (Haberl et al., 2013b); (50) (Muys et al., 2014); (51) (Egeskog et al., 2011); (52) (Diaz-Chavez, 2012); (53) (Ewing & Msangi, 2009); (54) (De Moraes et al., 2010); (55) (Goldemberg, 2007); (56) (Walter et al., 2008); (57) (Langeveld et al., 2013); (58) (Van Dam et al., 2009a,b); (59) (Van Dam et al., 2010); (60) (Van Eijck et al., 2012); (61) (van Eijck et al., 2013, 2014); (62) (Martinez et al., 2013); (63) (Van der Hilst et al., 2010); (64) (Van der Hilst et al., 2012a,b,c); (65) (Hoefnagels et al., 2013); (66) (Immerzeel et al., 2014); (67) (Lynd et al., 2011); (68) (Smeets et al., 2008); (69) (Smeets & Faaij, 2010); (70) (Wicke et al., 2011a); (71) (Wicke et al., 2013); (72) (Wiskerke et al., 2010); (73) (De Wit et al., 2011); (74) (De Wit et al., 2013).

Table 1 Potential institutional, social, environmental, economic, and technological implications of bioenergy options at local to global scale

	Scale	
Institutional issues and Governance systems		
May contribute to energy independence (+), especially at the local level (reduce dependency on fossil fuels) (2, 20, 32, 39, 50)	+	Local to national
Can improve (+) or decrease (–) land tenure and use rights for local stakeholders (2, 17, 38, 50)	+/–	Local
Cross-sectoral coordination (+) or conflicts (–) between forestry, agriculture, energy and/or mining (2, 13, 26, 31, 59)	+/–	Local to national
Impacts on labor rights among the value chain (2, 6, 17)	+/–	Local to national
Promoting of participative mechanisms for small-scale producers (14, 15)	+	Local to national
Social		
Competition with food security including food availability (through reduced food production at the local level), food access (due to price volatility) use usage (as food crops can be diverted toward biofuel production) and consequently to food stability. Bioenergy derived from residues, wastes or by-products is an exception (1,2, 7, 9, 12, 18, 23)	–	Local to global
Integrated systems (including agroforestry) can improve food production at the local level creating a positive impact toward food security (51, 52, 53, 66, 70, 71, 72). Further, biomass production combined with improved agricultural management can avoid such competition and bring investment in agricultural production systems with overall improvements of management as a result (as observed in Brazil) (59, 62, 67, 68)	+	Local
Increasing (+) or decreasing (–) existing conflicts or social tension (9, 14, 19, 26)	+/–	Local to national
Impacts on traditional practices: using local knowledge in production and treatment of bioenergy crops (+) or discouraging local knowledge and practices (–) (2, 50)	+/–	Local
Displacement of small-scale farmers (14, 15, 19). Bioenergy alternatives can also empower local farmers by creating local income opportunities	+/–	Local
Promote capacity building and new skills (3, 15, 50)	+	Local
Gender impacts (2, 4, 14, 15, 27)	+/–	Local to national
Efficient biomass techniques for cooking (e.g., biomass cookstoves) can have positive impacts on health specially for women and children in developing countries (42, 43, 44)	+	Local to national
Environmental		
Biofuel plantations can promote deforestation and/or forest degradation, under weak or no regulation (1, 8, 22)	–	Local to global
When used on degraded lands, perennial crops offer large-scale potential to improve soil carbon and structure, abate erosion and salinity problems. Agroforestry schemes can have multiple benefits including increased overall biomass production, increase biodiversity and higher resilience to climate changes (58, 63, 64, 66, 71)	+	Local to global
Some large-scale bioenergy crops can have negative impacts on soil quality, water pollution and biodiversity. Similarly potential adverse side effects can be a consequence of increments in use of fertilizers for increasing productivity (7, 12, 26, 30). Experience with sugarcane plantations has shown that they can maintain soil structure (56) and application of pesticides can be substituted by the use of natural predators and parasitoids (68)	–/+	Local to transboundary
Can displace activities or other land uses (8, 26)	–	Local to global
Smart modernization and intensification can lead to lower environmental impacts and more efficient land use (73, 74)	+	Local to transboundary
Creating bioenergy plantations on degraded land can have positive impacts on soil and biodiversity (12)	+	Local to transboundary
There can be trade-offs between different land uses, reducing land availability for local stakeholders (45, 46, 47, 48, 49). Multicropping system provide bioenergy while better maintaining ecological diversity and reducing land use competition (57)	–/+	Local to national
Ethanol utilization leads to the phase-out of lead additives and MBTE and reduces sulfur, particulate matter and carbon monoxide emissions (55)	+	Local to global
Economic		
Increase in economic activity, income generation and income diversification (1, 2, 3, 12, 20, 21, 27, 54)	+	Local
Increase (+) or decrease (–) market opportunities (16, 27, 31)	+/–	Local to national
Contribute to the changes in prices of feedstock (2, 3, 5, 21)	+/–	Local to global

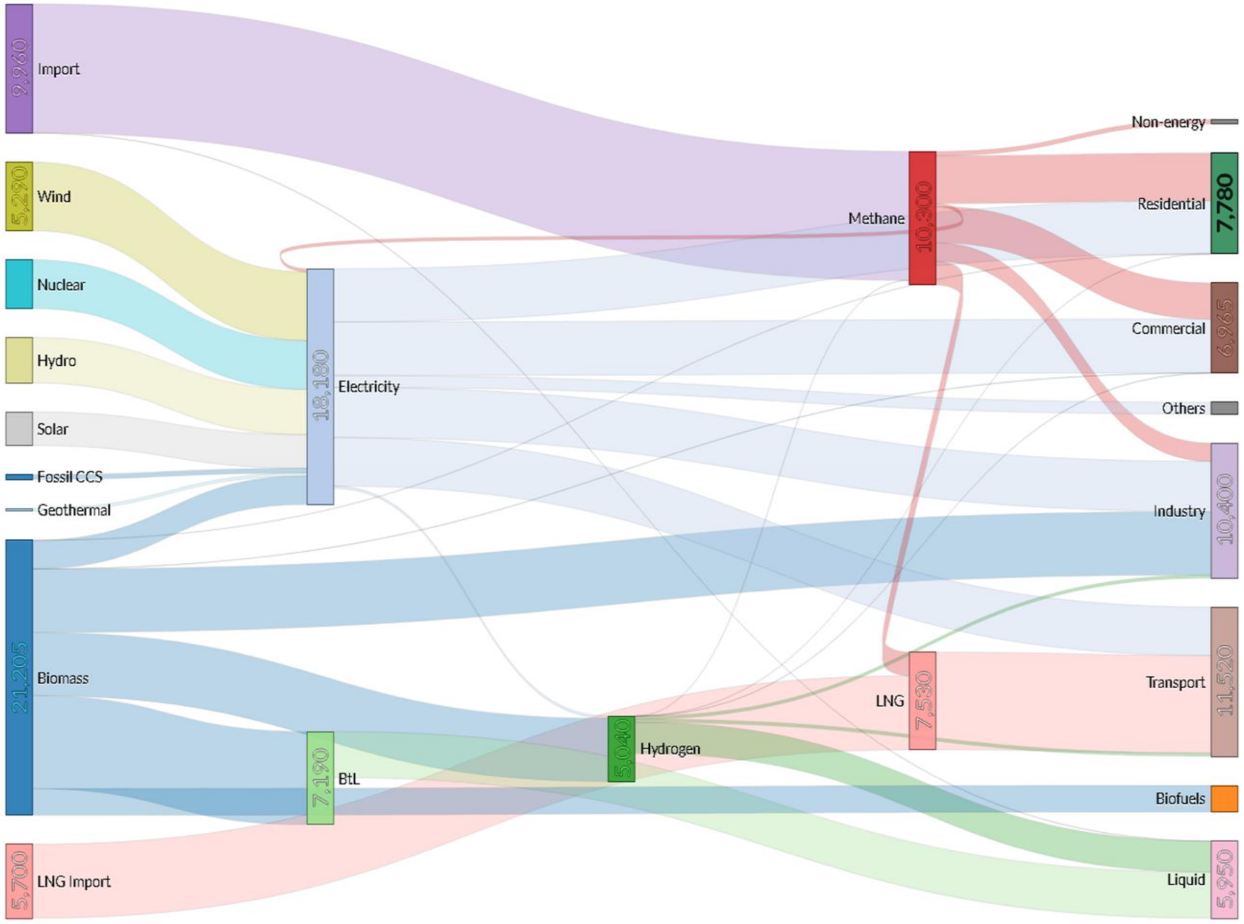
Full impact analysis; biomass integrated in agri-region in western Poland (no –iLUC!)

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.

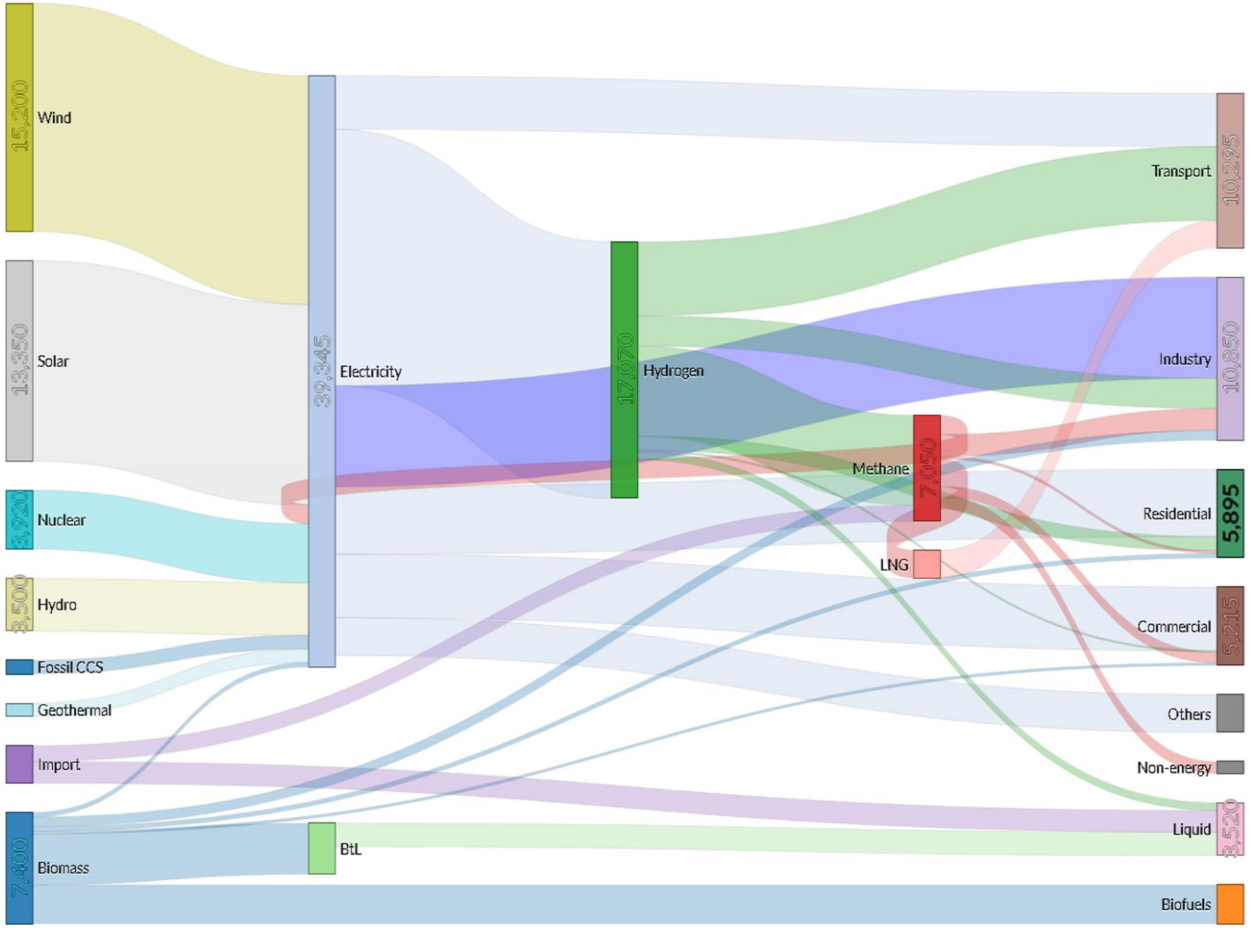


[Gerssen-Gondelach et al., GCB Bioenergy, 2016]

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]

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Total energy system costs EU in 2050 (Tr Euro/yr)

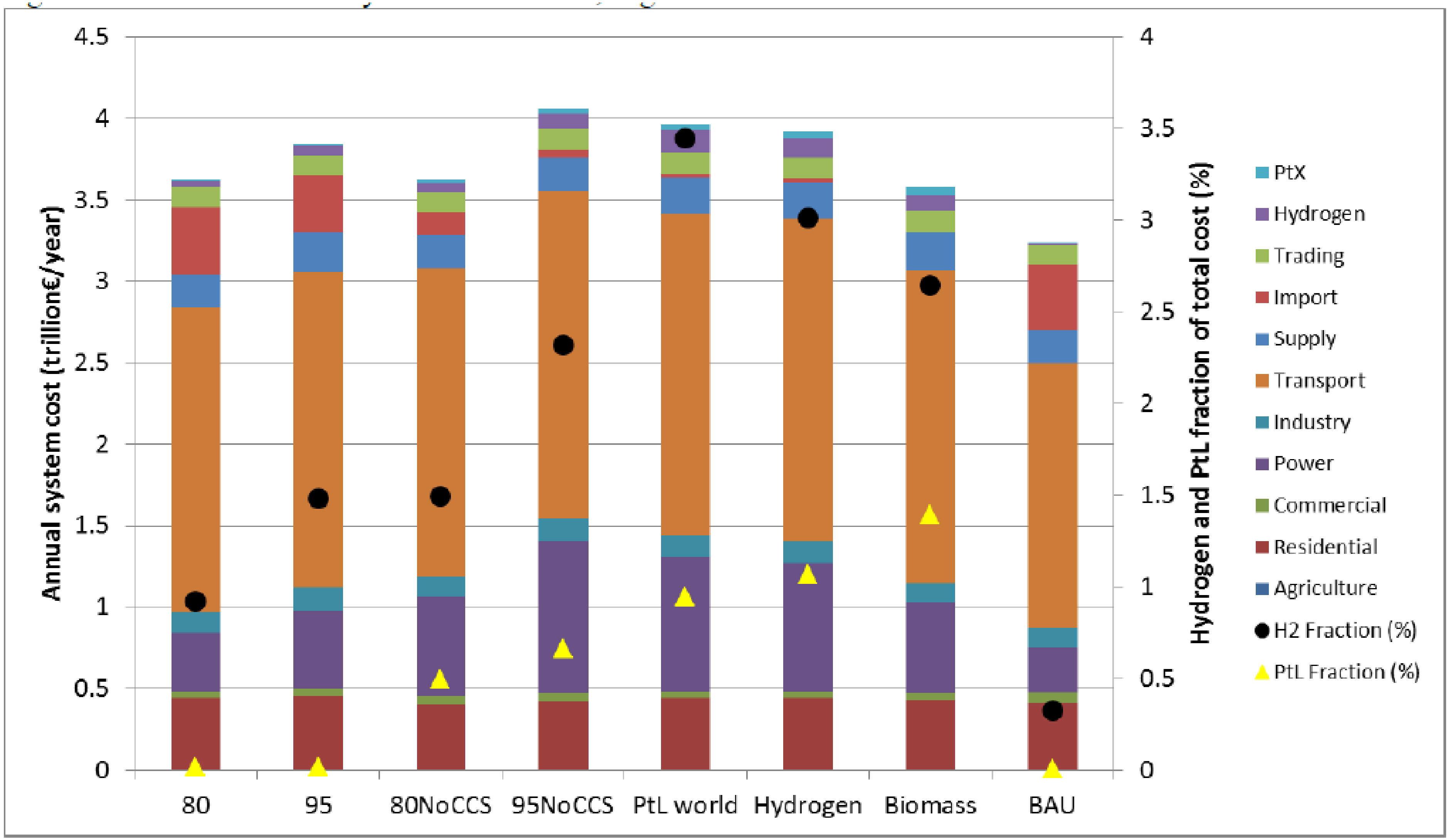
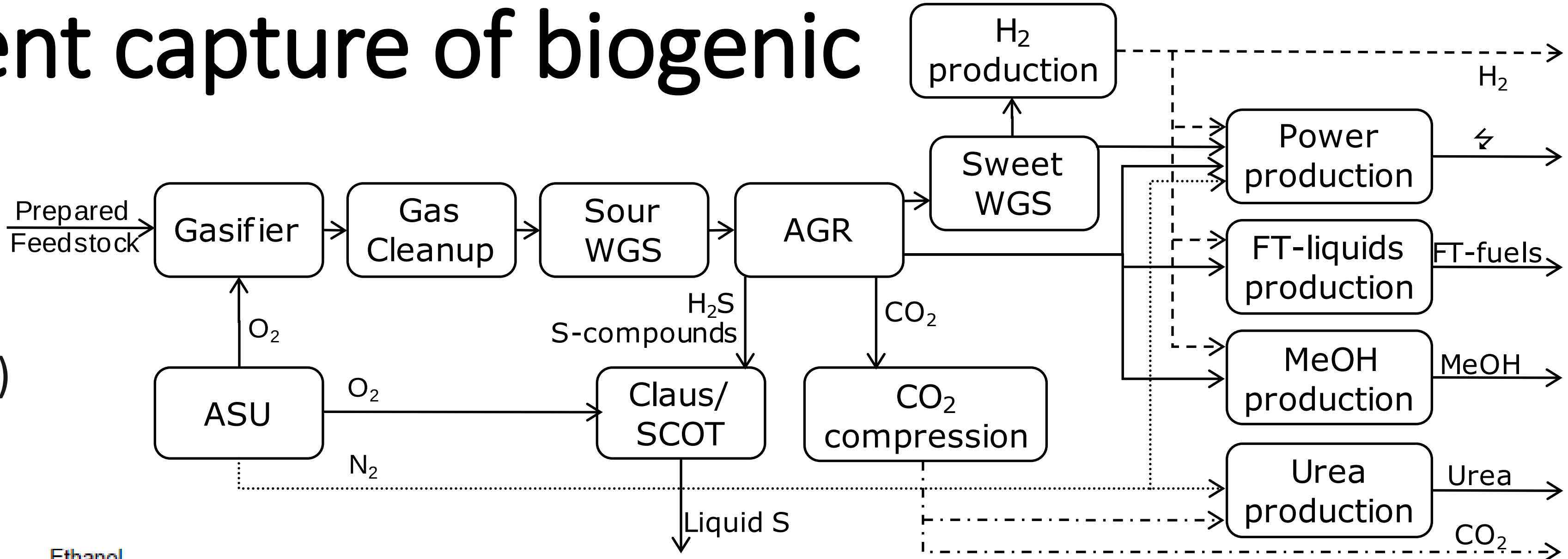


Figure 16. Sectorial split for annualized system cost for 2050 including H_2 and PtL fraction.

[Blanco et al., applied Energy 2018]

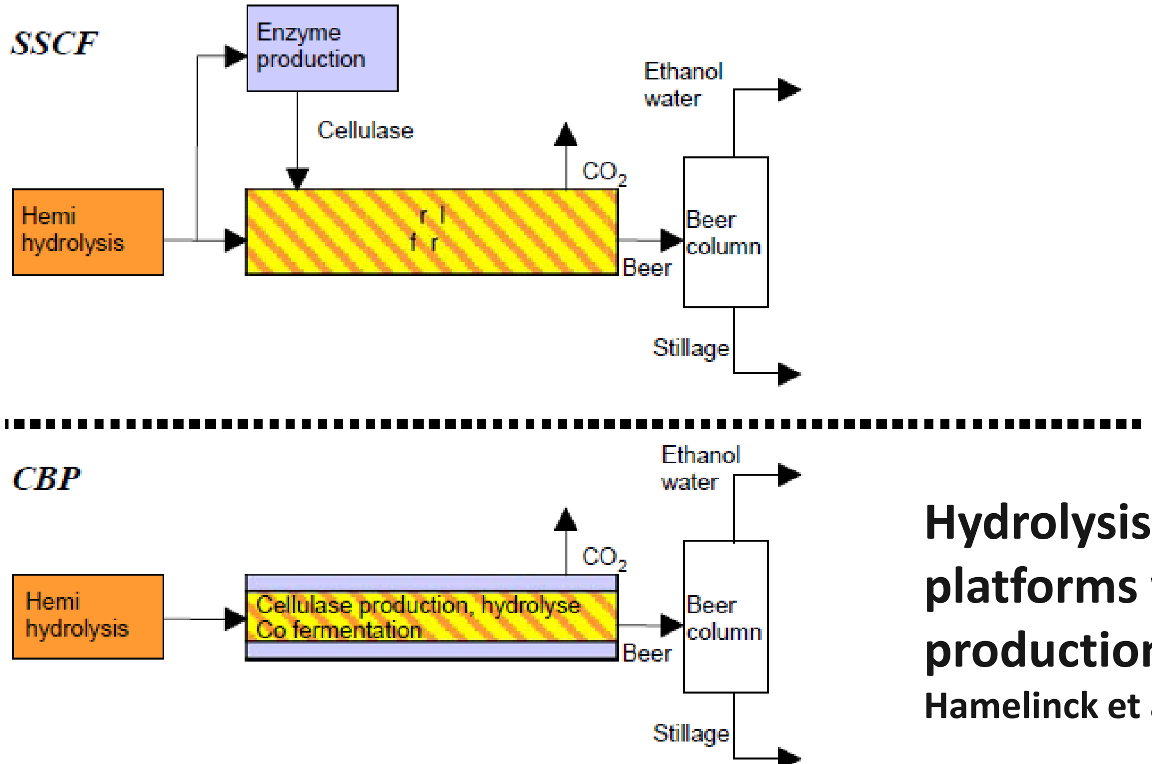
Advanced biomass conversion allows for efficient capture of biogenic CO2

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



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

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.

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EU2018 GHG EMISSIONS 4.4 GTON CO2EQ 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

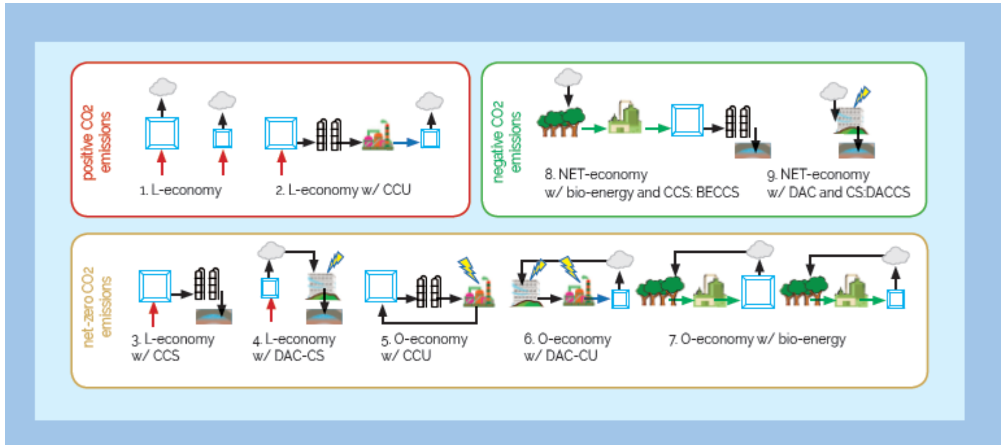
In addition: - BECCS options may contribute up to 700 Mton/yr.
- Carbon stock increases due to additionally planted perennial crops, increased productivity of marginal and degraded lands and increased carbon stocks due to improved agricultural productivity may contribute another 10-50 Mton/yr up to 2050.

[Faaij, Energies, 2022]

BBE options essential for deep GHG mitigation and energy & industry transitions: IAM's, ESM's (EU, national) with the right granularity say:

- EXCLUDING biomass from increases mitigation costs substantially and in many cases makes achieving a 1,5oC pathway impossible.
- Over time, optimal biomass use shifts from heat and power to advanced fuels and feedstock for industry.
- Sustainable biomass is always a highly attractive mitigation option.
- BECCS options are of major importance to achieve negative emissions, lower overall mitigation costs and essential to deal with the overshoot emission pathways.

- Biomass use get's intermixed with green Hydrogen and CCUS options; not so much competition but synergy between these key mitigation options.



- Scenario's that include LUC and carbon stock impacts show the additional benefit of increased C-storage combined with good land use practices.

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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.
- **Many** schemes are known, possible and can be implemented over time .
- 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 competitively with **negative emissions**.
- Biobased economy in the EU with European biomass resources can tackle **> 1/3 of the required GHG mitigation effort in 2050 (and beyond).**

energies

MDPI

Perspective

Repairing What Policy Is Missing Out on: A Constructive View on Prospects and Preconditions for Sustainable Biobased Economy Options to Mitigate and Adapt to Climate Change

André P. C. Faaij [1,2,3]

Energies **2022**, 15, 5955.
https://doi.org/10.3390/en15165955

Key points:

- focus on synergies between biobased economy options, sustainable land use better agriculture and climate change adapation
- Get such thinking embedded in the policy nexus between energy, climate, environment and agriculture.
- Make such concepts part of the green taxonomy of the EU.