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Food for All and Biobased Economy: Fundamental Conflict or Essential Synergy for Sustainable Development.

2015 CRC LCA of Transportation Fuels Workshop
27th October 2015, Argonne Il, USA.

Prof. Dr. André P.C. Faaij

Academic Director - Energy Academy Europe

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1. Biobased economy in a climate friendly future (keeping 2 oC GMT in sight…)

- 300 EJ deployment 2nd half of this century needed
- Bio-CCS (negative emissions) now paramount (e.g. in advanced biorefining).
- Especially for advanced biofuels and biomaterials (ratio some 10 – 5 : 1, comparable to oil use today).
- Leads to substantial moderation of mitigation costs (vs. no BBE).
- Many BBE options can become competitive vs. fossil reference on medium term.

Global biomass deployment in relation to GHG mitigation (IPCC AR 5, 2014)

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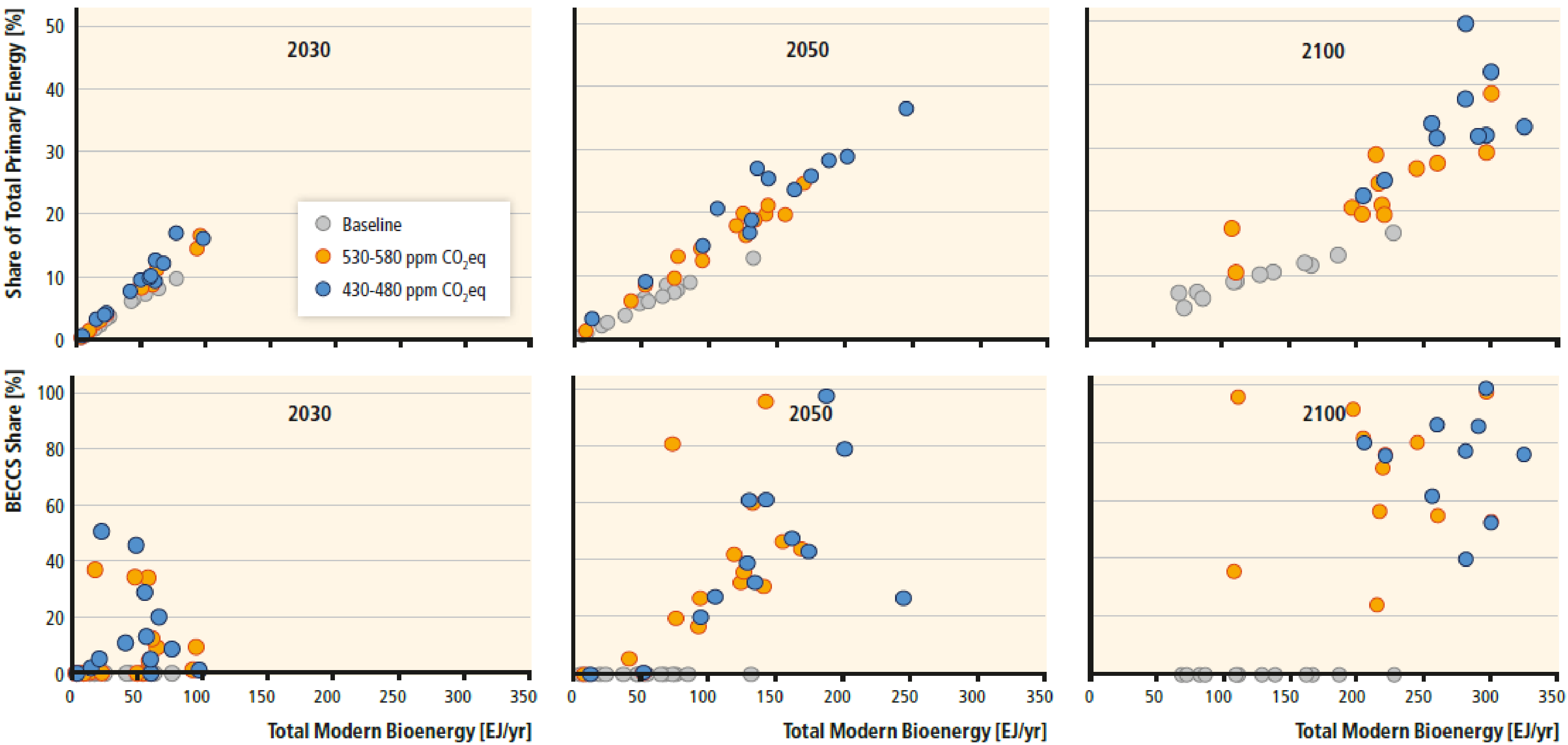

2. Biomass resource potentials (sustainable)

- Suffice for 300 EJ (some 80 EJ residues, 20 EJ organic wastes, 150 EJ from 500 Mha better quality land and some 50 EJ from 500 Mha degraded lands.
- **Provided** agriculture modernizes fast enough to absorb growing food demand on less land.
- Yield gaps in livestock and cropping sufficient to do so (some 10% of arable & pasture lands, 5,000 Mha, needed).
- **Can** also be done fast enough in coming 3-4 decades.
- **Can** provide major synergies in improved resource efficiency (land, water, nutrients) and increased carbon stocks.
- Major addition economic value in rural areas and marginal lands (300 EJ equals several trillion U$/yr).

Key factors biomass potentials

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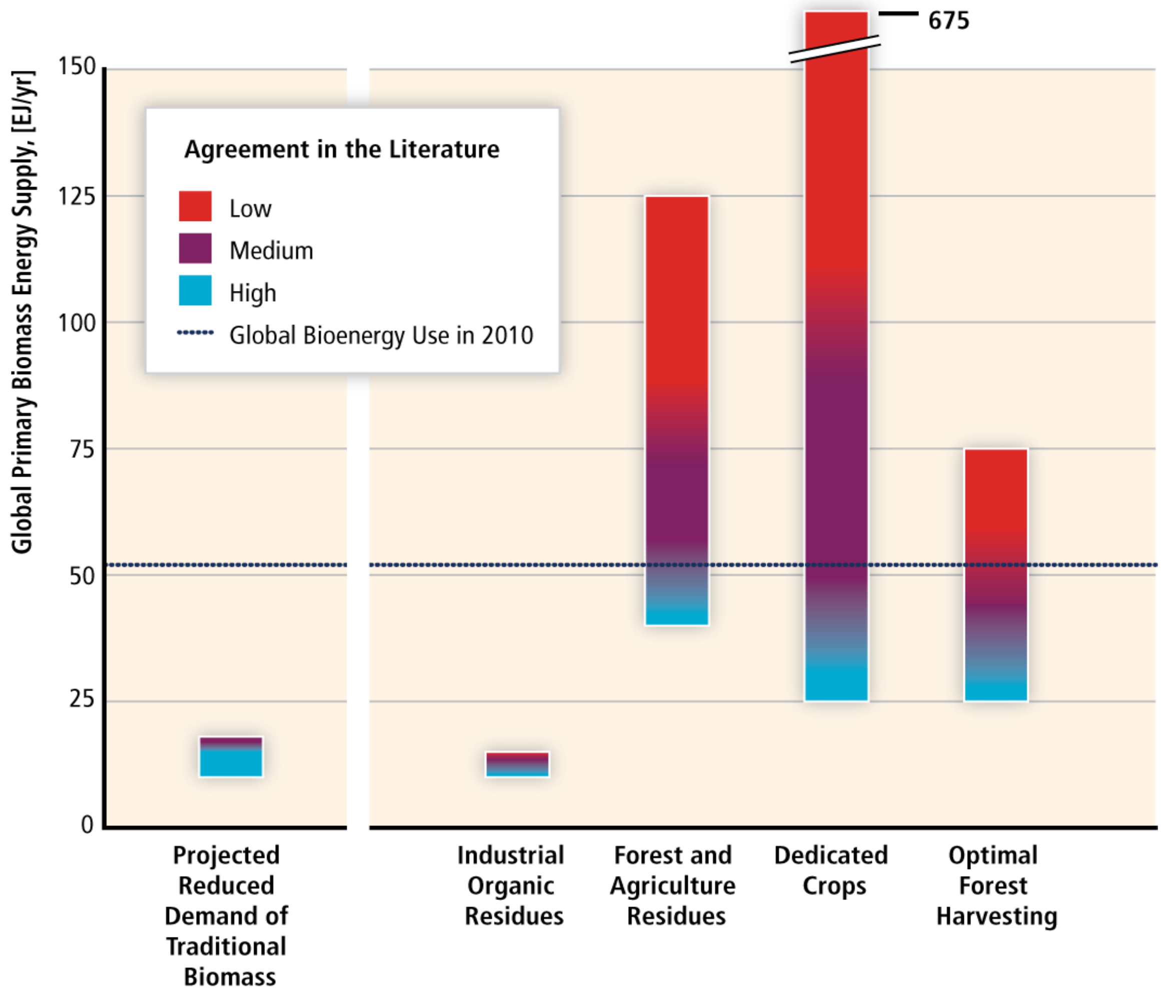
Issue/effect	Importance
Supply potential of biomass	
Improvement agricultural management	***
Choice of crops	***
Food demands and human diet	***
Use of degraded land	***
Competition for water	***
Use of agricultural/forestry by-products	**
Protected area expansion	**
Water use efficiency	**
Climate change	**
Alternative protein chains	**
Demand for biomaterials	*
Demand potential of biomass	
Bio-energy demand versus supply	**
Cost of biomass supply	**
Learning in energy conversion	**
Market mechanism food-feed-fuel	**

[Dornburg et al., Energy & Environmental Science 2010]

Bioenergy potentials [2050] (ranges based on expert opinion). (IPCC – AR5 WGIII, 2014)



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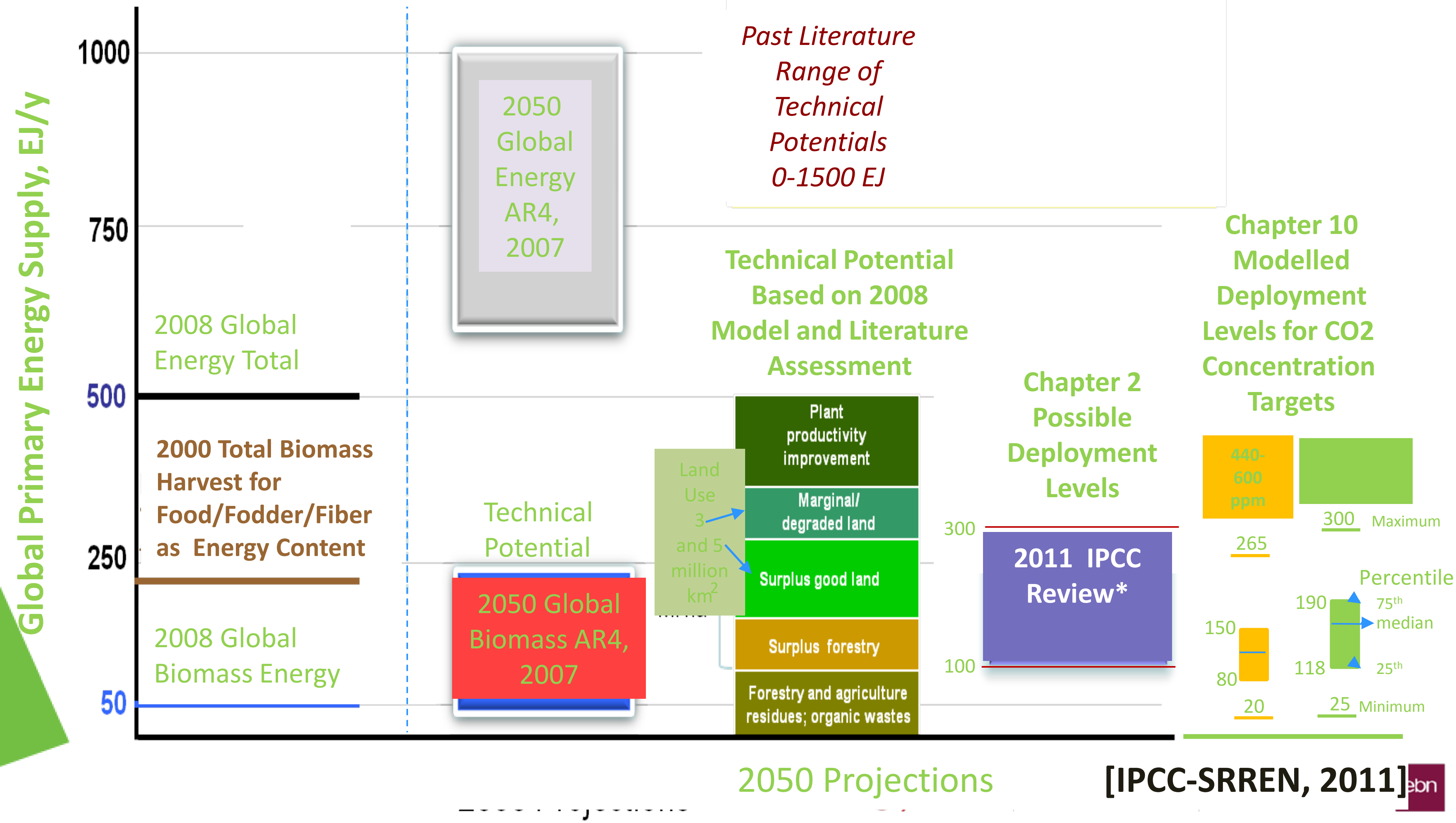
2050 Bioenergy Potentials & Deployment Levels



[IPCC-SREN, 2011]

Further investigations yield gaps

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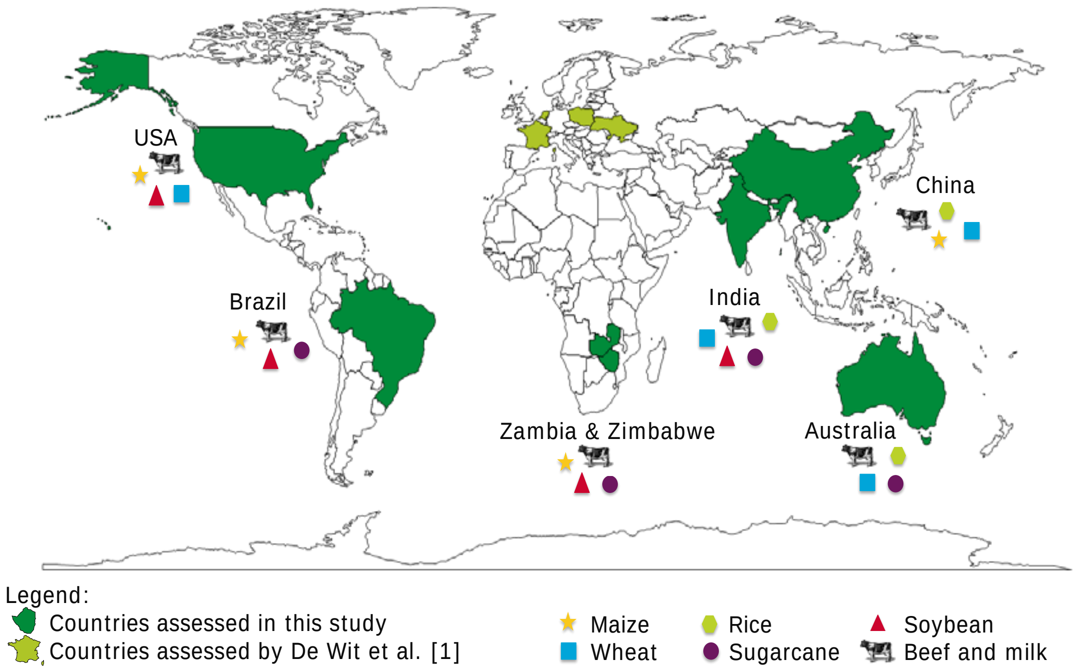
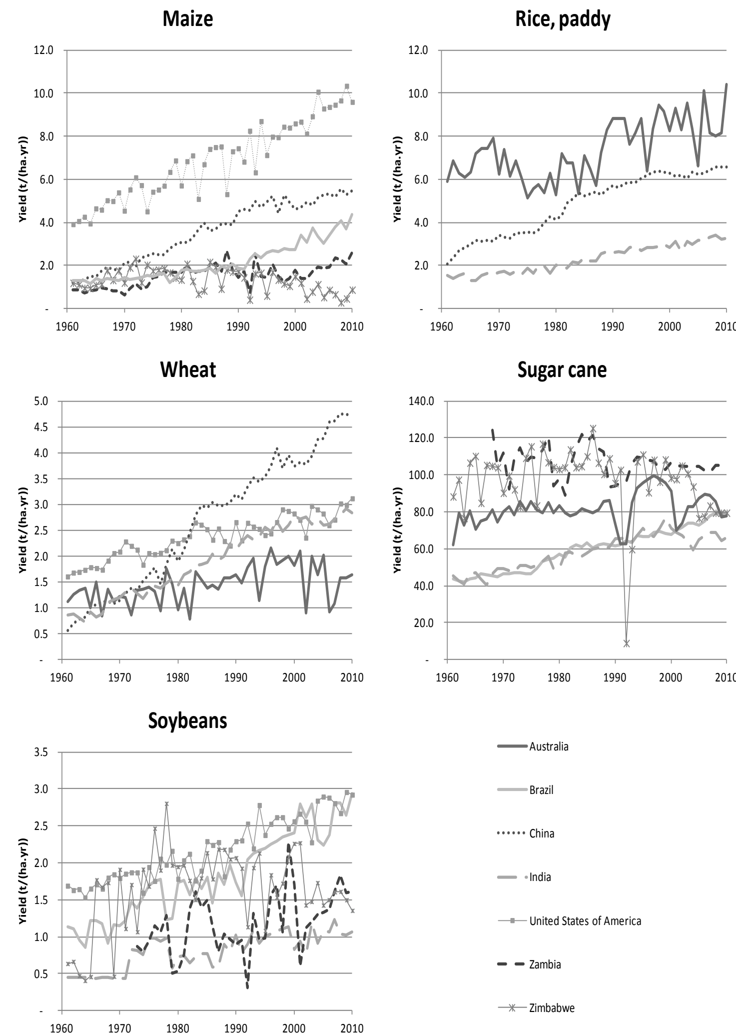
Livestock footprint per unit of meat of milk may Improve a factor 2-20+ depending on setting

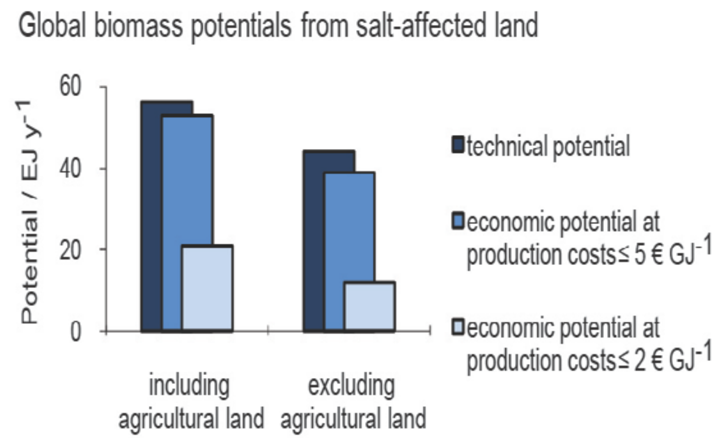




Key options such as intercropping, agro-forestry and multiple harvests poorly included (e.g Camelina).

[Gerssen-Gondelach, et al., Food & Energy Security, 2015]

Potential biomass production on saline soils.



[Wicke et al, Energy & Environmental Science, 2011]

3. GHG mitigation performance & iLUC mitigation

- Avoided GHG emissions of well managed biofuel chains (1^{st}, 2^{nd}) amount 50-90%+ compared to fossil reference.
- Simulated iLUC impacts CAN overrule those…
- …but analysis of iLUC (risks) systematically exclude or underplay mitigation options (BAU scenarios based on CGE modelling)…
- ..and are not underpinned by observations (US, Brazil, Europe) over the past 6-7 years.
- Key is to combine (gradually increasing) biomass production on productive land with (gradually increasing) productivity of agriculture & livestock -> iLUC mitigation.
- Should be part of biofuel policies, certification and governance; KEY PRIORITY!

Confrontation bottom-up vs. top down iLUC modelling

Key steps iLUC modelling efforts:

- CGE; historic data basis
- Model shock, short term, BAU, current technology.
- Quantify LUC
- Quantify GHG implications (carbon stocks)

Bottom-up insights:

- Coverage of BBE options, advancements in agriculture, verification of changes (land, production)
- Gradual, sustainability driven, longer term, technological change (BBE, Agriculture, livestock)
- LUC depends on zoning, productivity, socio-economic drivers
- Governing of forest, agriculture, identification of ''best'' lands.

[IEA & other workshops, 2011-2013; Wicke et al, GCB-B, 2014, a.o.]

Example: Corn ethanol
Results from PE & CGE models

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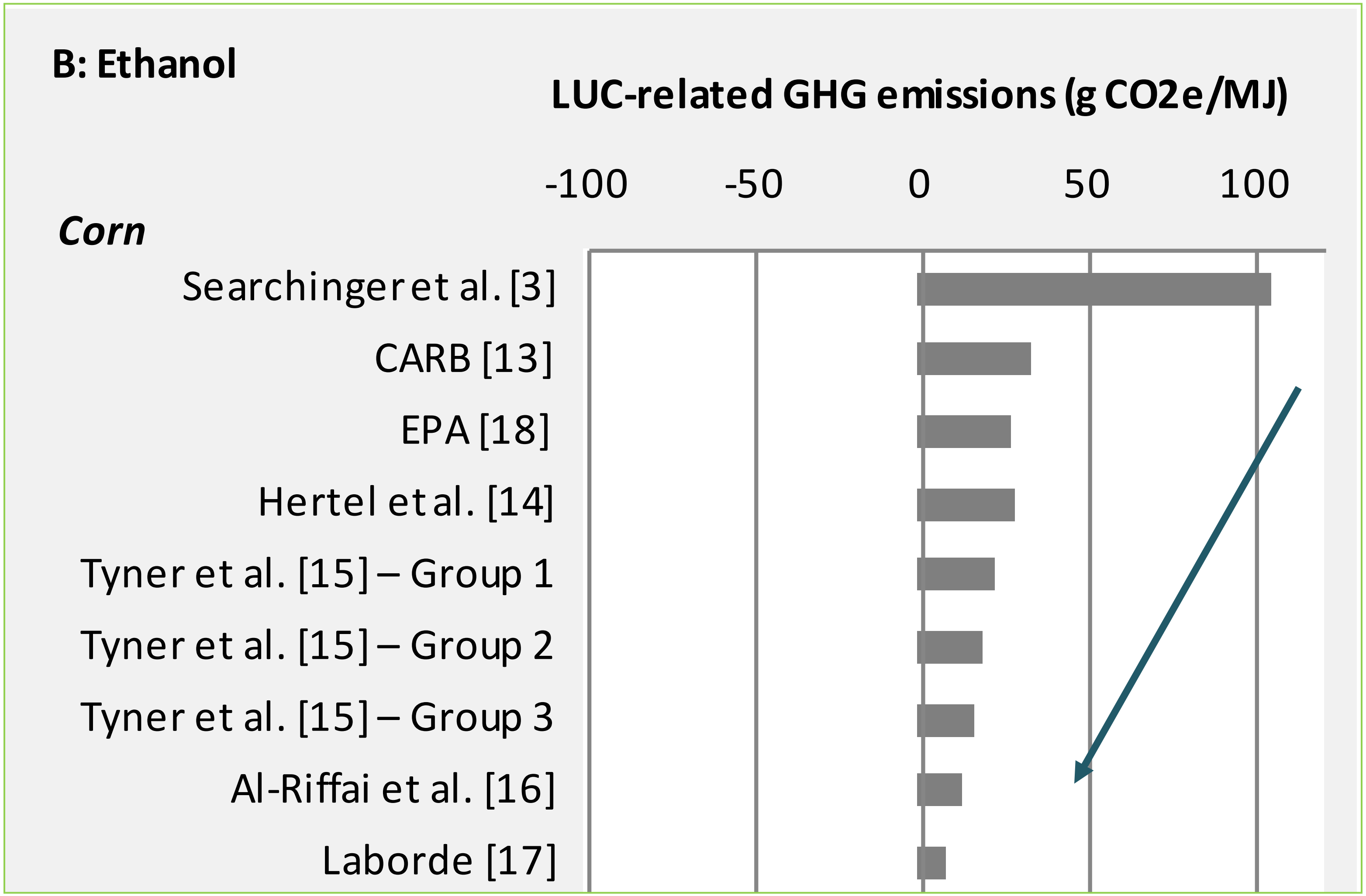
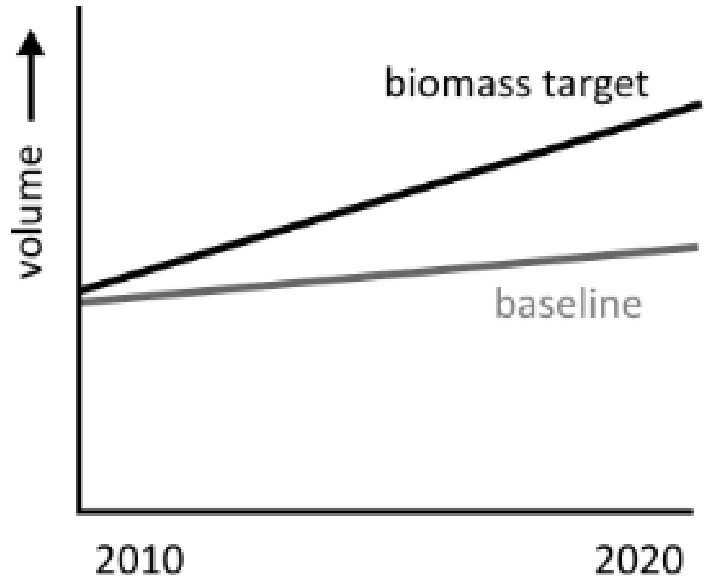


[Wicke et al., Biofuels, 2012]

General approach iLUC mitigation



- From economic models
  - Baseline: developments in food, feed and fibres
  - Biomass target: the amount required to meet targets such as RED.

[Brinkman, et al. , 2015]

General approach

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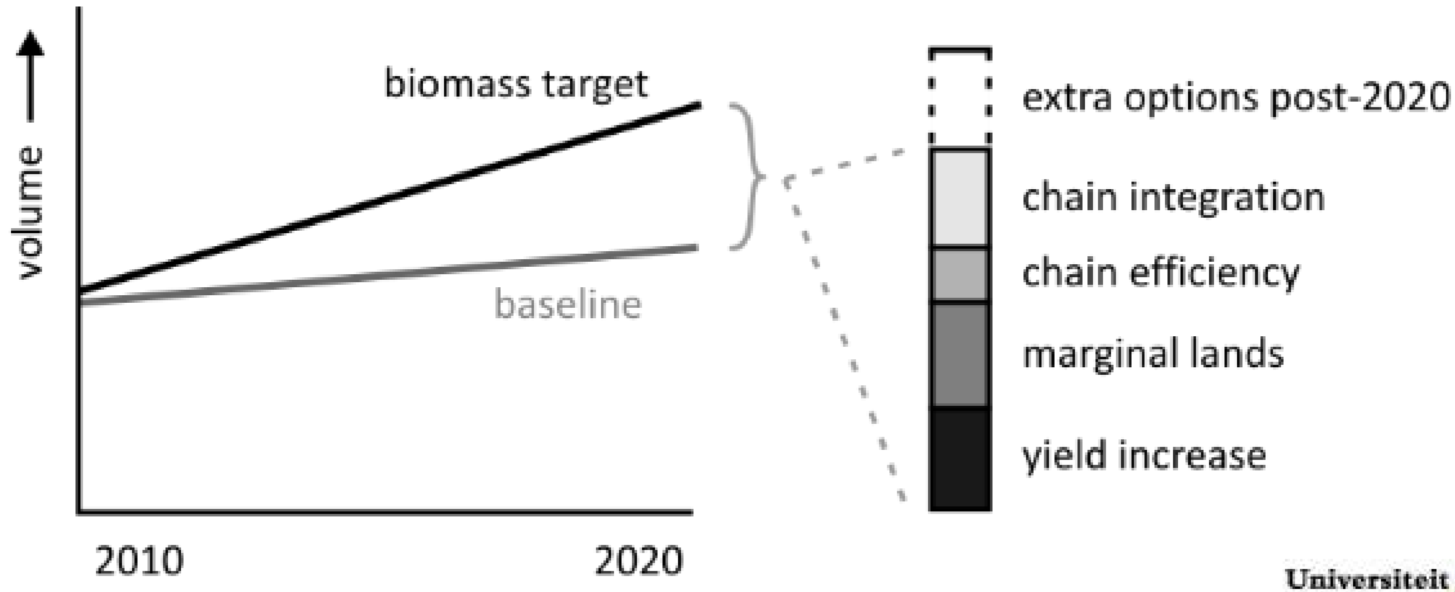

[Brinkman, et al. , 2015]

Regional assessment

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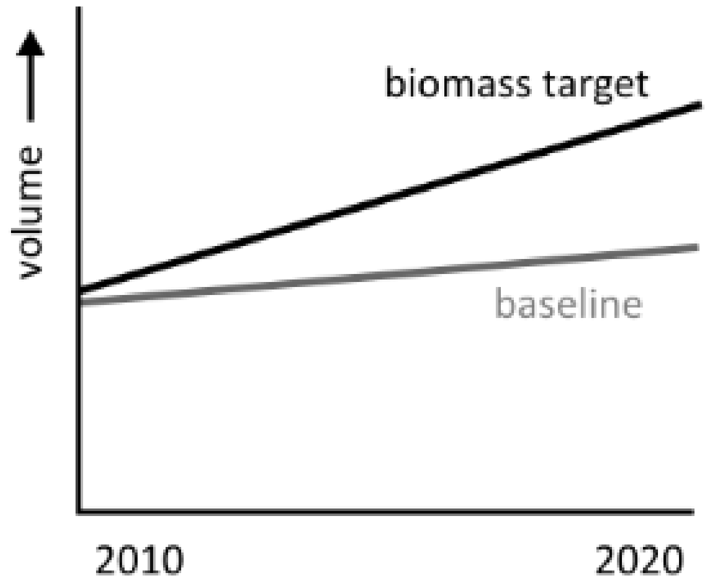
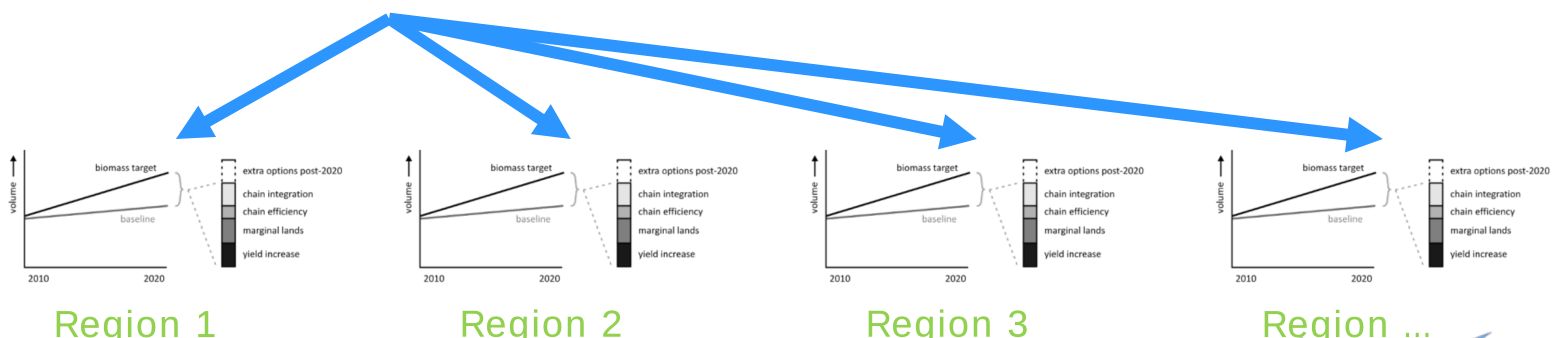


Each region has its own target. If all reach the target without displacing production ILUC can be avoided.

String of case studies available: Kalimantan, Hungary, Poland.



4. Impacts of biomass production vs. governance of land use and production chains/systems.

- Environmental and socio-economic impacts depend on crops X land type, spatial planning and organisation (e.g. smallholder vs. plantation)
- …implying also that impacts can be steered.
- More efficient agriculture and livestock = smaller footprint for food, lower GHG emissions, water use, better nutrient utilization (per unit of output) and increased carbon stocks.
- Perennials on surplus (& degraded) land; positive impact on biodiversity, erosion, soil formation and C-stock build up.
- In total synergy; *also* desired as *adaptation* to climate change.

F. Creutzig, N.H. Ravindranath, G. Berndes, S. Bolwig, R. Bright, F. Cherubini, H. Chum, E. Corbera, M. Delucchi, A. Faaij, J. Fargione, H. Haberl, G. Heath, O. Lucon, R. Plevin, A. Popp, C. Robledo-Abad, S. Rose, P. Smith, A. Stromman, S. Suh, O. Masera, *Bioenergy and climate change mitigation: an assessment*. (Global Change Biology – Bioenergy, 2014)

One strand of literature highlights that bioenergy could contribute significantly to mitigating global GHG emissions via displacing fossil fuels, better management of natural resources, and possibly by deploying BECCS. Another strand of literature points to abundant risks in the large-scale development of bioenergy mainly from dedicated energy crops and particularly in reducing the land carbon stock, potentially resulting in net increases in GHG emissions.

GLOBAL CHANGE BIOLOGY BIOENERGY

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

REVIEW

Bioenergy and climate change mitigation: an assessment

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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) (Jeuland & Olsson, 2013); (43) (Catning & 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).

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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

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Global Assessments and Guidelines for Sustainable Liquid Biofuel Production in Developing Countries

FINAL REPORT, March 2013

UNEP

http://www.unep.org/bioenergy/Portals/48107/publications/Executive%20Summary_FINAL.pdf

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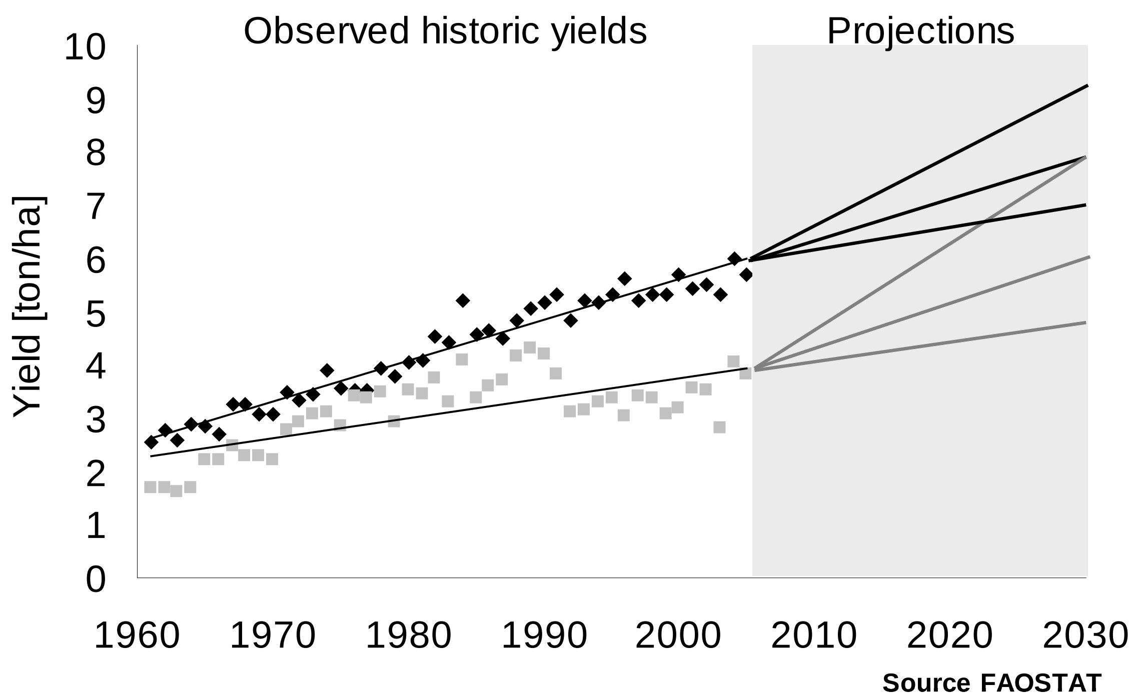
Yield projections Europe

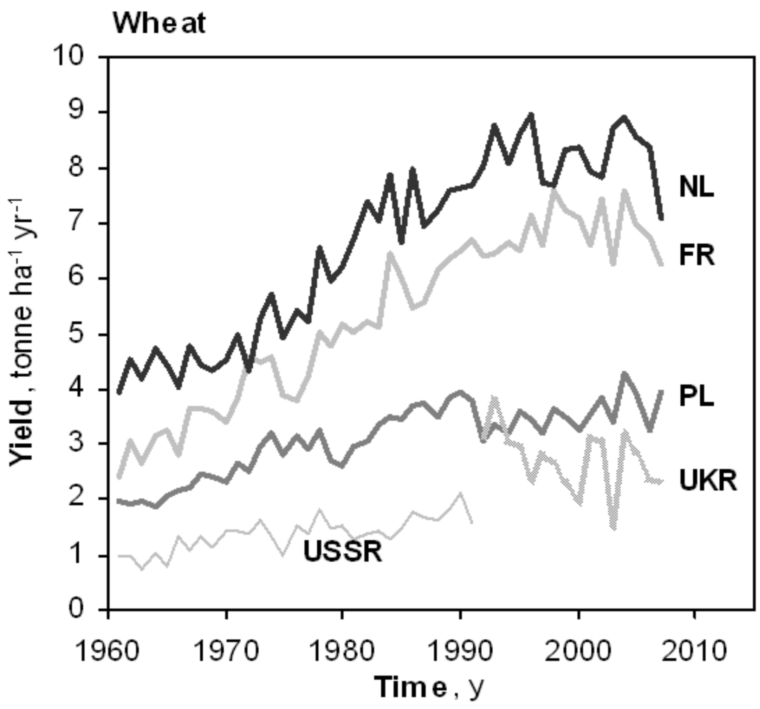
- Observed yield
  - CEEC and WEC
- Linear extrapolation of historic trends
  - Widening yield gap
- Applied scenarios
  - Low, baseline and high

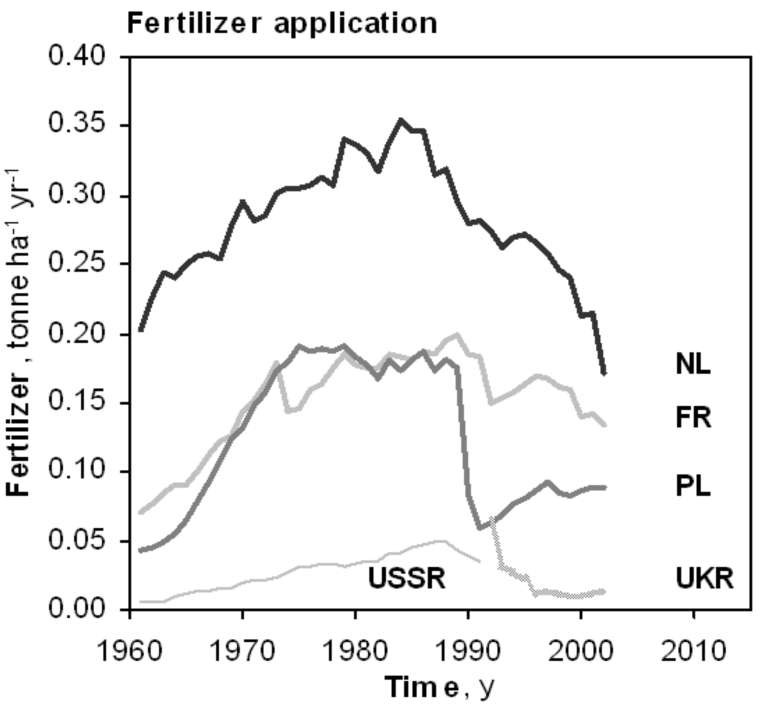


[Wit & Faaij, Biomass & bioenergy, 2010]

Developments in yields and inputs

Source: FAOSTAT and own calculations





[De Wit et al, RSER 2011]

Results - spatial production potential

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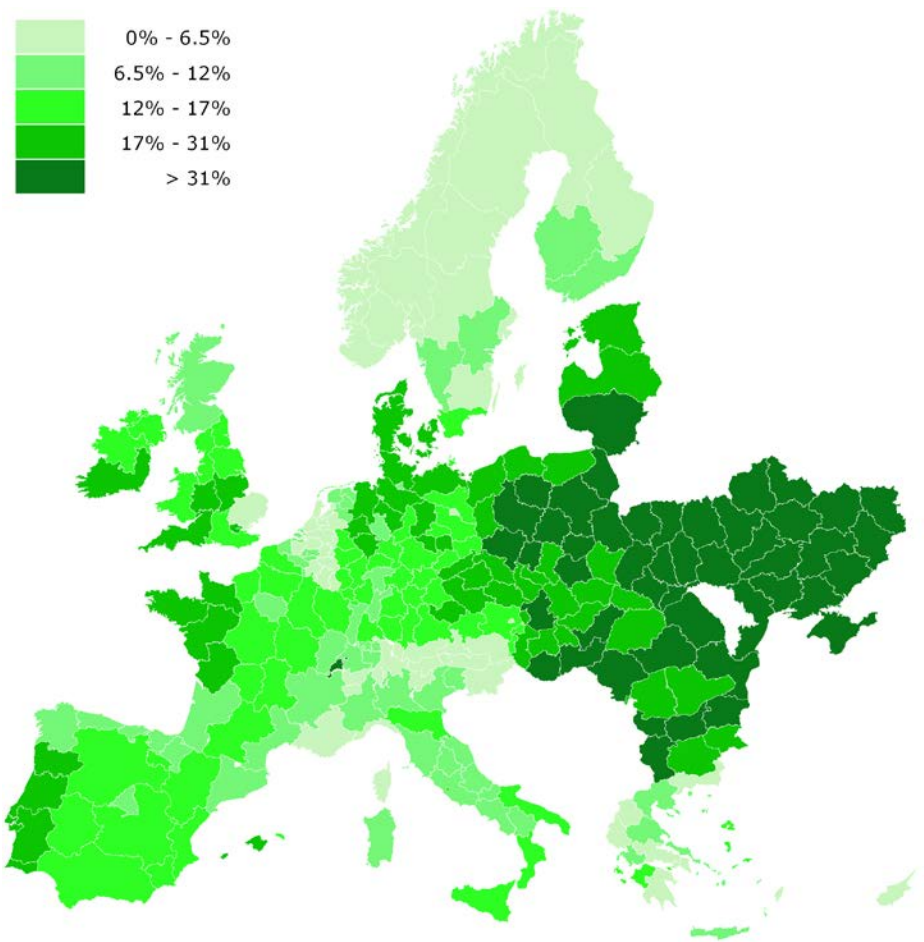
Arable land available for dedicated bio-energy crops divided by the total land

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]

Results - spatial cost distribution

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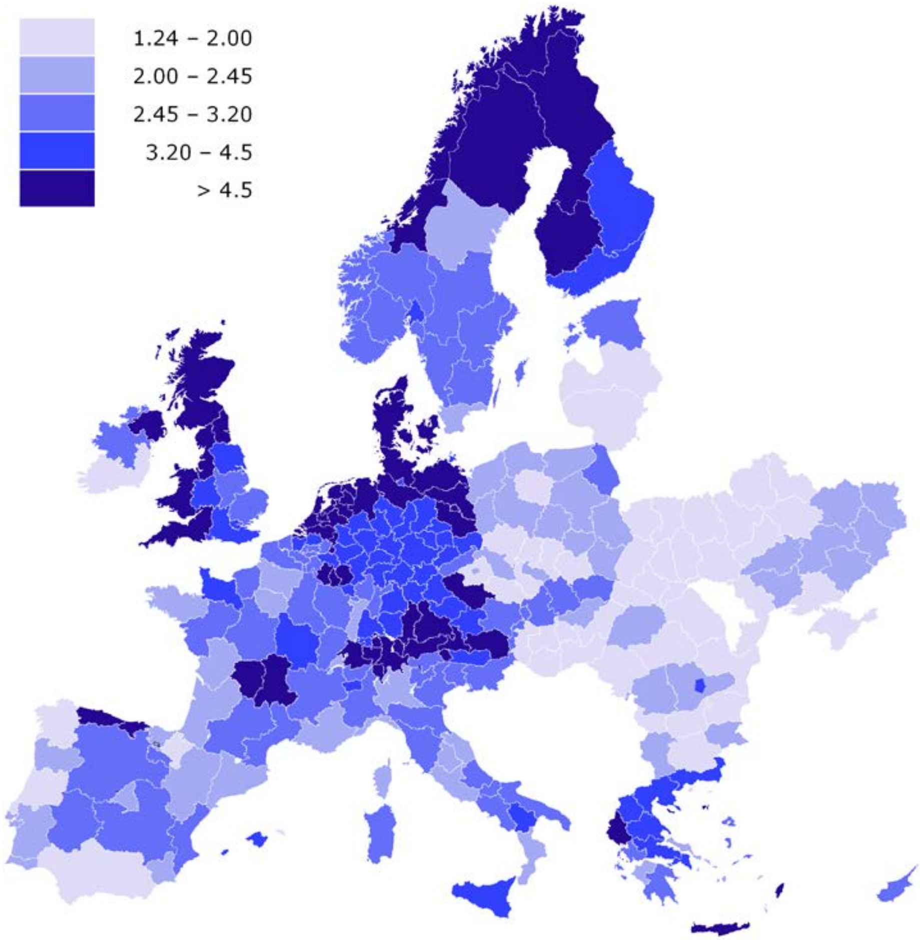
Production cost (€ GJ^{-1}) for Grassy crops

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]

Crop specific supply curves

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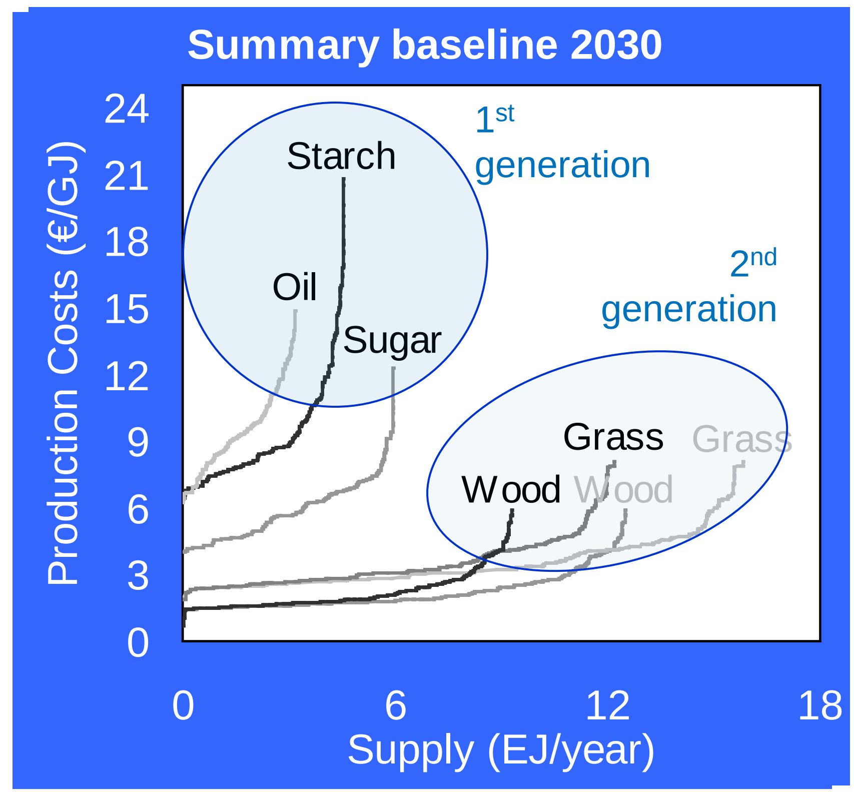
- Feedstock potentials Produced on 65 Mha arable and 24 Mha on pastures (grass and wood)

- Significant difference between '1st and 2nd generation crops'

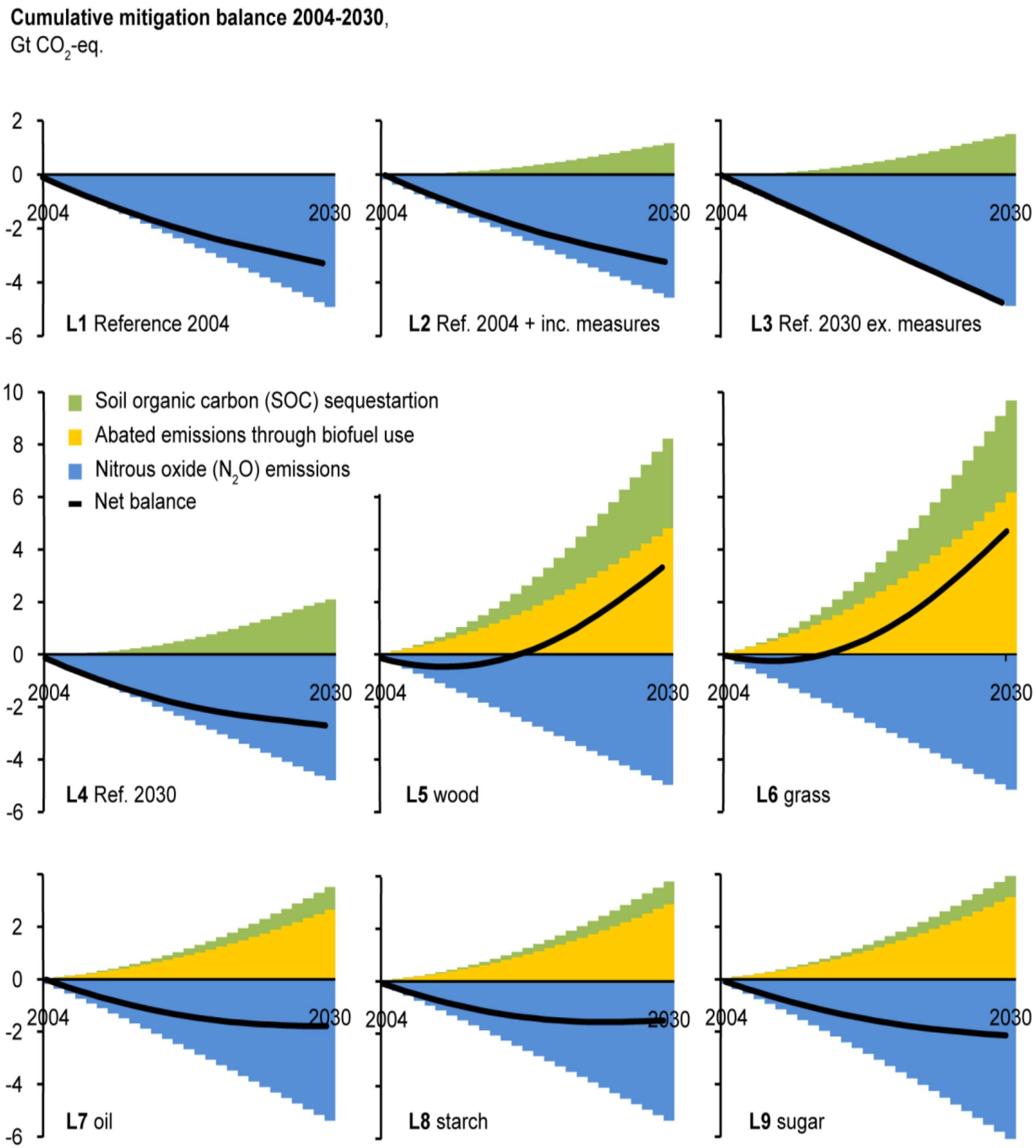
- Supply potentials high compared to demand

2010 (0,78 EJ/yr) and 2020 (1,48 EJ/yr)



1 EJ (ExaJoule) = 24 Mtoe

[Wit & Faaij, Biomass & Bioenergy, 2010]



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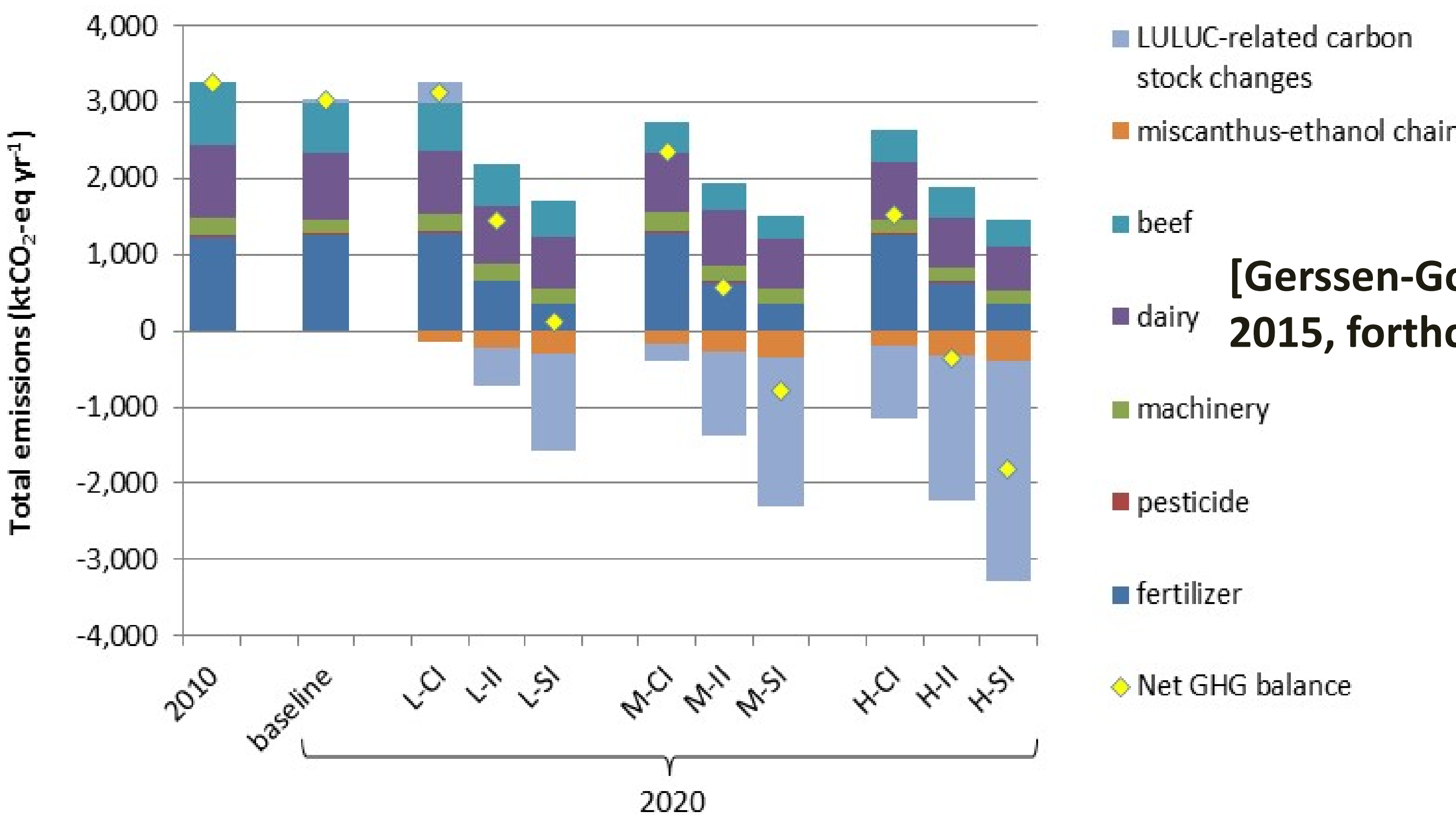
Example:
GHG balance of combined agricultural intensification + bioenergy production in Europe + Ukraine

[Wit et al., BioFPR, 2014]

of
Hanze University of Applied Sciences Groningen
energy valley
GasTerra
ebn

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., 2015, forthcoming]

Other estimated impacts of intensification strategies

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	Risk factor	Conventional intensification	Intermediate sustainable intensification	Sustainable intensification
Biodiversity				
Habitat functions in HNV areas	Conversion to miscanthus[a]	-	+/-	+
	Agricultural intensification	+/-	o	+
Species abundance in non-HNV areas	Agricultural intensification	--	+/-	+
	Cropland conversion to miscanthus	+/-	+	++
	Grassland conversion to miscanthus	--	-	+/-
Water				
Water quantity	Agricultural and miscanthus production	--	-	+/-
Water quality	Agricultural intensification	--	+/-	+
	Miscanthus cultivation	+/-	+	++
Soil				
SOC	Management and conversion of agricultural land	+/-	+	++
Soil erosion	Water erosion	-	+/-	+
	Wind erosion	+/-	+/-	+
Air				
Air quality	Airborne emissions of non-GHG pollutants causing acidification	--	-	+
	Emissions of PM_{10}	-	+/-	+
	Pesticides	--	-	+

[Gerssen-Gondelach et al., 2015, forthcoming]

5a. Policy perspective

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- From iLUC risk to mitigation; growing consensus that focus on biomass/biofuels alone is inconsistent.
- Modernization and improved efficiency of conventional agriculture (and livestock) essential in itself (!)
- Changes perspective from hedging problems to achieving synergies (governance of land use).
- Essential: "incentivise practices that prevent or mitigate ILUC"; only penalizing contributes little.
- Mitigation of iLUC fits sustainability frameworks (covering regions, settings; see e.g. RSB).
- BBE certification sets the pace for conventional agriculture…
- Major agenda for science (agronomy, LU modellers, env. Sc., BBE community…) and work beyond LCA's.

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5b. Summary

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- BBE with deployment ~300 EJ after 2050 required (mix of advanced fuels (!!!), power (!), heat, biomaterials (!) + bio-CCS (!!)) required for essential GHG mitigation effort (BBE may take up to 40%).
- Potentials (technical, economic, sustainable) suffice when combined with modernization of agriculture and good land management.
- This offers **synergies** with more resilient food production, more **efficient use of natural resources, increased carbon stocks** and rural development + required investments for capacity building, infrastructure and RDD&D (shift of fossil fuel expenditures to rural areas can amount several trillion U$/yr).
- This is **not easy nor a given** and **understanding + avoiding risks of negative impacts is crucial** for sound implementation & scale-up.
- However, alternatives for BBE come with similar complexities or do not exist; synergies equally important next to BBE as such.
- **Focus on constructive ways forward to achieve this paramount** for policy, science and industry (that need to work together).
- Logical and efficient pathways take decades and **gradual development of (biomass) markets, infrastructure and technologies**.

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No time to waste (to cite Greenpeace) & Thank you very much for your attention

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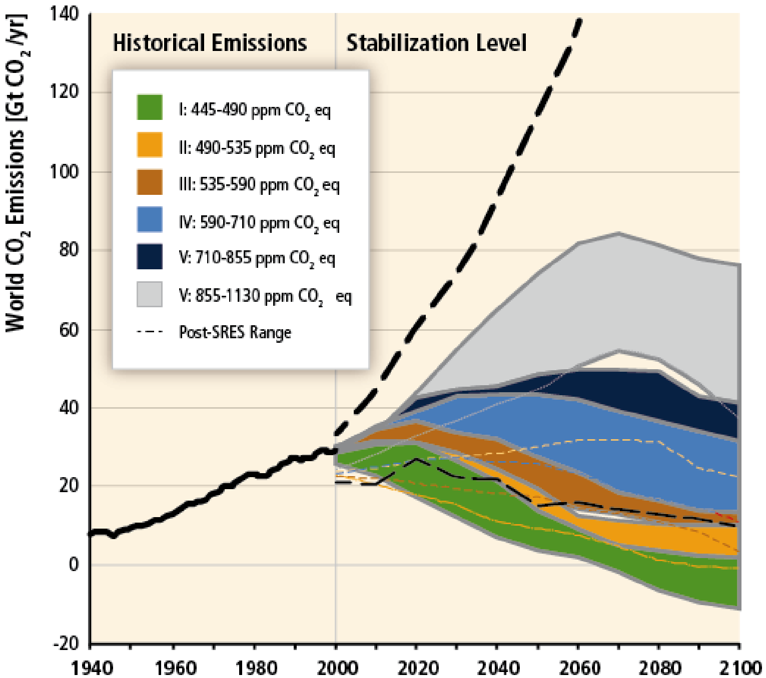
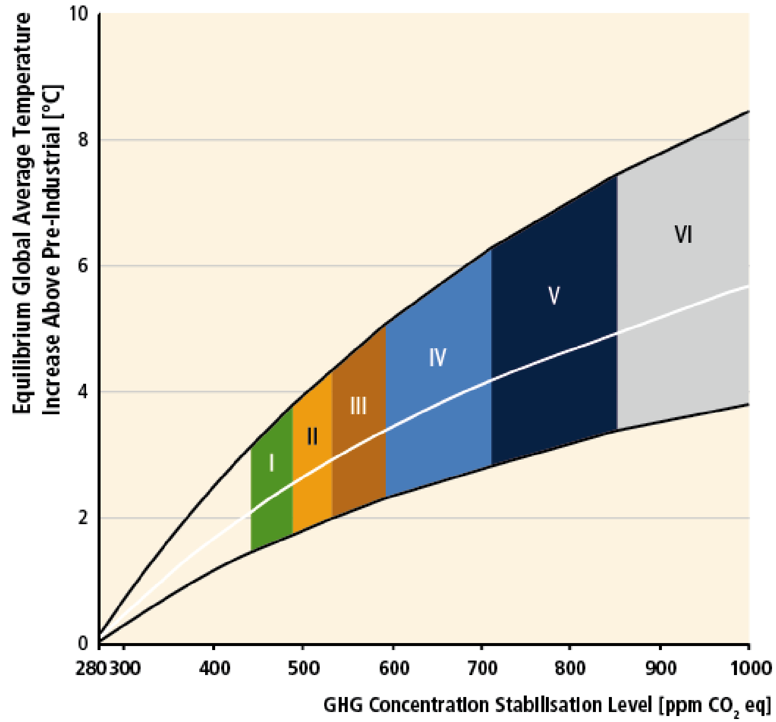
Energy demand, GHG emissions and climate change…





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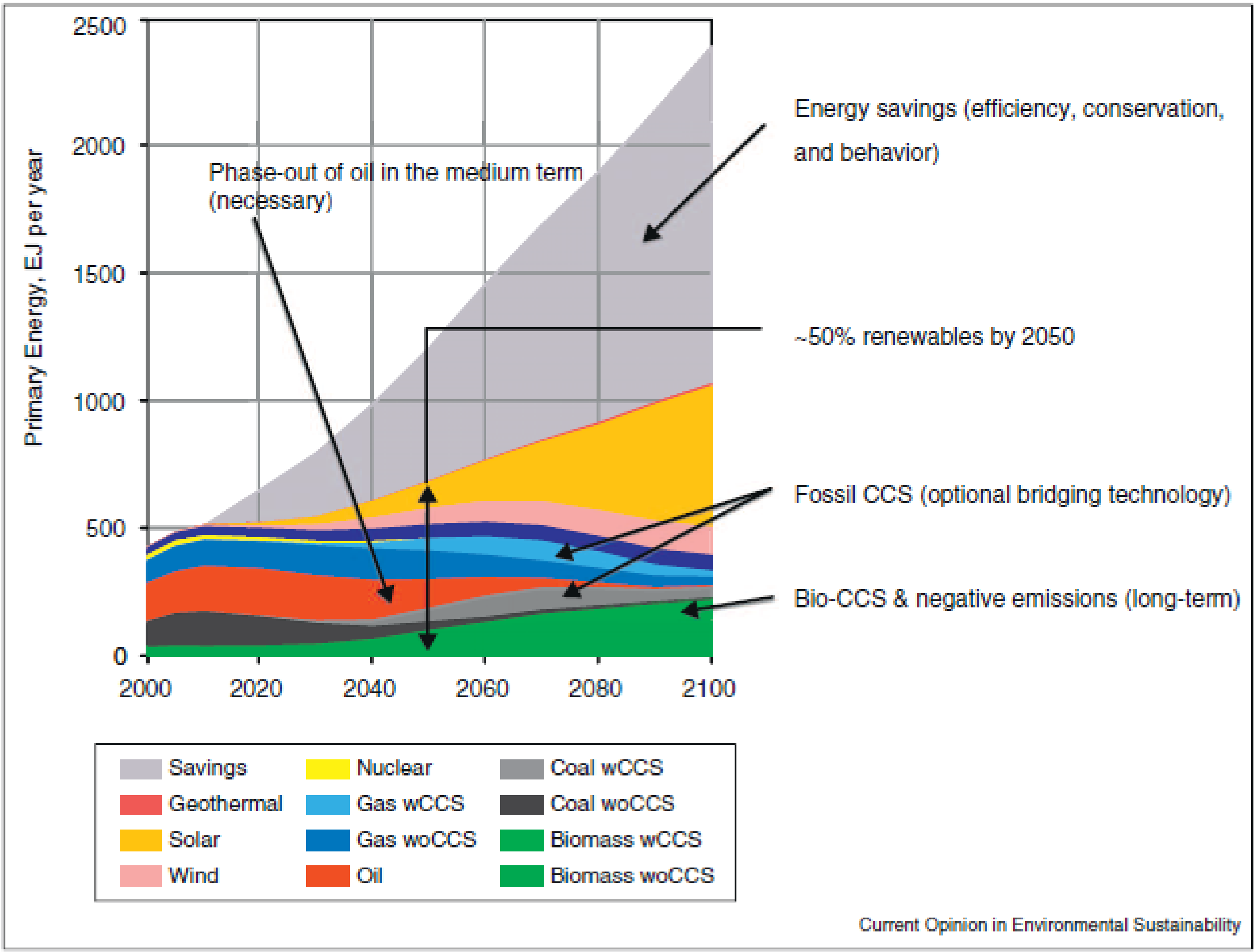
Energy system transformation…



[GEA/van Vuuren et al CoSust, 2012]

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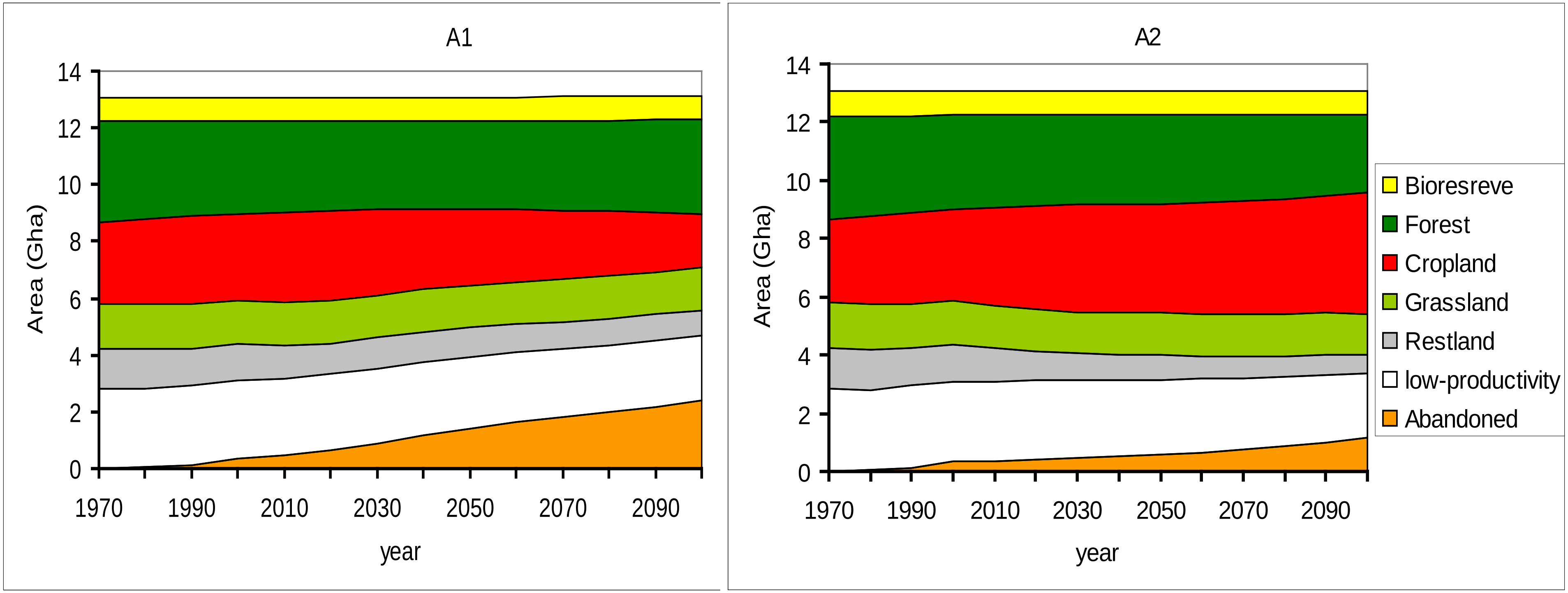
Potential land-use pattern changes (integral update finalized now)



[Hoogwijk, Faaij et al., 2006]

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iLUC mitigation options…

- Controlling (i)LUC
  - Increasing efficiency in agriculture, livestock and bioenergy production
  - Integrating food, feed and fuel production
  - Increasing chain efficiencies
  - Minimizing degradation and abandonment of agricultural land

- Controlling type of LUC
  - Sustainable land use planning (incl. monitoring)
  - Excluding high carbon stock and biodiversity areas
  - Using set-aside, idle or abandoned agricultural land
  - Using degraded and marginal land

Contrast:

- Modeling for iLUC factors is only half the science we need; **reactive** instead of **pro-active** concept.
- ''old'' Biofuel policies also half the policy we need; mandates without proper preconditions, resulting in **CONFLICTS**

Versus

- Interlinked agricultural& biobased economy policies (agri, clima, energy…).
- Investigate (and implement) Integral land use strategies (agriculture, BBE, nature, rural development) to achieve **SYNERGIES**

GHG/MJ of major modern bioenergy chains vs. conventional fossil fuel options

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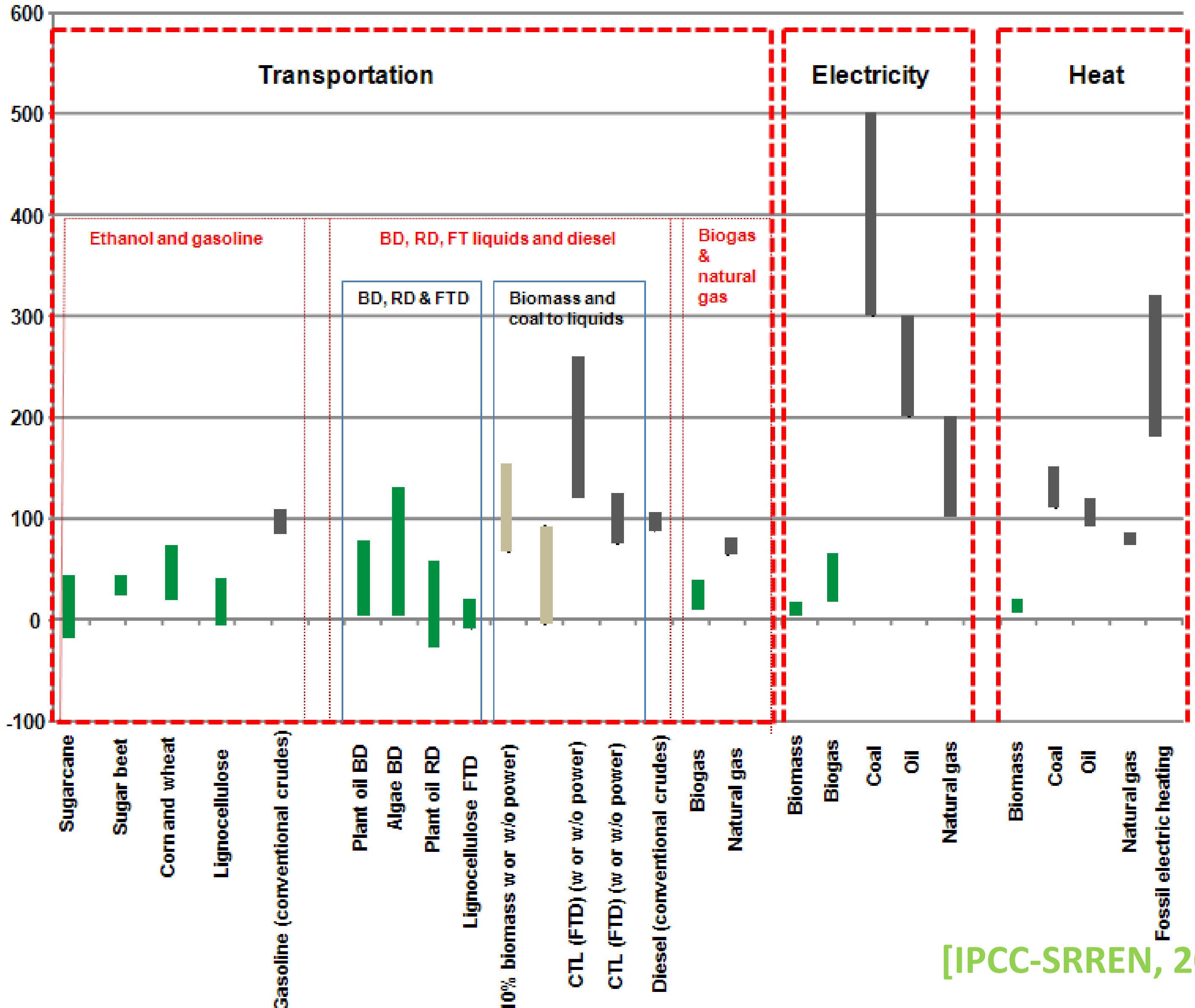


Excluding (i)LUC effects; these can have strong impacts

[IPCC-SRREN, 2011]

Direct land use change GHG emissions examples

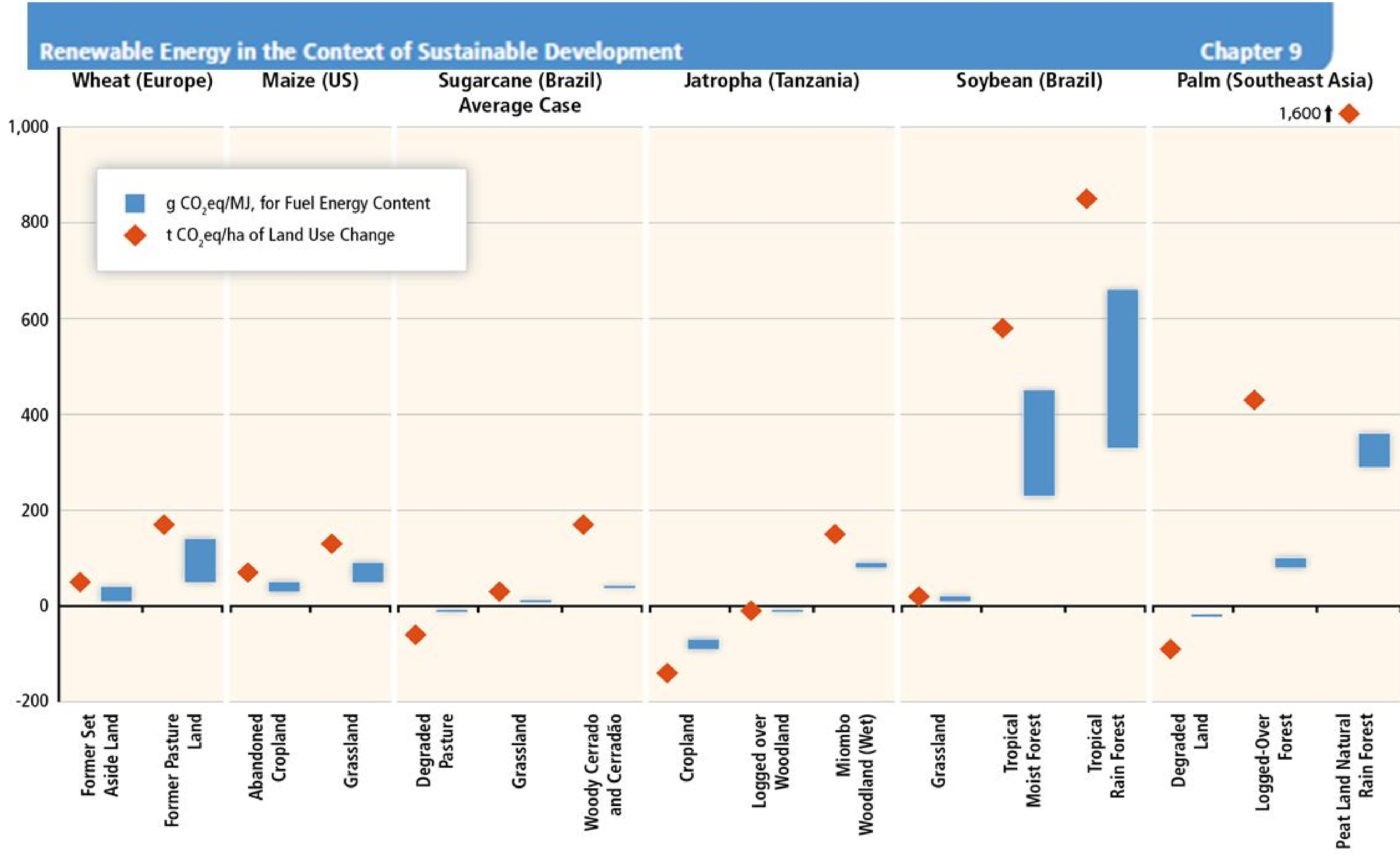
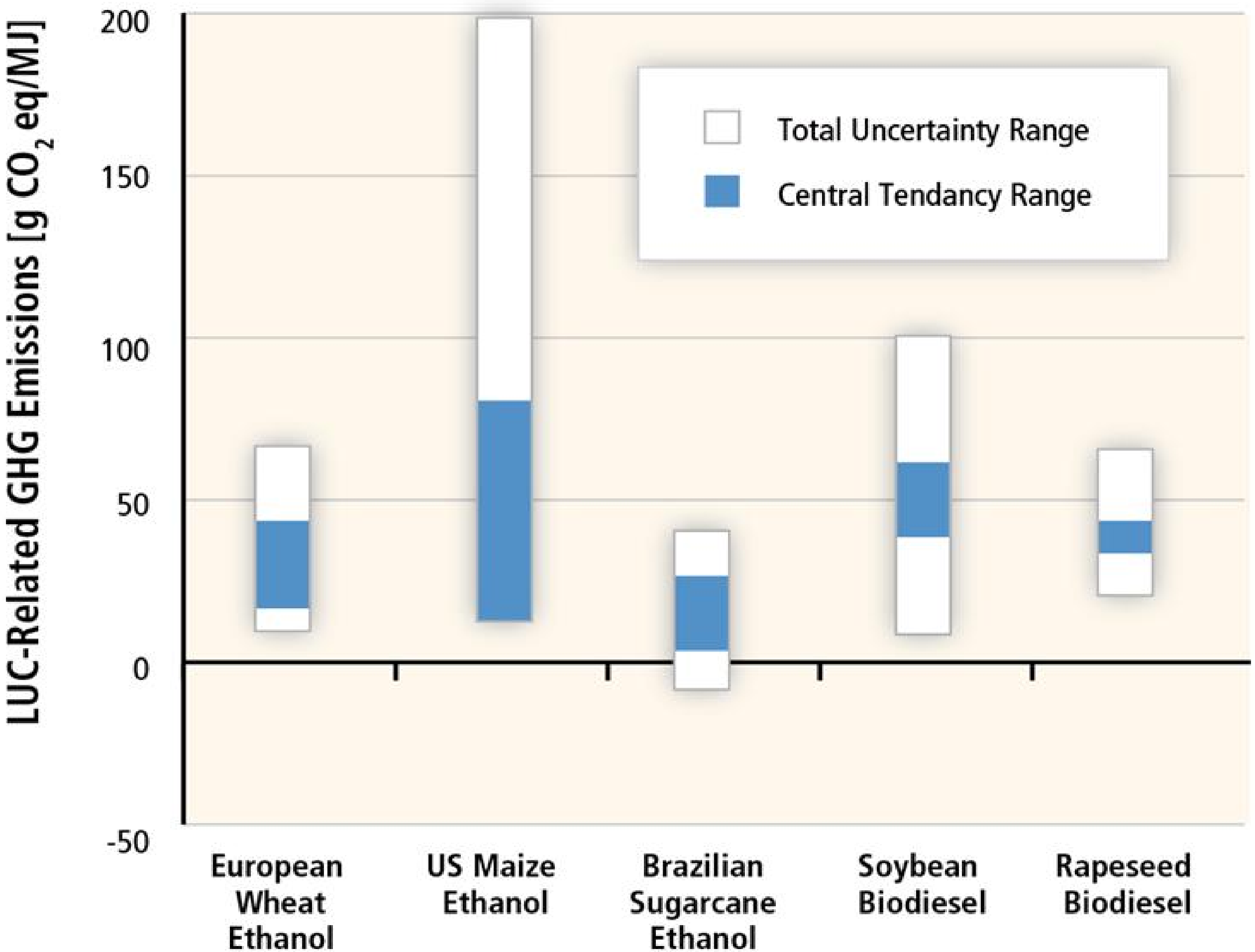


Figure 9.10 | Illustrative direct LUC-related GHG emission estimates from selected land use types and first-generation biofuel (ethanol and biodiesel) feedstocks. Results are taken from Hoefnagels et al. (2010) and Fargione et al. (2008) and, where necessary, converted (assuming a 30-year timeframe) to the functional units displayed using data from Hoefnagels et al. (2010) and EPA (2010b). Ranges are based on different co-product allocation methods (i.e., allocation by mass, energy and market value).

Site and prior use specific ….

Direct and indirect land use GHG emissions – Take II (Chapter 9)



References:	3	5	2	3	2

Figure 9.11 | Illustrative estimates of direct and indirect LUC-related GHG emissions induced by several first-generation biofuel pathways, reported here as ranges in central tendency and total reported uncertainty. Estimates reported here combine several different uncertainty calculation methods and central tendency measures and assume a 30-year time frame. Reported under the x-axis is the number of references with results falling within these ranges (Sources: Searchinger et al., 2008; Al-Riffai et al., 2010; EPA, 2010b; Fritsche et al., 2010; Hertel et al., 2010; Tyner et al., 2010).

Uncertain!!!

'depreciation Carbon losses over 20 years; after that iLUC = zero.

Carbon intensity fossil ref excludes upstream Emissions. These will increase (>200 g/MJ possible)